Robust Lec 9

Digital interfaces for
μ-Controllers

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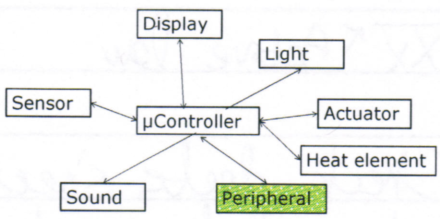
## Interfaces




(What you can find inbetween)

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## Peripherals or I/O-units

Digitally connected

- Counter
- D/A converters
- Memories
- Speech circuits
- Cameras
- And more...

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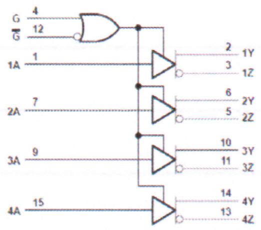
## If encoder only have A and B output

Use a line driver for getting both A,B and /A, /B (RS422) 26LS31 for example.

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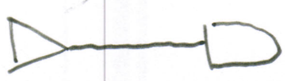

## Levels for digital communication

Acceptable voltage are different for input/output

Input levels of 74XX00

| Symbol | Parameter | Min | Nom | Max |
|---|---|---|---|---|
| $V_{CC}$ | Supply Voltage | 4.75 | 5 | 5.25 |
| $V_{IH}$ | HIGH Level Input Voltage | 2 | | |
| $V_{IL}$ | LOW Level Input Voltage | | | 0.8 |

Output levels off 74XX00

| | | | | | |
|---|---|---|---|---|---|
| $V_{OH}$ | HIGH Level Output Voltage | $V_{CC}$ = Min, $I_{OH}$ = Max, $V_{IL}$ = Max | 2.7 | 3.4 | |
| $V_{OL}$ | LOW Level Output Voltage | $V_{CC}$ = Min, $I_{OL}$ = Max, $V_{IH}$ = Min | | 0.35 | 0.5 |
| | | $I_{OL}$ = 4 mA, $V_{CC}$ = Min | | 0.25 | 0.4 |

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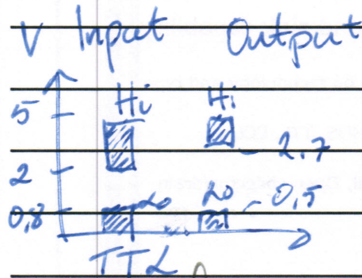


Never leave pins hanging, must have well defined voltage.

## Levels for digital communication

Logic level Hi or Low

Physical voltage
Different technologies

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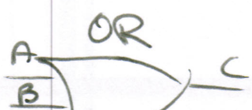
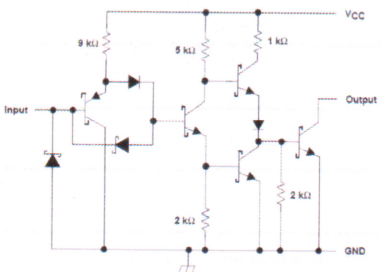



| A | B | C |
|---|---|---|
| 0 | 0 | 0 |
| 1 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 1 | 1 |

TTL - Transistor-Transistor Logic

## Levels for digital communication

Open collector output

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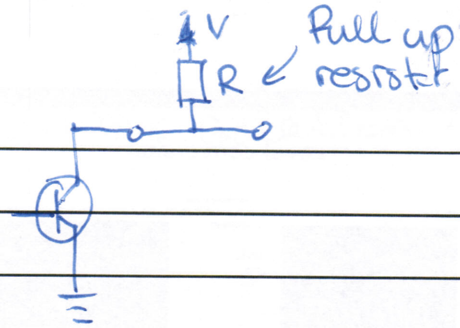


## Source and sink

Current for output 74LS00
(Push/pull) in mA

| | | | | | |
|---|---|---|---|---|---|
| $I_{OH}$ | HIGH Level Output Current | | | | −0.4 |
| $I_{OL}$ | LOW Level Output Current | | | | 8 |

- means going out

What happens if you source/sink more current?

If more current is used, voltage levels will be wrong.

Mainly the same on all digital circuits.

And do not forget the decoupling capacitor!

Decoupling near Vcc pin
0,047 µF

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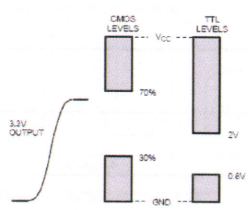
## Level conversion

The problem

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Robust Lec 10

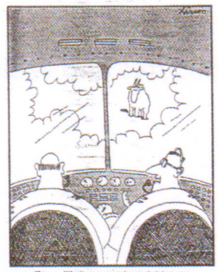
# Design of electronics systems for harsh environments

Lecture at Royal Institute of Technology

Christian Björlin 2015



## A crash course on robust electronics design



"Say . . . What's a mountain goat doing way up here in a cloud bank?"



## Agenda

**First section – Design of an electronics system**

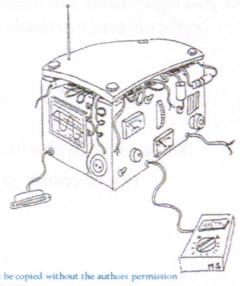
- Enclosures and sealings
- Sealings
- Corrosion
- Coating of circuit boards
- Heat handling
- Surface treatment

**Second section - Testing**

- Handling of electronic circuit boards
- Vibration durability
- Testing and the Bath Tub Curve
- Burn in
- Common causes to common problems
  Example pictures
- Pictures, video shots, questions



## The Electronics Box



## Hermetic enclosure

- Laser welded housings
- Hermetic connectors
- Closed cooling system
- Expensive
- Complicated service

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Thermal overpressure

## Non-hermetic enclosures

- **Open housings** – typically with a draining hole in the bottom – requires coated circuit boards and corrosion resistant sub-assemblies
- **Closed housings** (non-hermetical) will need to get rid of humidity with either heat, desiccators or Nitrogen filling

  Monitoring of the dew point might be needed in order to control heaters for humidity removal (humidity sensor + temperature sensor)
- **Important**: make sure what operational profile that the device will be subject to. Equipment that is not operational 100% of the time is subject to accumulate vapor
- Desiccators can be breathing or non-breathing
- Desiccators are changed at certain intervals – used desiccators are baked in high temperature for re-use

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## Sealings

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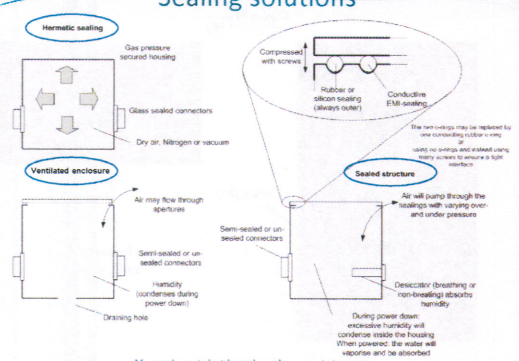
## Sealing solutions

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## Sealing for Electromagnetic Interference

...also...

our equipment must be protected from external sources of disturbance and needs:

Resistance to **Radiated Susceptibility (RS)**

and

Resistance to **Conducted Susceptibility (CS)**

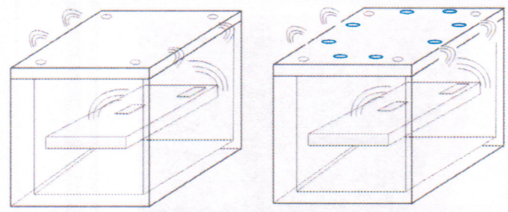
- *(not covered by this lecture)*

Surges, spikes etc.




## Sealing for Electromagnetic Interference

Make tight contact between conductive mechanical parts !






## Sealing for Electromagnetic Interference

Electromagnetical fields leak out

Imperfections in the EMI sealing


Microscopic gaps in the mechanical metal-to-metal interface

How to improve this?

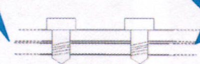
- Short distance between screws
- Good mechanical tolerances on the flatness of the mechanical interfaces
- Good conductivity of the surfaces being in contact
- Anti-corrosion plating of the surfaces in contact




## Sealing for Electromagnetic Interference

Electromagnetical fields leak out if poorly tightened

It is necessary to maintain good conductivity over time and environmental stress



The screws shall be chosen so that the metal does not cause galvanic corrosion together with the metal in the enclosure

## Corrosion

| Alloy | A380 | A360 | A360.2 | K-Alloy | A518.2 | A413.2 | A356 | 6061-T6 |
|---|---|---|---|---|---|---|---|---|
| Copper, Cu | 3.5 | 0.6 | 0.1 | 0.065 | 0.1 | 0.1 | 0.25 | 0.23 |
| Iron, Fe | 1.3 | 1.3 | 0.6 | 0.9 | 0.7 | 0.2 | 0.6 | 0.7 |
| Magnesium, Mg | 0.1 | 0.5 | .5 | 0.4 | 8.0 | .5 | 0.32 | 0.15 |
| Manganese, Mn | 0.5 | 0.35 | .05 | 0.4 | 0.1 | 0.07 | 0.35 | 1 |
| Silicon, Si | 8.75 | 9.5 | 9.5 | 10 | 0.25 | 12 | 7 | 0.2 |
| Zinc, Zn | 3 | .5 | 0.05 | 0.15 | 0.15 | 0.1 | 0 | .25 |
| Nickel, Ni | 0.5 | .5 | 0 | 0.01 | 0.05 | 0.1 | 0 | 0 |
| Tin, Sn | 0.35 | .15 | 0 | 0.01 | 0.15 | 0.1 | 0 | 0 |
| Other | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0.15 |
| Aluminum, Al | 81.5 | 86.6 | 88.75 | 88.1 | 90.75 | 87 | 91.13 | 97.3 |
| Corrosion Rating | E | C | C | C | A | C | B | A |




## Causes of corrosion

- The wrong choice of surface treatment on the metal with respect to the operational environment
- The wrong choice of coating (paint or similar)
- Sharp edges
- Not designing the product for the real operational environment regarding the presence of salt, chemical agents and water
- Mixing of metals: galvanic corrosion in the presence of salt water and wind (*typically connector to enclosure*)
- Electrolytic corrosion: electrical currents flow over interfaces of two different metals in the presence of salt wind or water




Heat dissipation and EMC

## Avoiding corrosion

**Questions**:

- What are the consequences of just replacing a metal enclosure with a plastic or composite fibre housing ?
- Wouldn't all corrosion problems be solved doing so?
- Wouldn't it be good idea to anodize the aluminium housing?



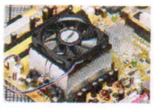

Anodized aluminium is a bad conductor, EMC-problems.

## Coating of circuit boards

## Thermal considerations

Hot spots in the electronics system:

- Processors
- FPGA:s
- Power modules
- Motors
- ...







## Component types

Electronic components are available in four major temperature grades . Typical intervals are:

**Commercial** temperature: 0 to 70 °C ("C-temp")

**Industrial** temperature: -40 to +85 °C ("I-temp")

**Automotive**: -40 to +105 °C (limited)

**Military**: -55 to +125 °C (less common)





## Thermal design criteria

For a new design:

- Determine what thermal conditions that will apply for the product
- Determine the temperature rise from exterior to the inside of the enclosure
- Make component choices





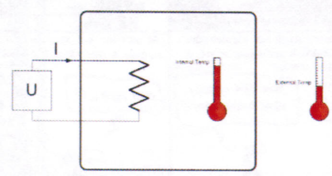
## Determining enclosure temperature rise

An easy test to check for the systems ability to dissipate heat from the inside:

- Apply the estimated total power (=U×I) inside the enclosure by using a resistor and a power supply
- After stabilisation> Measure the temperature difference between inside and outside temperatures.

Normal $\Delta T$ is between 10-15 degrees. For outdoor systems operating in warm climates, the following is common:

<10 degrees: often OK
<15 degrees: a bit high, but can normally be dealt with
>15 degrees: Re-design an option?



## Surface treatment




## Surface treatment

Surface treatment of the enclosure is necessary to

- Prevent corrosion
- Maintain high electrical conductivity to provide good grounding of parts and connectors




## Surface treatment

Applicable to Aluminium

**Anodizing**:
+Very good corrosion resistance
+ Good adhesion for coating.
- Corrosion prevention only on surfaces that do not need electrical contact
- Expensive to mask parts that shall not be anodized.

**Chromating**:
+ Good (Cr VI)/ fairly good (Cr III) corrosion prevention maintaining proper electrical contact
+ Good adhesion to coating
+ No need to mask.
- Very hazardous (Cr VI)
- Not good enough for extreme conditions (Cr III)



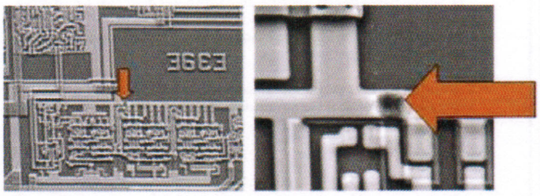

## Chromating


**Yellow chromate**
Efficient but contains hexavalent Chrome. Very little Chrome left on the final plating, but dangerous for the staff working with the process. (Closed circulation process).

**SurTec 650 chromitAL**
White in colour. More environment friendly method than yellow chromate. Contains trivalent Chrome.

**E-CLPS**
White in colour. Chrome-free.

## ESD Damage



## Silicon contamination

## Silicon contamination

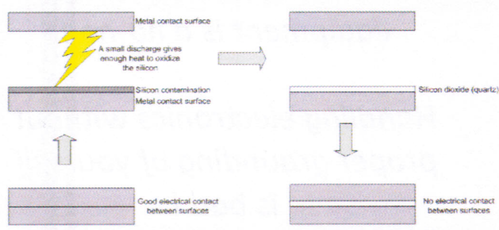
The use of **silicon based substances** are prohibited in all environment where electronics or electrical equipment are being handled.

Silicon causes poor contact between contact surfaces and may also lead to cold solder joints on circuit boards

Very **small amounts** of silicon may cause **big damage** in electrical equipment (primarily contacts, rotating electric motors, relays and wherever electrical contact between metal contact surfaces is used).

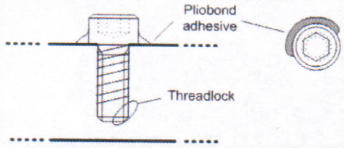
## Silicon contamination



## Vibration durability

- Screws:
  are fastened with a small amount of threadlock in the threads
- Screw heads and nuts:
  are fastened with the adhesive Pliobond around half the circumference

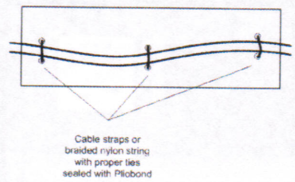







## Vibration durability

- Cables:
  are fixed with cable straps or tied with braided nylon wire

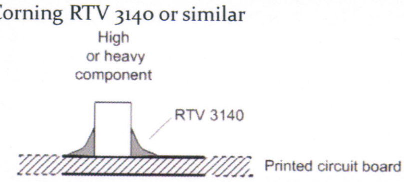







## Vibration durability

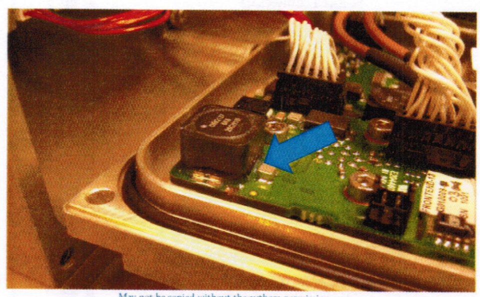
- Electronic components:
  high components (typically electrolytic capacitors)
  heavy components (typically ferrites and inductors)
  shall be fastened to the circuit board with Dow Corning RTV 3140 or similar

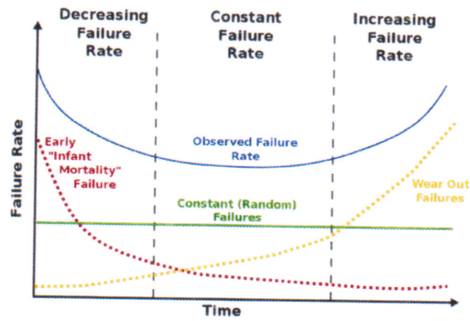







## Fastening of components









## Pre-delivery procedures




## Formation

Formation is a method to thermally and mechanically stabilize the product before it is being delivered to the customer. This is primarliy used for systems containing optics (lenses), like cameras and similar.

**Thermal formation:**

The finished and tested product is temperature cycled between a cold and a hot temperature a few cycles. All mechanical tensions will neutralize.

**Mechanical formation:**

The finished and tested product is bumped with some g a number of times (perhaps 20 times). All mechanical tensions caused by misalignment during assembly will neutralize.




## Burn-In

In order to make sure that all early faults have been found before delivery, finished systems are subject to a longer time of constant 24/7 use at the factory.

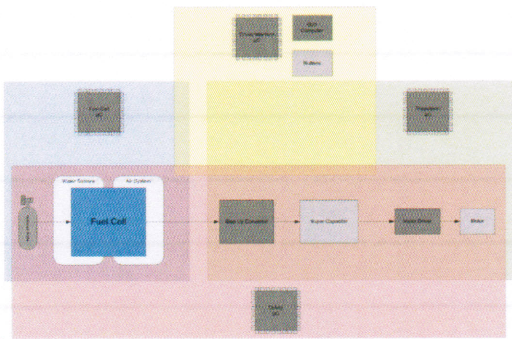
In some cases for mission critical systems, up to 1/3 of the products' expected life time is consumed as Burn-In.

Robust lec 11 (1/2)

Assembly of mechatronic systems

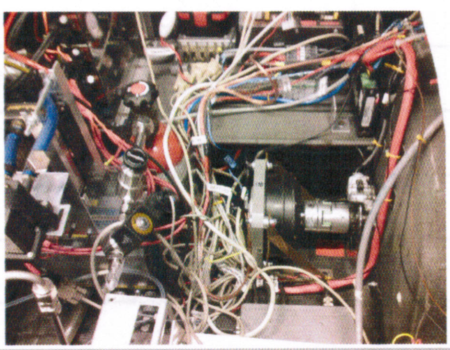


## Overview of system






## And in reality...



## Wiring

- Use the structure to "hide" your wires. Wires should usually not be outside the product.
- Rotating structures could give you the possibility to put wires in the centre.
- Loose wires have to be clamped.
- "High frequencies" are quite low in long wires => ringing effects possible.

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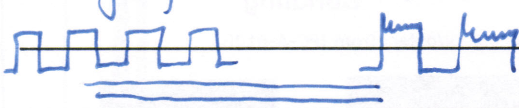
Ringing

Ringing



## Clamping wires to some structure

Why?

How?

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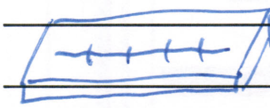
- Vibrations
- Isolation can be scratched off



## Strand, wire and cable

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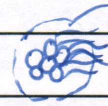
Strand = kardel

Wire =




Cable =

## Cables


Lot of different types

- Build a cable from single wires and bundle it
- Unshielded
- Shielded
- High flexible
- Twisted pair
- High temperature
- Flatcables

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- If unshielded, filter input.
- Flexible for vibration resistance.

## Connectors

It's a jungle

Connectors can be bulky and expensive but extremely important

- MIL-specified
- D-subs
- Board
- And many more

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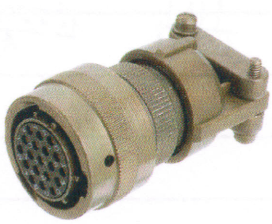
## Mil specified

- Robust!

Male receptacle



Female cable socket

- And expensive

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## Solder or crimp

- The most common types of connector are solder or crimp.
- N.B. Solder type should be soldered and crimping type should be crimped...

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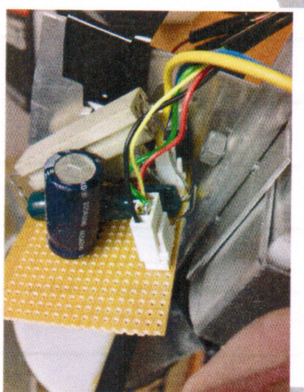
## Crimpsoldered



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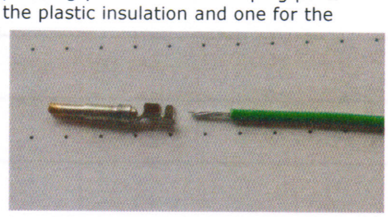
Stoopid!
Crimped is flexible,
solder makes it rigid.

## Crimping

- Use the right tool!
- For roll pressing you have two crimping parts one for the plastic insulation and one for the strands



- Other types of crimping types exists of course

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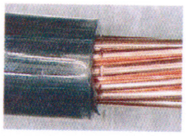
## Common for both types

- When cutting the insulation do not destroy the strands!



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## Shielding

- The shield from the cable should be connected for the metallic house of cable socket connector
- The connector part on the box should have a good electrical connection (low impedance) to the box
- This gives you a solution where the box and the cable are within the same zone.

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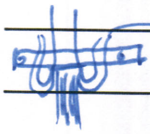
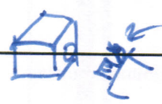
Fastning of shielded cable:



Shieled cable



Braid soldered to wire to box

## Clamping of cables

- All cables must be clamped outside the electrical connection.

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Robust Lec 11 (2/2)



Troubleshooting

# Troubleshooting

- A structured way of working
- What do you need?
  - a) Appropriate instruments
  - b) Function description over the system
  - c) Schematics
  - d) PCB layout
  - e) Datasheets
- Two types of Troubleshooting
  - Static
  - Dynamic

# Tools for troubleshooting

- **Static**
  - Multimeter
  - Oscilloscope
  - Logic probe
- **Dynamic**
  - Logic probe
  - Oscilloscope
  - Logic analyzer
  - Spectral analyzer
  - In Circuit Emulator, Debugger (JTAG)

Logic analyzer measures logic level in several points.

## FTA, Fault Tree Analysis

- Find dangerous or unacceptable event
- Find lower level causes for the event
- Structure them with AND/OR logic operators
- Go down to a level of single component failure



Top-Down

## FTA, Example

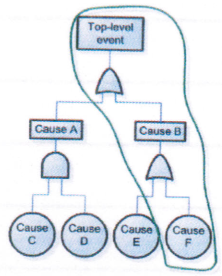


Figure 1.1: An example of a fault tree where a minimal cut set is encircled



## Failure Mode and Effects Analysis

- Bottom up approach
- Could be used either at function level or component level

Robust Lec 12

## Lab resumé

Mikael Hellgren

KTH ROYAL INSTITUTE OF TECHNOLOGY

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## Lab 1 - 4

Problems and (some) solutions that have occurred during labs

+ CE marking

+ Exam

2

Capacitor model:

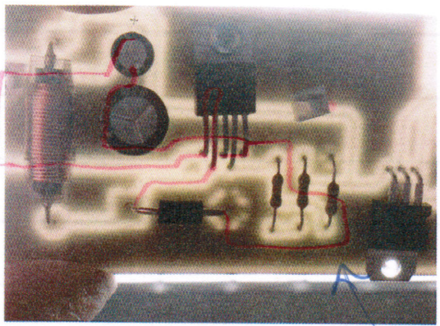
## Lab 1 Voltage regulators

1. Incoming capacitor important also small one.
2. Some had warm capacitors…
3. How to calculate dissipated power in 2673?
4. Max 0,5 A out, solution?

3

Warm caps. - losses in R and L part. L is R in High freq.

## Reality



The hot loop

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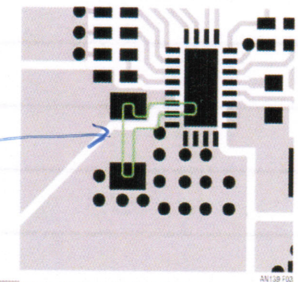
## Solutions

Minimize area

Hot loop



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## Impedance in ground plane

Cu-plane => low inductance

Test 10x10 cm

$f$ =25 MHz

Tabell 1

| d (mm) | f (MHz) | C (pF) | L (nH) | | Faktor jämfört med d=0,12 mm |
|---|---|---|---|---|---|
| | 18.4 | 400 | 187 | Enkelt lager öppen slinga | 14,4 |
| | 21,2 | 400 | 141 | Intern kortslutande kopparslinga | 10,85 |
| 1,5 | 38,9 | 400 | 42 | Helt kopparplan | 3,23 |
| 1,5 | 34,7 | 400 | 53 | Rektangulär slinga utan överlappning | 4,08 |
| 0,5 | 52,1 | 400 | 23 | Tunn rektangulär | 1,77 |
| 0,27 | 55 | 400 | 21 | | 1,61 |
| 0,12 | 69 | 400 | 13 | Papper | |

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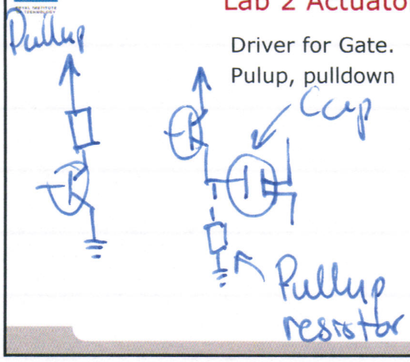
## Lab 2 Actuators

Driver for Gate.
Pulup, pulldown

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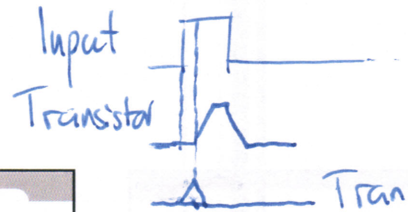
Cap can't discharge without pullup resistor, will make transistor stay on.




Transistor if too fast switching. Resistive mode → big losses.

## Lab 2

H-bridge
PWM frequency vs motor τ

Efficiency vs PWM frequency

Two different efficiencies

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If in fast mode, more EMI but faster response.

## Lab 3 Filter

- Active filter.
- Lower voltage out then expected with inverting amp
- Non inverting amp
- LM10 OP amp

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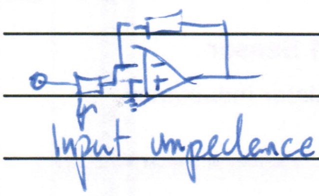
Input impedence might be reason



## Lab 4 Sensor

Power resistor inductance

If 1uH and 20 kHz

⇒an extra
0,13 Ohm!

But, it was not only reason..
Input cm voltage gives problems

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## Lab 4

Common mode voltage amplification (not wanted)

Differential mode voltage amplification (wanted)

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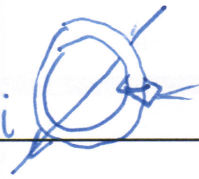
i  Proportional to i (magnetic flux)

Hall effect sensor.

## Lab 4

Sens resistor not connected to anything => max volt out.

Current sensor on breadboard

Input filter and symmetry

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## CE-marking

Some products that require CE-marking

- Machinary
- Electrical and electronic equipment
- Medical devices
- Toys
- Personal protective equipments

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## New Approach Directives

Four basic principles

1. The Directives regulates only the essential safety and health aspects
2. The detailed technical requirements are covered by harmonized standards
3. Products designed according to requirements in the harmonized standards are presumed to fulfil the essential requirements in the Directives
4. It isn't mandatory to comply with the standards but you must comply with the essential requirements of the Directives

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## Directives

- The Machinery Directive (MD) 2006/42/EC regulates products used commercially and which contains moving parts
- The Low Voltage Directive (LVD) 2006/95/EC regulates electrical products
- The Electro Magnetic Compatibility Directive (EMC) 2004/108/EC regulates radio Frequency emission and immunity
- The Radio and Telecommunications Terminal Equipment Directive (R&TTE) 1999/5EC regulates products which incorporates radio transmitters
- The Restriction of use of certain Hazardous Substances Directive (RoHS) 2002/95/EC, from 2013 2011/65/EC
- More than one Directive can be applicable depending on kind of product and function

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## CE-marking documentation

- **Technical File**, including documents concerning the product and test reports verifying the requirements in the Directives, harmonized standards or other verifying methods
- **Declaration of Conformity** (DoC), the manufacturer or authorized representative within the Community declares the conformity with the Directives and standards
- **CE** marking on the product

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## Declaration of conformity

Should at least contain:

- name and address of the manufacturer /the authorised representative
- identification of the product (name, type/model, batch etc.)
- referenced standards
- the first time it was put on the market
- date of issue
- signature and title of authorised person
- statement that the declaration is issued under the sole responsibility of the manufacturer and, if applicable, the authorised representative.
- Where applicable: Notified bodies

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