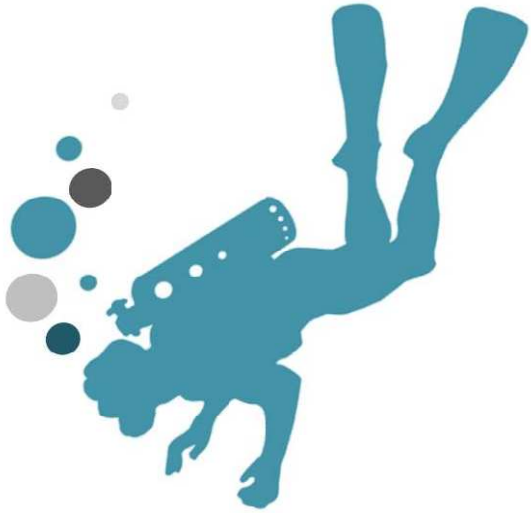
INGENIØRHØJSKOLEN I KØBENHAVN

# DELPHINUS

## Development of a Digital Communication Device for Diving



Document: Appendix

Date: 2 December 2010

Version: 1.0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Supervisor: Emil Piper


EPS 2010, Autumn

Group 7

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# 1 Project management

EPS 2010, Autumn
GROUP 7

Document: Project management

Version: 1.1

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## 1.1 The basic elements

### 1.1.1 The task

The aim of our project is to find a solution of communication for divers and create a working prototype device. Old reports from previous semester projects will be utilized to take information out and improve the application benefits.

### 1.1.2 Project process

- Gathering information and data
- Analyzing data
- Choosing a useful part of work that is done
- Choosing a appropriate parts and devices for our project
- Doing marketing research
- Generate and evaluate new idea's
- Designing a structure of a system
- Programming and assembling
- Testing the prototype in different kind of aspects
- Preparing the documentation of a project
- Preparing the presentation

### 1.1.3 Project specification

The main aim consists of examining and analyzing the device, looking for appropriate component parts and materials, and its functionality. We put an effort on making system cheaper and more usable for potential customers.

**General specifications**

- The device fits to the arm of each diver.
- The device must have a touch screen. No buttons.
- Use the international hand signal as the method of communication.
- Enables 2 or more scuba divers to communicate.
- Resists corrosion from salt, chlorine and other chemicals.
- Functions at up to 30 meters below the water's surface.
- Complies with all relevant European legal and safety standards.
- Unaffected by exposure to UV light.
- Adjusts to fit all potential users.
- Must be durable, having an adequate life-span.
- Must run for at least the length of a dive time on one battery charge.
- The product should be reasonably lightweight to ensure comfort when on a person's wrist.
- Developing the most suitable strap to guarantee the product is properly secured on the arm comfortably.
- Must be cheap then other similar products.

**Casing specifications**

- The device has to be 100 % waterproof.
- When assembled the unit must be completely sealed.
- A compact design, ensuring probability of damage on surrounding objects is minimized.
- The casing must fit a variety of users comfortably whilst remaining secure.
- All components must be accessible for repair and replacement.
- Needs to be suitable for mass production.
- Touch screen needs to be very close to casing to ensure it will function properly.
- No physical connections will be installed into the product. This is done to reduce the number of entry points to the product. Instead wireless charging will be implemented.

**Interface specifications**

- Simple to understand. Avoid too many functions on the main screen so the user will not be confused.
- Easily controllable. All buttons should be at a significant size, for the diver to be able to touch the button on the screen when wearing a glove.
- It must be able to run with a small power source.
- The system should be made basic and fast responding.
- The images are very clear and understandable.
- There will be an emergency button.

### 1.1.4 Project structure

The project is focused in different areas. The main areas are electronics and design, so that is the reason we have divided the team into two sub-groups. One of them is in charge of the electronic section. The other one takes charge of developing the casing and the marketing research.

- Looking for and reading materials.
- Considering many ways of device design, communication.
- Solving construction issues.
- Seeking alternatives at different fields of project (e.g. algorithms)
- Finding and examining proper materials.
- Evaluating electricity consumption and defining a way of power supply.
- Evaluating approximate costs of device.
- Project management.

### 1.1.5 Resources

- Team members
  - David Pinilla Ramiro. Telecommunications
  - Pawel Gorski. Mechatronics
  - Marcin Samsonowski. Computer science
  - Tamanna Zirak. Human Technology
  - Luna Vaquero Aso. Industrial Design
- Supervisor: Emil Piper
- Laboratory
- Electronic stuff
- 3D printer
- GPW Rooms

- Interviews with divers
- Video of divers
- Old reports from previous semesters

### 1.1.6 Environment

The areas that affect and are affected by the project are

- The market place
- The current level of technology,
- Competing products
- Usability
- Design
- Programming

### 1.1.7 Interested parties

Interested party could be

- Military
- Diving club
- Professional divers
- An innovation company
- Company with similar product

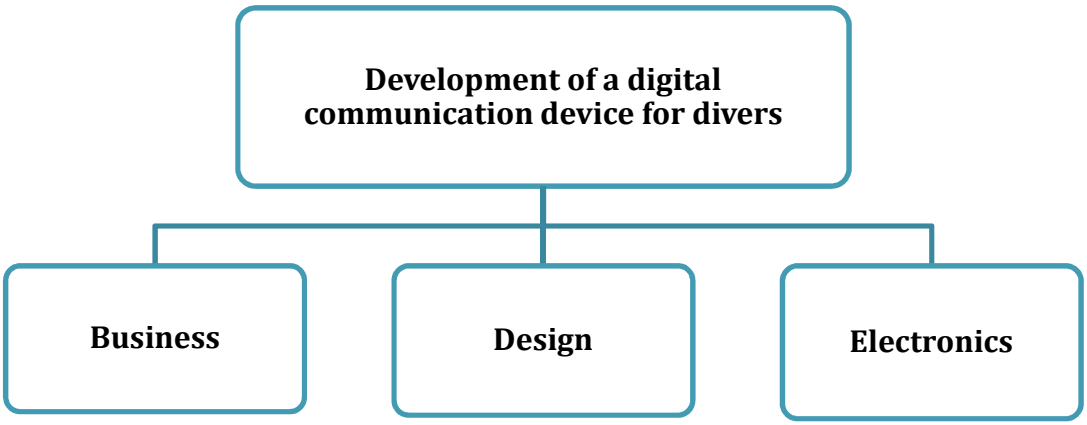
## 1.2 Responsibility Matrix

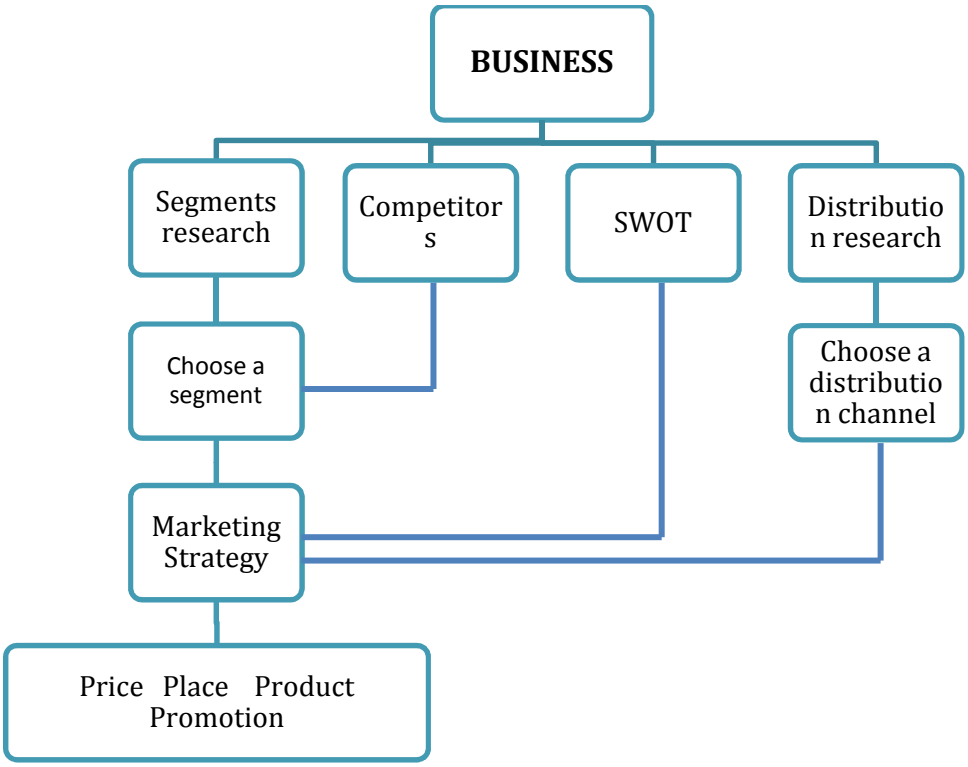
| Task | Pawel | David | Marcin | Luna | Tamanna |
|---|---|---|---|---|---|
| **SWOT** | | | | S | **R** |
| **Competitors** | | | | | |
| **Segment research** | | | | | |
| **Choosing segment** | | | | | |
| **Distribution research** | | | | | |
| **Distribution channel** | | | | | |
| **Price, Place, Product, Promotion** | | | | | |
| **Design** | | | | **R** | S |
| **Analyze previous reports on design** | | | | | |
| **Writing interim report** | | | **R** | | |
| **Writing RS** | S | S | S | S | **R** |
| **Environmental** | | | **R** | | |
| **Background** | **R** | | | | |
| **Method** | S | | | S | S |
| **Results** | S | S | S | S | S |
| **Discussion** | S | S | S | S | S |
| **Conclusion** | S | S | S | S | S |
| **Electronics** | | | | | |
| **Research about display** | S | S | S | | |
| **Choose a display** | S | **R** | S | | |
| **Research microcontroller** | S | S | S | | |
| **Choose a microcontroller** | **R** | S | S | | |

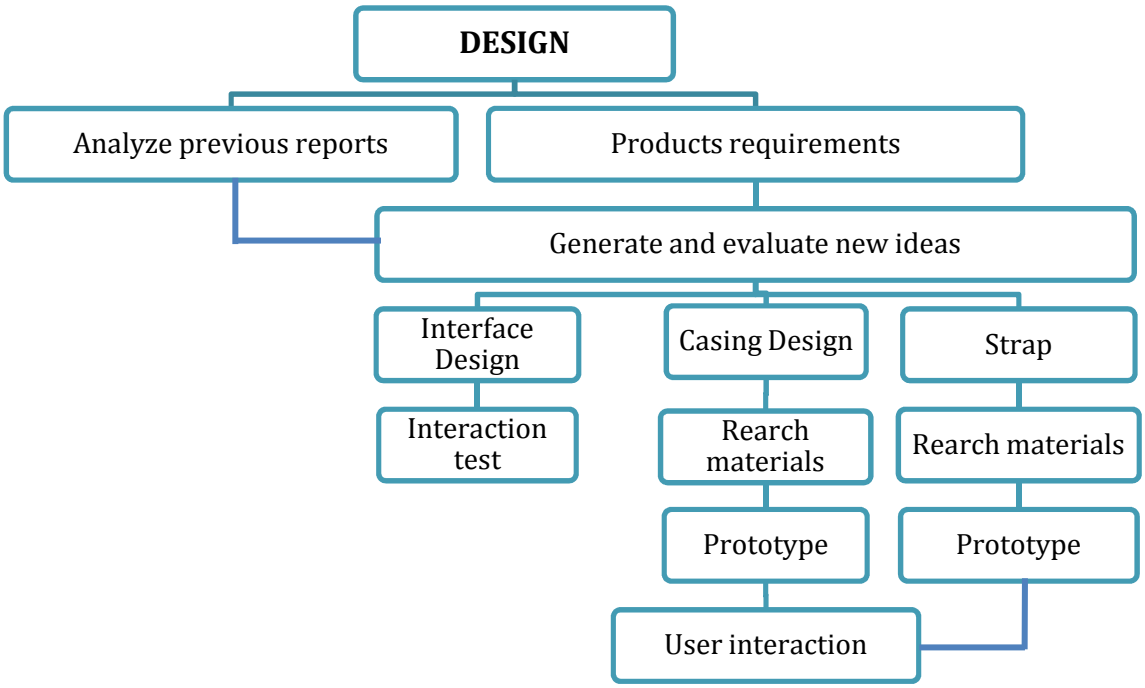
| | | | | | |
|---|---|---|---|---|---|
| **Building a circuit** | S | **R** | S | | |
| **Testing** | S | S | **R** | | |
| **Programming** | | | | | |
| **Circuit design** | S | S | **R** | | |
| **Overall design** | S | S | S | S | S |
| **Programming display** | S | S | **R** | | |
| **Visualization interface design** | S | S | S | S | **R** |
| **Programming microcontroller** | **R** | S | S | | |
| **Programming prototype** | S | **R** | S | | |
| **Design** | | | | | |
| **Generate and evaluate new ideas** | | | | S | S |
| **Describing interaction** | | | | S | **R** |
| **Research casing materials** | | | | **R** | S |
| **Research strap materials** | | | | **R** | S |
| **Display design** | | | | **R** | S |
| **Interaction test** | | | | S | **R** |
| **Prototype** | S | S | S | S | S |

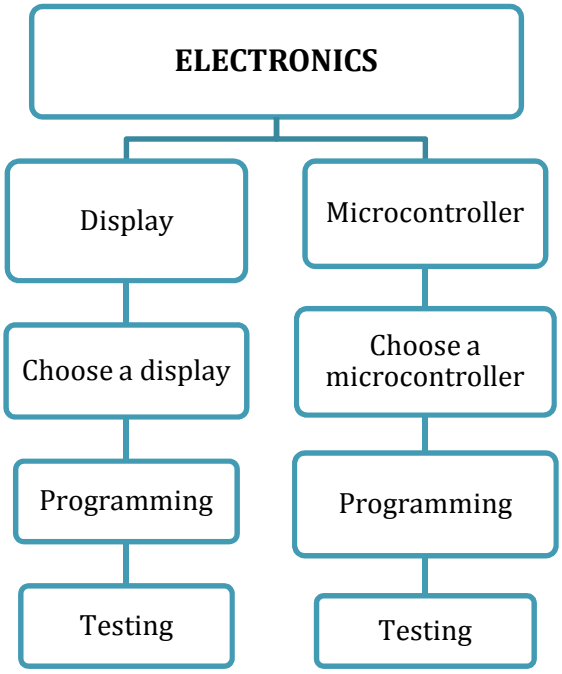
| **Final report** | | | | | **R** |
|---|---|---|---|---|---|
| **Results** | S | S | S | S | S |
| **Discussion** | S | S | S | S | S |
| **Conclusion** | S | S | S | S | S |
| **Presentation** | | | | | |
| **Preparing oral presentation** | **R** | **R** | S | S | S |
| **Preparation for Oral exam** | | | | | |
| **Management Exercise** | | | | | **R** |
| **Making exercises** | S | S | S | S | **S** |
| **Presentation** | | | **R** | | **S** |

## 1.3 Work Breakdown Structure

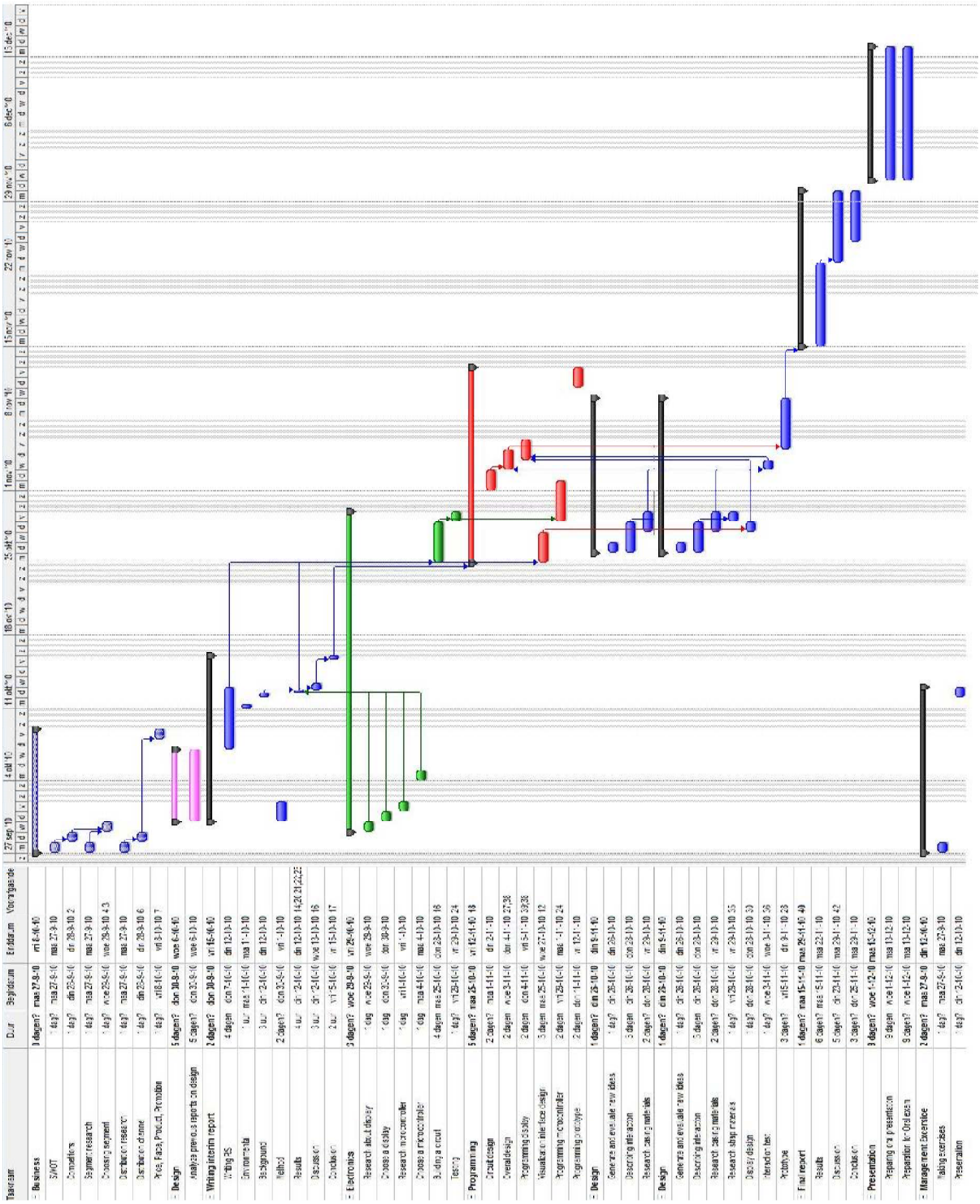



DESIGN
Analyze previous reports
Products requirements
Generate and evaluate new ideas
Interface Design
Interaction test
Casing Design
Rearch materials
Prototype
Strap
Rearch materials
Prototype
User interaction


ELECTRONICS
Display
Microcontroller
Choose a display
Choose a microcontroller
Programming
Programming
Testing
Testing

## 1.4 Gantt Chart



# 2 Requirements specifications

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## 2.1 Who, what, when and how?

Who?

The users of the Delphinus are people who are training at diving clubs and professional divers. The diver must be known with the diver's signs.

What?

Divers need to communicate with each other under water in order to be safe. The environment underwater is different so the communication is limited.

So it is necessary to communicate under water without making all the time eye contact with each other. So the communication there will be a device build that is wireless and works between two or more divers.

When?

The parameters depend on sea condition, because of the waves and the environment where the divers are in.

The device has to work underwater with a depth parameter of minimum 10 meters.

Delphinus has to work at distance of minimum 25 and maximum 100 meters between the divers.

How?

The device is used with Ultra Sonic waves. The device will be used on the arm. The device has a touch screen display. The communication will be visualized with an interface on the display. The divers hand signs will be used for visualization. The divers has to use their finger to use the touch screen. There has to be the possibility to send the message to one or all divers at the same time.

There will be an emergency and an S.O.S function. The emergency can be send when one of buddy is in danger. It must be available to send the emergency and S.O.S message to all divers in the distance of minimum 25 and maximum 100 meters.

## 2.2 Purpose

### 2.2.1 Developer

The purpose is to make a working prototype. It is in a further development than the mock-up model from the previous project.

### 2.2.2 Customer

We want the customers to buy the product. The purpose of the device is that it satisfies customer's requirements. The customers can achieve their aim; communicate wireless under water.

### 2.2.3 Rules for RS changes

- To makes changes in RS it has to be discussed with Emil Piper.
- There should be explain which part will be change and why.

### 2.2.4 Product Purpose

The product has to work correctly. If there is some problem with the device then the error/warning message should be understood easily by everyone. It has to be smart. The price has to be cheaper than similar product. If the device is not cheaper, it must have more benefits compared to others.

## 2.3 Product features

**Sealing**

Delphinus should be charged before using it into water.

The battery uses wireless charging.

**Design (shape)**

The shape of Delphinus has to fit anyone on wrist/arm.

The transport case should be like the packaging from the mobile phone.

It has not any sharp-edges.

**Material**

It does not weight so much that is uncomfortable to wear.

The dimension is less than the mock-up model, so it looks smoother.

Delphinus is tough, so it won't break when it hits accidently to a rock.

The product is good visible in diving water.

Delphinus has resistances to water and chemical acids.

**Display (Interface)**

Delphinus saves energy while being off when it is not used.

Colours with short wavelength are used because those colours will be longer visible when getting deeper in the water**.**

A message can be sent to one or all divers.

Delphinus has no physical outputs.

Delphinus turns off when it is not used to for two days. To turn it on, it has to be recharge again.

Divers has to control Delphinus by touching the screen.

By touching the interface the diver gets feedback on the screen that she/he used the interface.

As feedback for receiving a message there is a vibration on the arm.

**Strap**

Delphinus has two straps so there is no possibility to lose Delphinus.

The strap is adjustable for all size of users.

### 2.3.1 Danger/ accidents

- The user of Delphinus should be aware of the this risks and the risks of diving before diving.
- Delphinus is 100% waterproof so there won't be no electrical danger.
- Sudden movements can be produced by crashing with rocks or avoiding aquatic animals and algae.
- Users must read the user manual before use it for first time. The device has a few functions; the learning how to use it is easy.
- Check before using Delphinus if there is enough power supply.
- Do not throw or explore Delphinus to fire.
- Keep Delphinus away from toxic materials.
- The user shouldn't open the casing and trying to fix it.
- Specialist knowledge: If the Delphinus doesn´t work, the user must send it to the technical service.

## 2.4 User characterize

The users are recreational and sport divers. Users can be of both sexes and into a large range of ages. But not including children and ancients. They could be novice to intensive user. More information about the user characterize can be found in the Final report (*Persona*).

Delphinus requires the following from the user:

- Capabilities to dive
- Knowledge related to their tasks
- Experience with the hand signals are needed to use the device
- Level of proficiency
- Healthy diver condition.
- The ability to read and write
- Good visibility
- Non-colour-sensitive
- Normal mental
- Experience in Delphinus, knows how to interact before the dive
- Good and calm reaction against risks or unexpected situations

### 2.4.1 Man-machine interaction

The interface of the man-machine should be based on the heuristics of Jakob Nielsen. It is used for users test to have friendly man- machine interaction. The heuristics of Jakob Nielsen is included in the appendixes chapter.

Apart from the criteria of Jakob Nielsen the interface has to be effective, efficient, easy to learn how to use it and easy to remember how to use it. When using affordances (using features that are recognizable) the device is easier to use.

Other requirements to the interface are:

- 'Don't make me think': users should not have to think for example if something is they could click on something or not. (Steve Krug, 2005)
- 'Mindless choices': users should make mindless choices. (Steve Krug, 2005)
- There is no concentration demanded while using the device.
- In case of panic the emergency function is used to warn the other divers.

To know how the interaction takes place task requirements are needed. There is a conceptual model used, figure 2.1. The conceptual model shows what the tasks are and how the task will be used. The figure is an overview. Further in this chapter will be the parts shown, figure 2.1 A, B and C. Those tasks are translated in functions. Below explains the functions of the interface.

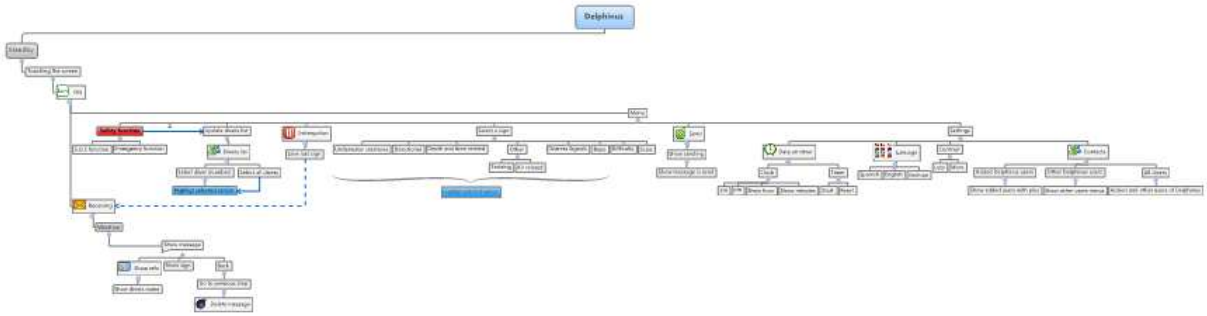


Figure 2.1, Conceptual model

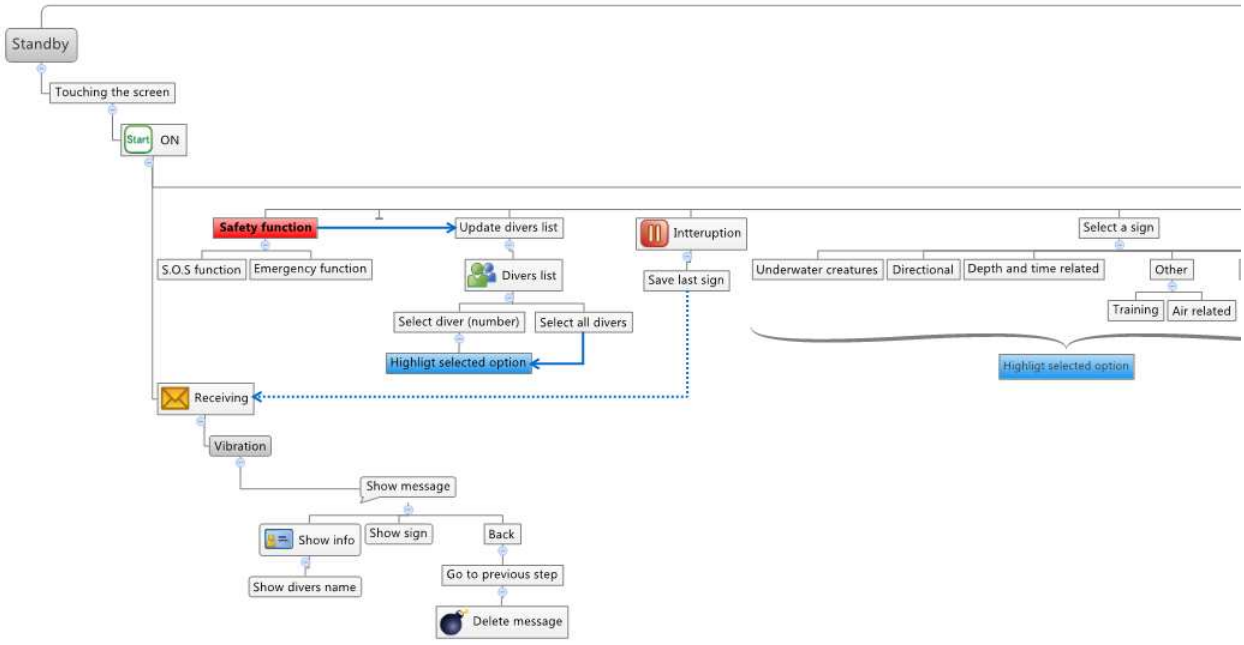



Figure 2.1 A, Part 1

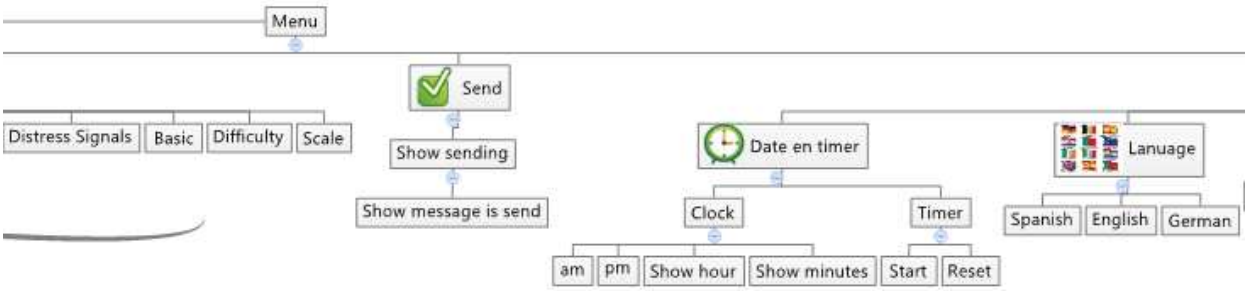



Figure 2.1 B, Part 2

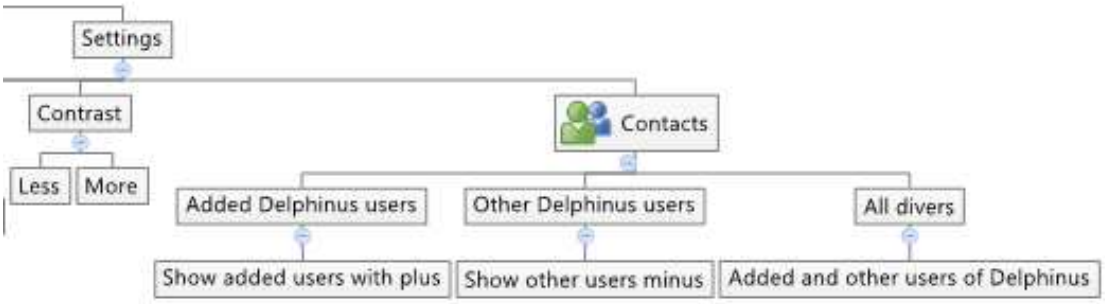



Figure 2.1 C, Part 3

**STANDBY → Touch the screen →Delphinus ON**

***MAIN MENU***

1. ***S.O.S***

   1.1 Send to all divers (Diver ID) needs help.
   1.2 Go forward by using left arrow/ or make a movement from left to right

2. ***DANGER***

   2.1 Send to all divers: (Diver ID) warns: Check around and go a.s.a.p. to the surface.
   2.2 Go back by using right arrow / or make a movement from right to left

3. ***SETTINGS***

   **3.1 Timer**

   3.1.1 Start

   3.1.2 Reset

   **3.2 Time**

   3.2.1 AM

   3.2.2 PM

   3.2.3 Choose hour

   3.2.4 Choose minutes

   3.2.5 Change opacity 15% of selected option.

   3.3 **Language**

   3.3.1 Choose English

   3.3.2 Choose Spanish

   3.3.3 Choose German

   3.3.4 Change opacity 15% of selected option.

   **3.4 Contrast**

   3.4.1 Plus

   3.4.2 Minus

3.4.3 Show contrast in percent

### 3.5 Contacts

3.5.1 Press plus to delete it from receiver list

3.5.2 Press minus to add it to receiver list

3.5.3 Show all the Delphinus users who are not added at the first pages.

3.5.4 Show page sum of page numbers (for example 3/13)

***4. MENU***

**5. SELECTED RECEIVER**

5.1.1 Select receiver from the list
5.1.2 If receiver is selected→ Change opacity to 15%.
5.1.3 Show page sum of page numbers

**6. SELECT CATEGORY**

6.1.1 Select one category from the eight categories.

6.1.2 Select a sign from the category.

6.1.3 Show page sum of page numbers

**7. SEND**

7.1 Press the green button to send the sign.

7.2 Show time of squared timber.

**8. REPLY**

8.1 Send to same sender

8.2 Repeat step 6 and 7.

**9. BUTTON BACK**

9.1 Go back to previous step until 'Home' is reached.

9.2 If a message is shown by pressing back, deleted message

**10. HOME**

10.1 Go back to main menu

**11. Interruption**

**11.1** If step **5.1.1** was chosen by doing step **9** → go to step **6.1.1**

**11.2** If step **6 .1.1** was chosen by doing step **9** → go to step **6.1.2**

**11.3** If step **6 .1.2** was chosen by doing step **9** → go to step **7**

## 2.5 Product relation

### 2.5.1 Hardware

Product has three important parts: casing, hardware and software.

Hardware includes display, touch screen, battery, board and acoustic sensors.

- OLED Display is used to show messages.
- The display has its own microcontroller and memory.
- The touch screen is joined to the display.
- It will be possible to manage Delphinus by touching the screen, as well as send and read the different signals.
- The battery is rechargeable.
- It is allocated inside the casing and it is possible to take it out easily.
- It supplies power to all the components in Delphinus.
- The board is composed of microcontroller, ATMEGA16L, electronic components and the communication system. This is amplifiers, filters and acoustic sensors.
- Acoustic sensors are the responsible for sending the ultrasound signal and also for detecting when a signal is incoming and capture it in the system.

### 2.5.2 Software

Microcontroller in the board is in charge of running the implemented program. In order to handle the input signals, interruptions will be used. When the microcontroller will detect a signal in its input pin, an interruption will be enabled and the process to handle the message will start. If the message is addressed to our device, the analogic-digital converter (ADC) in the microcontroller will transform the signal to a digital one. After that, the right message will be identify and the microcontroller will send it to the display, which will handle it and show it in the screen.

Similarly, when the user pushes the screen, the display manage the orders and send them to the microcontroller. If it must send a signal, it takes the different parts of the data, the CRC code and creates the message. Later, the digital-analogic converter (DAC) transforms the signal and puts it in an output pin of the microcontroller. This is connected to the communication part, which converts the signal in an ultrasound wave. The acoustic sensors send it to the other diver.

To manage the messages, the display uses its own microcontroller. It is the responsible for showing the drawings in the display, handling the functions after pushing the screen and sending to the ATMEGA16L the right data and orders to send the ultrasound signals. Therefore, it is needed an accurate program that dealt with that. And also, this program must be related with the software in our board.

## 2.6 Product function

**Main function:**

Make possible the wireless communication between two or more divers.

| **COMPONENT** | **FUNCTION** |
|---|---|
| Casing | Contain and protect the components |
| Strap | Hold the device on the arm |
| Sealing | Compile components and makes it waterproof |
| Battery | Supplies power |
| Touch Screen | Makes product – user – interaction possible |
| Display | Visualize information |
| Microcontroller | Convert the signal and process the messages |

## 2.7 Product limitation

### 2.7.1 Hardware

- In the worst-case scenario the distance between the divers are minimum within 25 meters.
- Delphinus works under good circumstance of the sea within 100 meters distance between divers.
- Board, circuits and battery are small as possible in order to the case fits the forearm.
- Battery must last more time than the oxygen bottles.
- Microcontroller has a 16 KB flash memory.
- Microcontroller has a 1 KB SRAM memory. The code is stored in this memory.
- Microcontroller has a 512 B EEPROM memory.

### 2.7.2 Interface for other applications

- There is no other application.

### 2.7.3 Safety conditions

- Case is able to work under water pressure.
- Board and circuits are dry. Wetness does not get in the casing.
- Connections between parts of the hardware must be clean.
- Display and screen are protected against knocks.

### 2.7.4 Data protocols (format)

- The length of a message is 18 bits.
- The first 4 bits is receiver ID.
- The second 4 bits is sender ID.
- Info field is 6 bits. There are 52 possible signals, so we need at least 6 bits to have 64 different possibilities.
- Last field is a 4 bit CRC code to check the messages.
- In the case receiver ID is 0, the message will be sent to all divers.
- Once the receiver gets the message, it is checked through the CRC code.
- If the message is wrong, the receiver will send a request for the message again.
- Otherwise, if the message is right, the receiver ID field will be read in order to identify it.
- Only in the case the message was addressed to our device, info field will be read, stored in the memory and showed in the display.
- Interruptions are used to handle the incoming messages.

An scheme of the message format can be seen in figure 2.

## 2.8 Product dependence:

### 2.8.1 Hardware

- AVR microcontrollers require software like: winAVR, AVR studio.
- It requires special programmers like stk 500, jtag. This software can be installed on every pc which has a windows XP or newer.
- The software can be downloaded from Atmel website for free.

- Software is dedicated to only one microcontroller because each microcontroller has its own architecture.
- Active peripherals of the microcontroller can be used for another microcontroller, passive peripherals are depended to each particular microcontroller.

These relations are showed in figure 1.

Furthermore, there is a functional diagram in figure 3 which explains how the application works.

## 2.9 Functional requirement

**Sending and receiving messages**

The main target of our project is to allow user to send message and another diver to receive it. The issue of diving in groups is the eye contact between divers. It's not so easy to have such contact at all the time. In case of emergency it can be vital to contact as quickly as possible. Delphinus solves that problem. Sending and receiving messages allows users focusing on something else than eye contact or distance between divers.

**Presenting signs as comprehensible pictures**

One message corresponds only one sign, as in natural diver's conversation under water – diver makes some gestures to give the one strict information. Every signal must be as clear as possible. To achieve it, every picture (presenting adequate sign) should be very intuitive.

**Information and warnings about battery charge**

There should always be the information on the display, about battery charge, and approximate time to dive with working device. User must know a long time before discharging, how long he can stay under water.

**Possibility to alarm at all the time**

Even if the battery is discharged (almost discharged – e.g. battery falls asleep when has only 10% of energy, but not waiting till will be completely discharged) there must be a possibility to raise the alarm. In case of bad visibility, there should be such possibility too. In summary, there should be one big button, active even if device is in sleeping state. User can click it even when he can't see anything at all. It should be very useful in case of emergency – diver is always safe.

**Clear and reliable display**

Display must be tough, because when hitting some obstacles, it can't hurt – it could be dangerous for diver. It must be clear too. Every unnecessary ornament will make the device less comfortable.

**Giving the names to users**

User must be allowed to assign user numbers in his device, to easy and short nicks of other divers. Thanks for that, sending and receiving messages will be quicker and more reliable, when don't need a time for thinking who is who at list of users on the device.

**User-friendly and convenient interface**

All of the project parts must be very intuitive. Signs must be grouped in the clever way. Using the device should be almost trivial, nice and helpful. Time of doing all the actions (e.g. sending) is very important, and should be as short as possible. Fast choosing of divers and signs will improve the way of quick using the device.

**Keyboard and touch screen**

Input signals come from touch screen. Any keyboard is not needed. Part of screen under the pressure of touch is clicked and activates the actions corresponding to the chosen elements. It is important to make the display tough and resistant to damages, but it must be sensitive enough to receive the actions from user.

**Modes of operation**

Our device has 2 modes of operation. The first one is normal mode, which allows using all the functions – sending, receiving or even only waiting for actions. The second is sleeping mode, which only gives the user opportunity to alarm other divers. This mode is activated, when battery is almost discharged (e.g. 10% of total charge).

**Timer duration**

Divers need to know how long they are in the water. Now they have a watch, but that would not anymore necessary. The timer is needed to check for example the decompression time.

**Other**

Divers carry many tools under water. There is more investigation needed to know if the tools are a burden and which additional feature they would like to have in Delphinus. The information that divers need are:

- Current depth
- Maximum range of depth
- Decompression time
- Water temperature
- Speed of landing
- Warning: of maximum of depth range or to fast going up to surface
- Compass: underwater navigation when environment changes
- Light, if its dark.

## 2.10 External interface requirement:

**Hardware interface**

There is no hardware interface. There are no plugs needed for microphone, speakers or any other sub-assembly.

**Software interface**

There is no software for external interface needed. Delphinus does not make any connection with PC.

User interface (Man-Machine Interface)

Instead of keyboard Delphinus has a touch screen. It will be very convenient way of using it. All the information will be shown on the display, and only way to control the device will be to touch the appropriate buttons on the display.

**Communication (internet)**

Delphinus would not make any connection with the internet.

## 2.11 Quality requirement

**User friendliness**

- The user can achieve his goal with the device.
- The diver can send all the signs in distance that are needed without making eye contact to the other diver.
- Delphinus fits everyone and the strap is comfortable for all range of users and easy to adjust.
- The interface is clear and easy to use for a good interaction.
- It has to be learnable; it must not take long time to learn how it works.
- It is recognizable. The interface is familiar with user experiences and their expectations on how to use it.
- The visibility of the functions will be clear and organized.

**Reliability**

- The divers can always communicate in long distance.
- The material for the casing is compact.
- Delphinus is waterproof.
- There is an emergency function.
- And a SOS, if the diver is in danger he can send a SOS message to all the other divers by taking one step.

- There will be a warning when the battery level is low.
- The materials of the casing must be resistant to chloride and other chemical substances.

**Efficiency**

- There will be no communication errors or troubles with the hardware.
- There will be less danger for divers, because the communication is better now.

**Maintenance**

- After every dive the user must wash and wipe down Delphinus and make sure that the contacts are dry prior to confectioning it to the charger.
- Do not use any chemical product to clean Delphinus.
- The device must be waterproof. The casing must be sealed.
- If the battery power is getting lower the user should send the device to the technical service.
- Delphinus should be not repaired by the user.
- Any replacement of the components must be done by the specialist.

## 2.12 Part delivering (test product )

**Delivery of minimum version**

- Programming of interface
- How to 'create' a message before sending

**Hardware requirements**

- OLED display
- Microcontroller
- Memory

- Touch screen
- Battery
- Amplifiers
- Filters
- Acoustic sensors
- Microcontroller has a 16 KB flash memory.
- Microcontroller has a 1 KB SRAM memory. The code is stored in this memory.
- Microcontroller has a 512 B EEPROM memory.

**Software requirements**

- AVR
- STK 500 Jtag

## 2.13 Appendix

### 2.13.1 Heuristics of Jakob Nielsen (2010)

These are ten general principles for user interface design. They are called "heuristics" because they are more in the nature of rules of thumb than specific usability guidelines.

1. **Visibility of system status**

The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.

2. **Match between system and the real world**

The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

3. **User control and freedom**

Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.

4. **Consistency and standards**

Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

5. **Error prevention**

Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

6. **Recognition rather than recall**

Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

7. **Flexibility and efficiency of use**

Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

8. **Aesthetic and minimalist design**

Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

9. **Help users recognize, diagnose, and recover from errors**

Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

10. **Help and documentation**

Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

### 2.13.2 Drawings

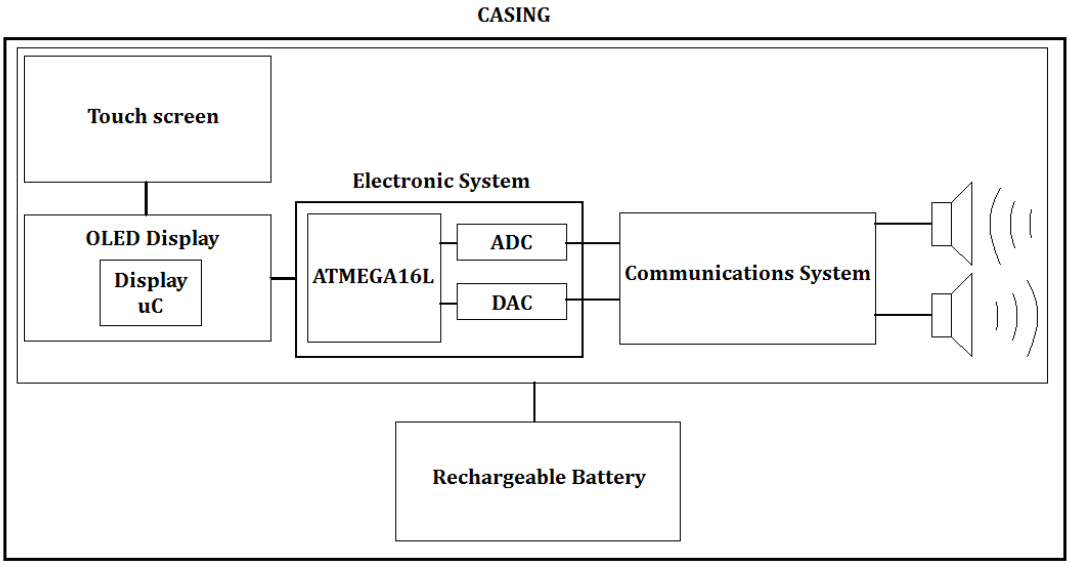



**Figure 1, System diagram 1**

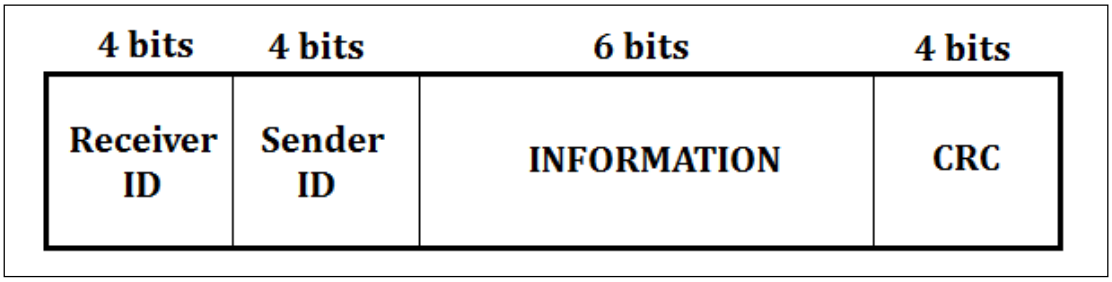



**Figure 2, Data protocol 1**

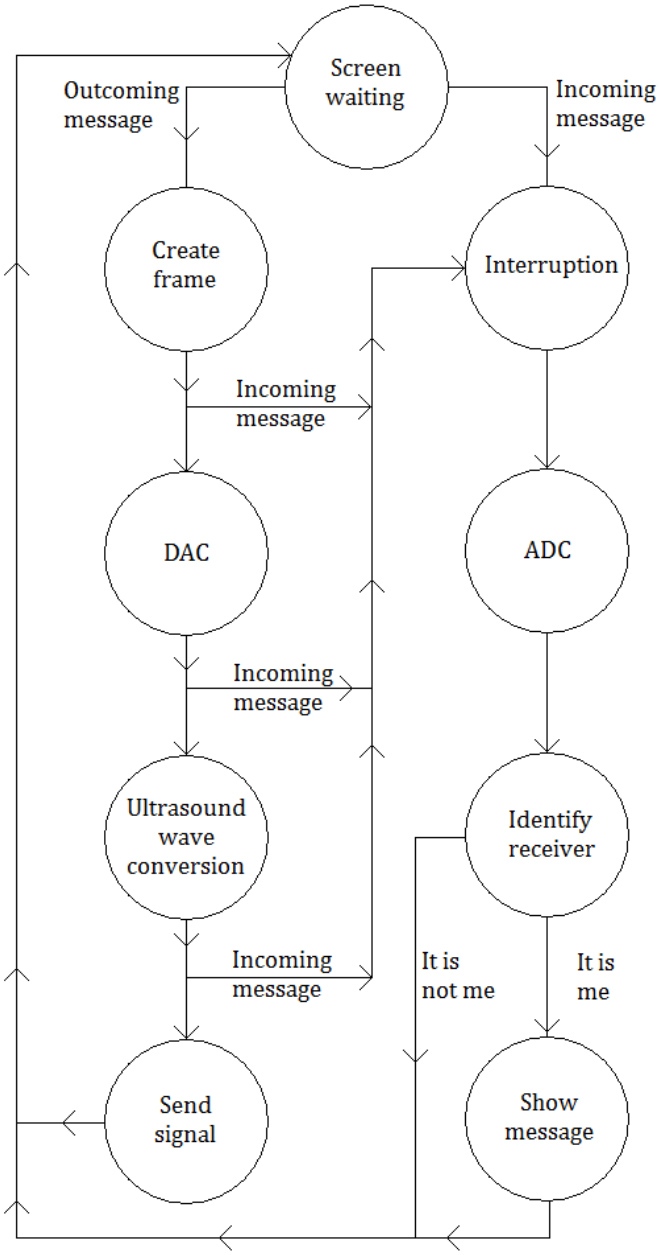



**Figure 3, Software diagram 1**

# 3 Marketing results

## 3.1 Porters five forces

**Force one: Degree of rivalry**

Diving takes Worldwide place. For an example in Asia there are 34 countries where you could dive, in Africa 18 countries and in Europe 39 ( www.scubish.com, 2010). Denmark has more than 29 diving centre (http://www.dykmag.net,2010), it is amazing because the size of the population are only 5 million people. It can be said that there is a market, where products can be introduced to.

While searching about competitors in Denmark, there are not many. The existing communication device for divers is not wireless and neither did it make a huge development over the years. One competitor has made a system that is similar to the system for scuba diving World, but failed in capturing good market shares (Team 9 – Final report, 2009).

Another is the UDI from the company Underwater Technology Center. The device is very expensive and can only send to 15 text messages.

Another could be XT-100 Buddy Phone from Ocean Technology Systems. When the diver enters the water, the XT-100 powers up and cycles to the receive mode. So in the water the device is ready to receive message, and to send message you have to push to talk button. But this data is heavier to send message, so it will take more time to process data. For more information about UDI and Buddy Phone you can have a look in the appendices.

So the teamproject would not have a main focus to the competitors, but more about the low price and a good design with high usability level.

**Force two: Threat of Entry**

Like the rivalry, the market for making a digital wireless communication device for divers is not big. It could be that the customers think it's expensive, or do not see its necessary because they already are used to communicate underwater with hand signals. If the device could be introduced well and has a good price compared to other similar devices the demand will increase because the target group will have faith in the product. Because the target group is big, the device could be introduced to sport divers, search & rescue, diving club, movie industry and military. To all these customers the connection to buy the device are low price and easy usage.

**Force three: Suppliers power**

Based on the design there will be parts manufactured. Before starting the process of designing the problems of manufacturing already has been defined and solved. This way the supplier has not a high power during the project.

**Force five: Buyer power**

Obviously the buyer power is high. To get the buyer less power, the device should be first introduced to the military and then to rest of the target group because of the military operations in the sea. The government could be interested to help the development of communication device under water. Therefore not only Denmark but also other countries will be interested in case of expanding.

## 3.2 SWOT – analysis

**Strength**

The strength of the project is that we are a multidisciplinary teamproject. The development of the device will have different study views, electronics & programming, designing & marketing. Using the strategy to introduce it to military will give the rest of the target group awareness of the device existence.

**Weakness**

Over the years there has been some technological development taken place for an example to make pictures under water and a communication device that allows surface personnel to talk with divers in the water or vice versa (Ocean Reef M100 Portable Surface Transceiver Unit (http://www.scuba.com, 2010))

The technology possibilities to make a wireless communication device underwater is not tried often except by the competitor with UDI, because it's difficult and its high price. If the product is still expensive nobody would buy it.

**Opportunities**

Because Seahorse is a small diving club the main focus would be on Danish sellers with the idea to expand. There has to be possibilities to add some new features or making improvement to the current features during the product lifecycle. Then there will be different target group interested.

**Threats**

Threats could be any other innovation company who wants to cooperate with the military to develop a new device. If the also use the penetration strategy, this could be harmful for Seahorse. Another threat could be if the design is more focused on usability.

## 3.3 Market and sales strategy

The market and sales strategy of the previous project will be used (Team 9 – Final report, 2009). The strategy is to operate on a business-to-business market and because nowadays people buy online it's a good strategy to have a small business-to-consumer sale from a website. Apart from that online selling is easier, there is not much staff needed, no indoor keeping, charges, so it's cheaper. Another reason is that you do not have a large target group at one place, they are dispersed.

Because the company has not to offer different kind of products, the relation with the consumer is not important to be close. On the other hand the business-to-business requires the relationship to be close. Customers from business-to-business could buy more amount of the device in case of improvement to the device. So it is good to win the loyalty of the customers.

**Positioning**

Positioning in the market is essential. If a company does not distinguish from another, the company has to compete with everyone. The company could position in different ways like on its functions or target group. While doing research about the competitors of Seahorse it is better to position in price and design (usability).

Compared to the competitors if it is cheaper, the number of customers will increase. If it cannot be cheaper, the positioning strategy should be on the design. Nowadays the aspect usability gets more attention of the design. If a user has not good interaction with the product, it makes the product worthless.

**Promotion**

After releasing the product, there has to be made an advertisement to show how the product is used. Why it satisfy the requirements of divers on communicating under water. This ad will be short and will be shown to potential customers.

Apart from the promotion to the business-to-business customers the product will also be promoted by:

- Mouth-to-mouth advertisement: introducing the product to diving clubs there will be mouth to mouth advertisement. This will go very fast and people will also tell each other for example on diving blogs.
- Demonstration to the military on how to use the product will be shown. And in commercial of the government for joining the military; the product will be used to let people see how the operation under water takes place using the product.

**Pricing strategy**

*This document about pricing strategy is copied from the previous team. It copied because this group will also use their strategy.*

By analyzing other areas of diving products such as diving watches, a need of regular servicing of the product will be needed. Therefore it has been decided that the company's concept is to sell the actual product at a lower price, but then producing a servicing contract with the individuals.

This ensures both that equipment will be up to date and working, but also ensure fixed income in the years to come. This strategic strategy is called penetration pricing, and with other words called a product service bundle pricing, which hopefully will gain percentages of the market. However the team's focus for now is the Danish market, but will also be sell to the rest of the world via the website. This means that product servicing from large distance could occur, and needs to be taken into account.

Mainly the issue will be the transport back and forth, which will have a high cost. This means that the servicing deals have to be differentiated compared to where the consumer lives, but also how many devices the consumer have purchased.
The price of the servicing deal maybe needs to be adjusted later on, because knowledge of the parts wear ability has not yet been gained, and therefore could change the price remarkably.
When trying to establish a quick overview of what kind of price would be reasonable for this product, the team has to bear these issues in mind:

- Development and manufacturing costs of the product

- Ensure a reasonable margin of income for the company.

- Compared to existing products, set a lower product price to gain sale.

- Introduce the monthly or yearly prescription of servicing deals.

Hopefully by introducing a lower cost price compared to the competitors, but making contracts to gain income instead will be a success. But the company is not in a position to try a different approach later on.

Already this product has a low limited customer market, which means that the feasibility of selling such a product onto the market already has low odds of succeeding.

**Production**

Looking at the advantage and disadvantage the company will have more disadvantages if they would produce it themselves. That the reason why they don't want to produce it. It will cost the diving club a lot and it will only survive if the sales numbers are high.

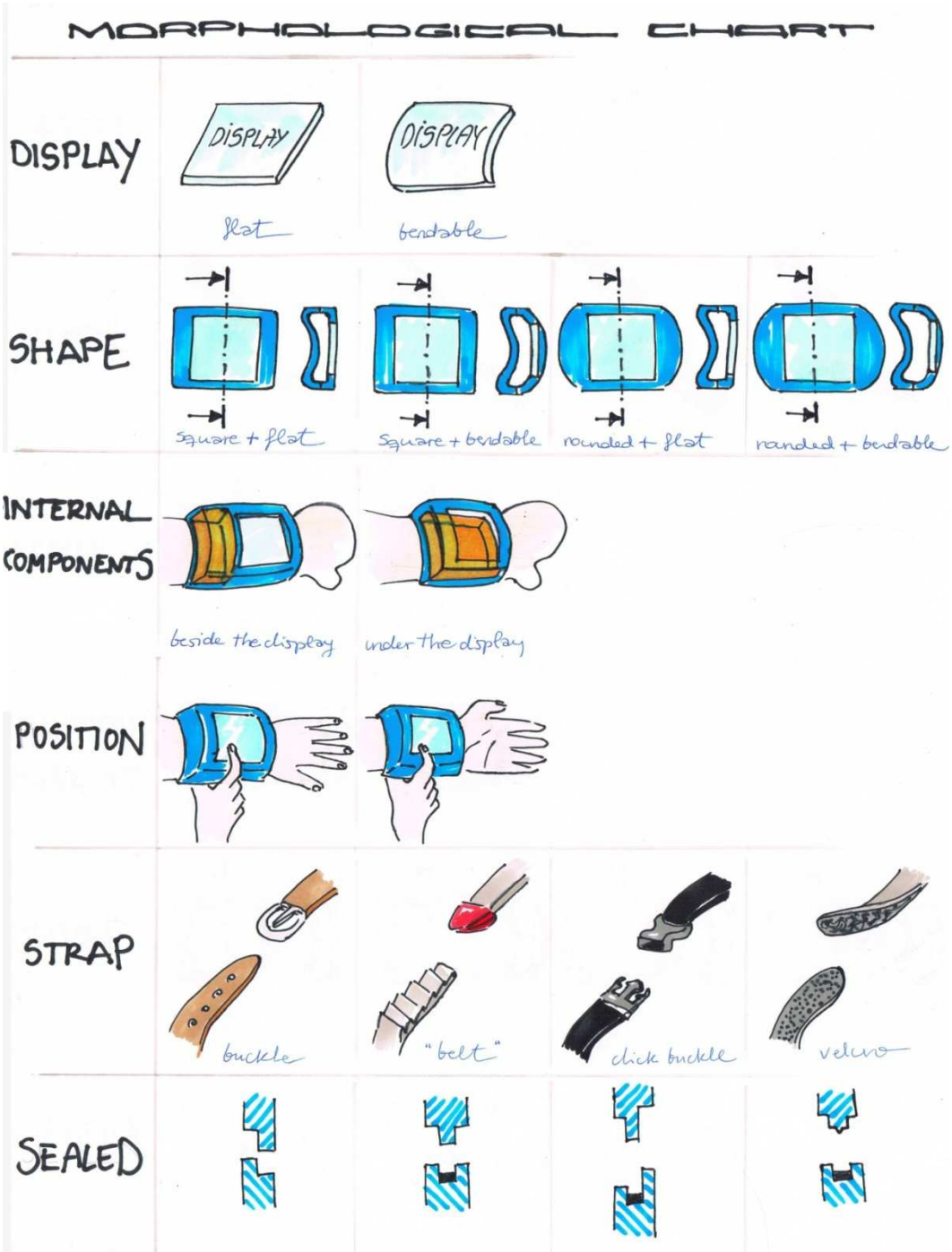
So if the production is done by some company there will be (Team 9 – Final report, 2009)):

- *Higher production costs of the different components, because the companies producing the different parts also want to earn money.*
- *Lower degree of the possibility to control when and how many parts are available to buy. The company would be totally dependent on the distribution chain from the other companies to this company.*
- *Low one off costs to obtain equipment for assembling the product.*
- *Lower number of employees.*
- *Better solution for a market that is limited.*

So it is better to produce the product by other companies. If the number of customers increase it is better for the company to produce it by their own. But it is not expected to increase very well, because of the small group and because of the price of the product. The best option would be to produce it in China, so the cost are low.

# 4 Design

## 4.1 Morphological chart



**Display**

- Bendable
  - Advantages: The product must be fit on the forearm so it would be a great goal if the display could be bended to
  - Disadvantages: This kind of display is a recent technology and it is not enough developed. It is impossible to find an appropriate bendable display for *Delphinus* on the actual market. For that reason the price would be higher.
- Flat
  - Advantages: There are lots of displays on the market, so we have a large range of displays with different characteristics and sizes to choose the most suitable for our device. It is cheaper.
  - Disadvantages: It is not bendable.

**Shape**

- Square & flat
  - Advantages: It is a simple shape. The manufacture of the housing would be easier.
  - Disadvantages: Edges can be dangerous for the user. They must be avoided. The display is not protected from possible external damages.
- Square & bended
  - Advantages: Is it compact. This shape fits properly the internal components.
  - Disadvantages: It would be better combined with a bendable display.
- Rounded & flat
  - Advantages: It is a simple shape. The manufacture of the housing would be easier.
  - Disadvantages: It takes more space than the square shape. The device must be as small as possible. Edges must be avoided.
- Rounded & bended

- Advantages: This shape fits properly the internal components.
- Disadvantages: It takes more space than the square shape. The device must be as small as possible.

**Internal components**

- Beside de display
  - Advantages: The thickness of the device is thinner.
  - Disadvantages: It is longer.
- Under the display
  - Advantages: The product is shorter
  - Disadvantages: It is thicker

**Position**

- Position 1
  - Advantages: It is more comfortable for the divers when they are using touching the screen.
  - Disadvantages: It is less comfortable for the divers when they are moving underwater.
- Position 2
  - Advantages: The screen is more protected from shocks.
  - Disadvantages: The muscles of the forearm could be in tension.

**Strap**

- Buckle
  - Advantages: It is a versatile system to adjust a product.
  - Disadvantages: The materials are not suitable. It is not easy for the user to close the buckle on its own.
- "Belt"

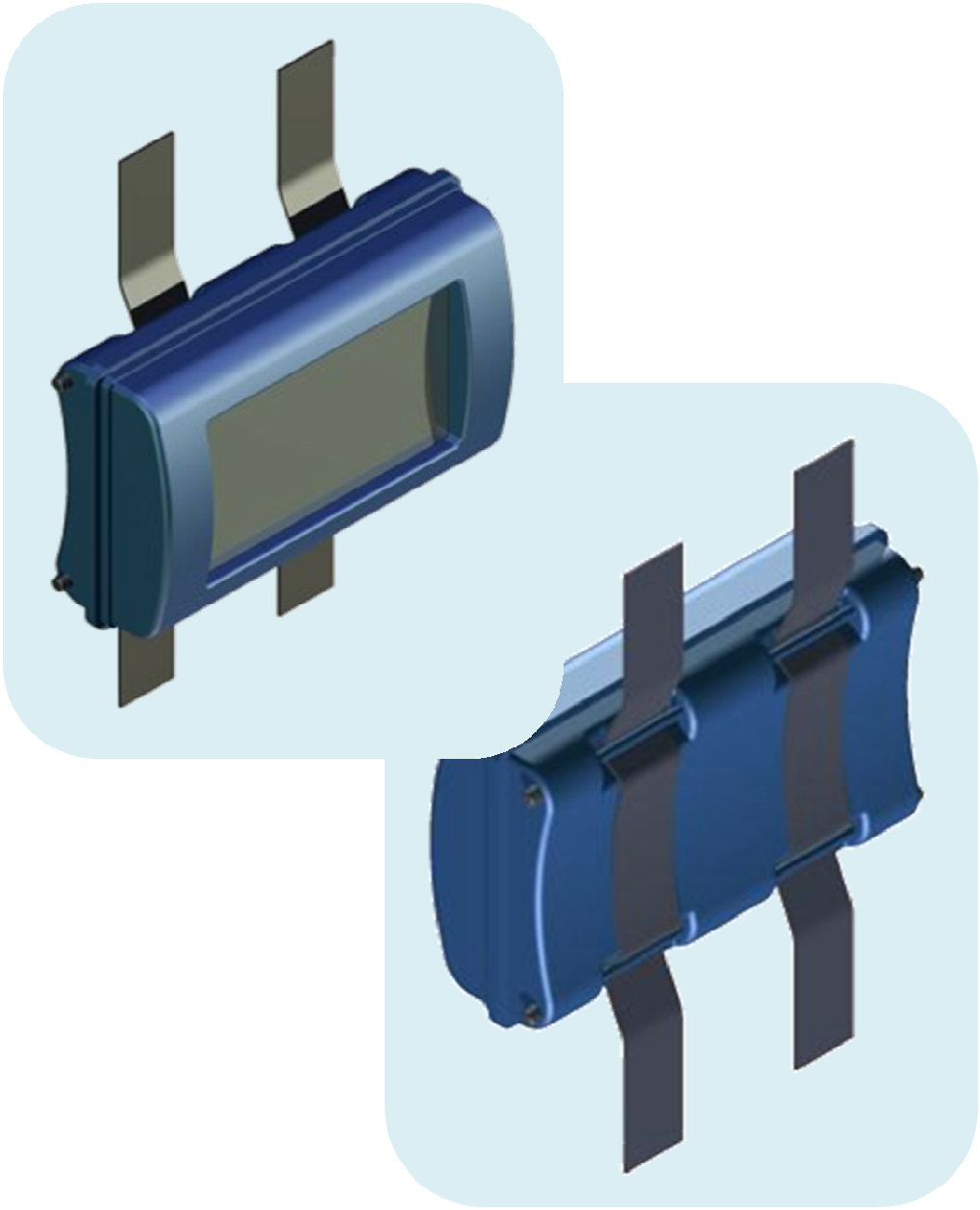
- Advantages: It is user friendly
- Disadvantages: The material of the strap is not flexible enough.

- Click buckle
  - Advantages: User friendly. There is a large range of sizes on the market.
  - Disadvantages:
- Velcro
  - Advantages: It would be the easiest and fastest way to fit the device.
  - Disadvantages: This material doesn't work well underwater for a long time. The straps would have been replaced in a short-term.

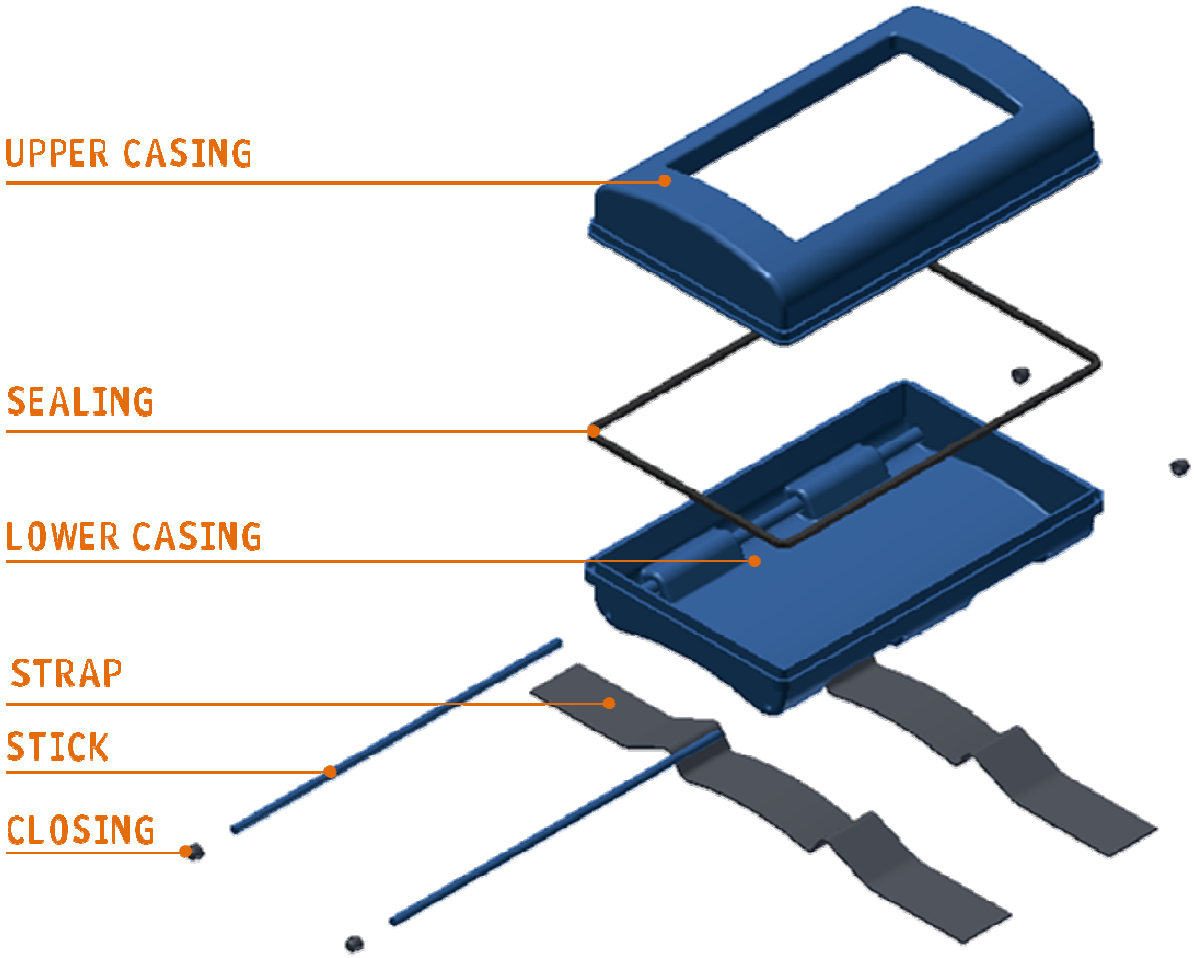
**Sealed**

- System 1
  - Advantages: Easier and lower costs of manufacture
  - Disadvantages: It is not waterproof
- System 2
  - Advantages: waterproof
  - Disadvantages: The thickness must be at least 4 mm
- System 3
  - Advantages: it is a improved version of system 2
  - Disadvantages: The thickness must be at least 4 mm
- System 4
  - Advantages: it is a improved version of system 2
  - Disadvantages: The thickness must be at least 5 mm

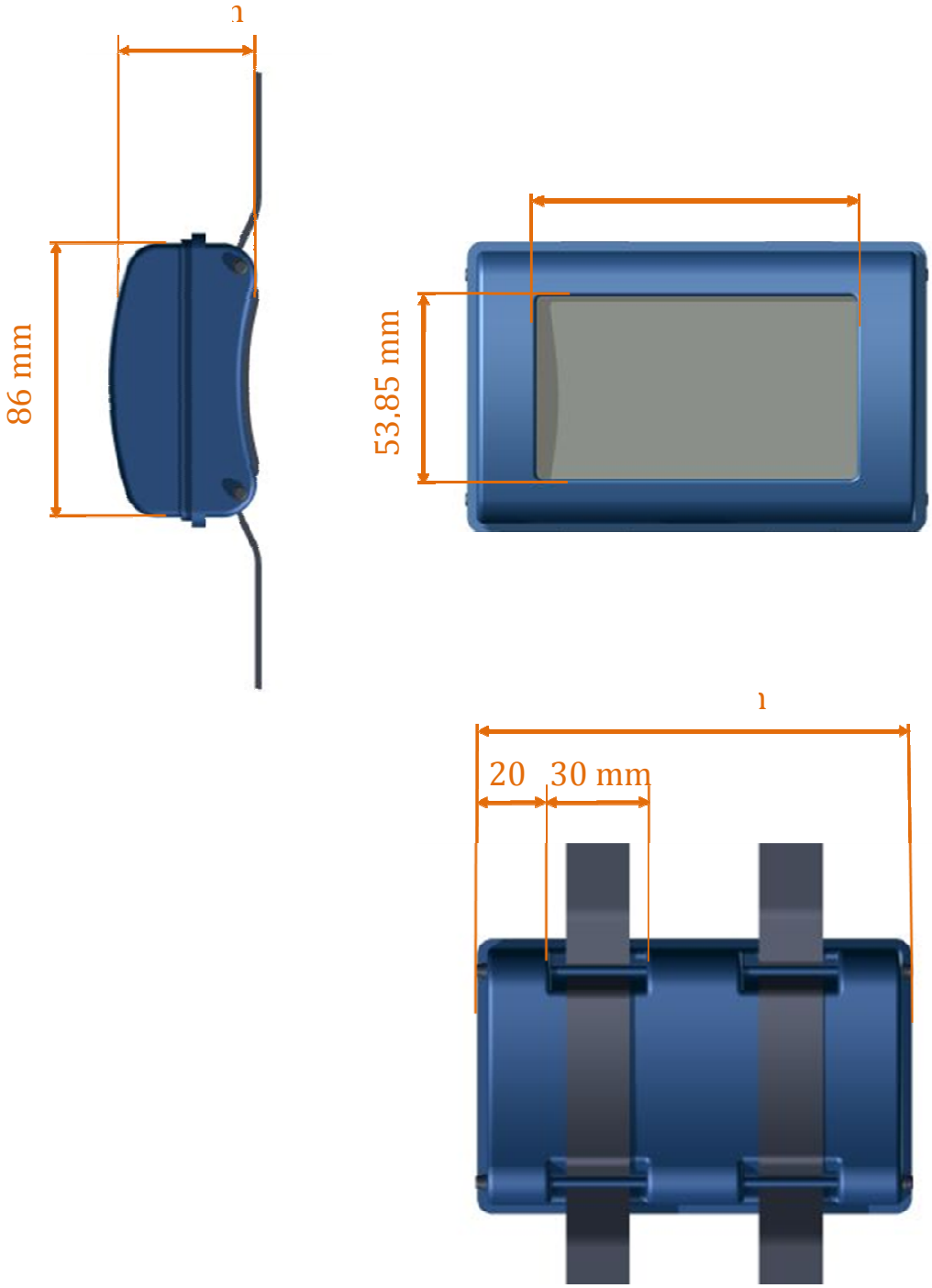
## 4.2 First Model



### 4.2.1 Components

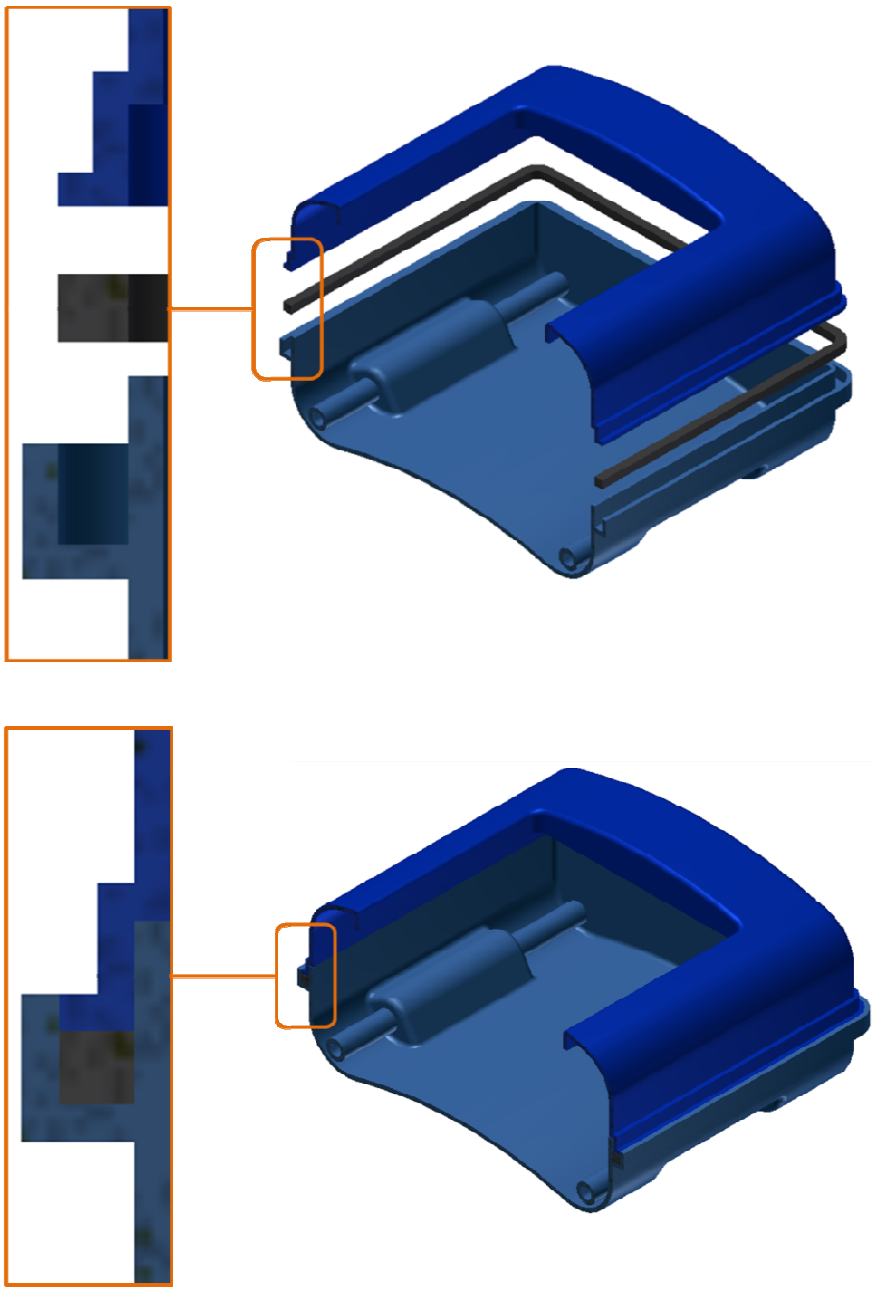


### 4.2.2 General measures



### 4.2.3 Sealing component

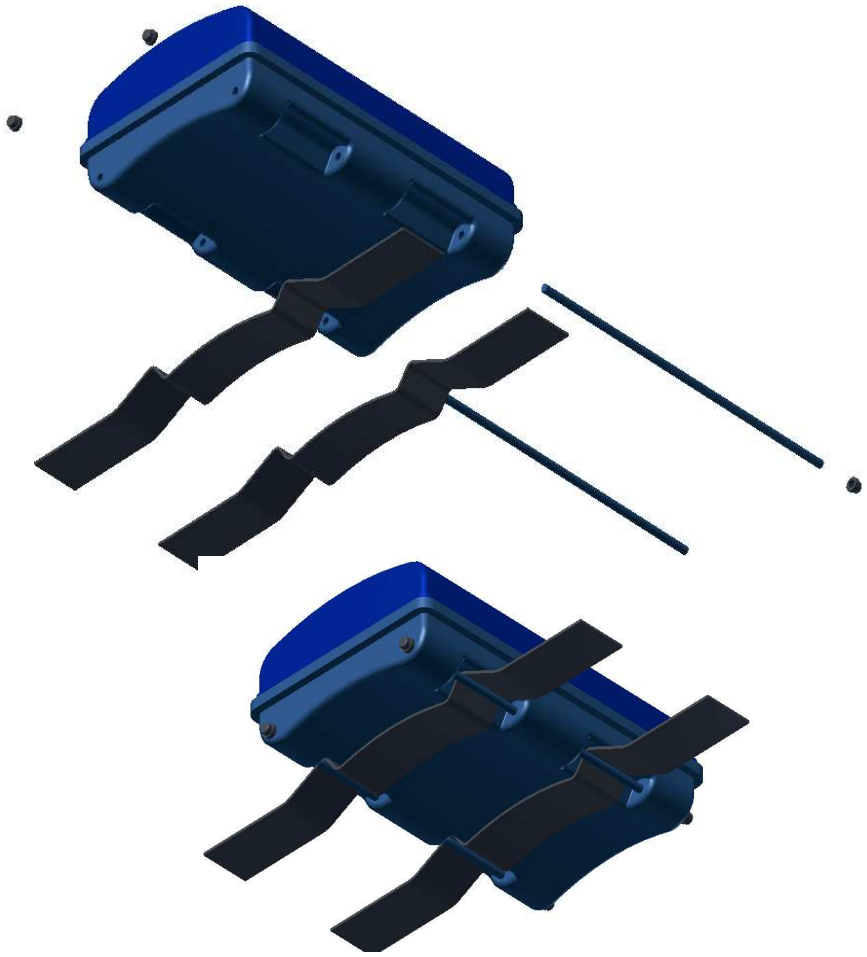
The same system that is commonly used in waterproof boxes on the market will be utilized for embedding the casing. Thereby there are many contact surfaces preventing the water for entering inside.



### 4.2.4 Strap

Two straps are needed instead of one to ensure the diver doesn't lose Delphinus if one of the straps will be opened or broken during the diving session.

The straps are subjected with the casing by two sticks. The user can separate the sticks after using the product to clean and wash the device and the straps.



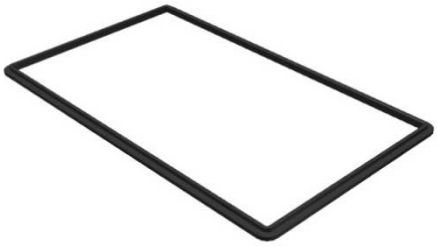
## 4.3 Final model

### 4.3.1 Components

1_ Top casing

| | |
|---|---|
| Quantity | 1 |
| General dimensions (mm) | 124 x 89 x 16 |
| Manufacturing process | Injection molding |
| Material | ABS (thermoplastic) |

2_ Waterproof bezel



| | |
|---|---|
| Quantity | 1 |
| General dimensions (mm) | 100 x 59 x 2 |
| Material | PU rubber (elastomer)/ Silicone (elastomer) |
| Manufacturing process | Injection molding |

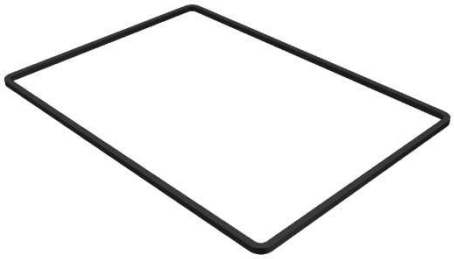
3_ Bottom casing

| | | |
|---|---|---|
|  | Quantity | 1 |
| | General dimensions (mm) | 124 x 89 x 16 |
| | Material | ABS (thermoplastic) |
| | Manufacturing process | Injection molding |

4_ Screw ring

| | | |
|---|---|---|
|  | Quantity | 1 |
| | General dimensions | ø4 x 2 |
| | Material | PU rubber (elastomer)/ Silicone (elastomer) |
| | Manufacturing process | Injection molding |

5_ "O-ring"

| | | |
|---|---|---|
|  | Quantity | 1 |
| | Material | PU rubber (elastomer)/ Silicone (elastomer) |
| | Manufacturing process | Injection molding |

The following components aren't produced by the manufacturer company.

6_ Display

| | | |
|---|---|---|
|  | Quantity | 1 |
| | External dimensions (mm) | 103,5 x 67 x 2,05 |
| | Type | AMOLED |

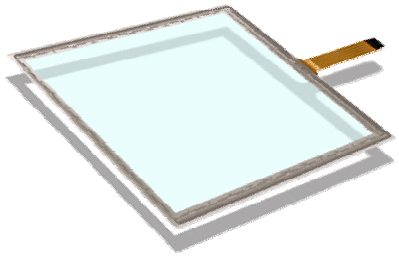
7_ Battery

| | | |
|---|---|---|
|   | Quantity | 1 |
| | Type | Li-Ion |
| | Dimensions (mm) | 61,5 x 34,5 x 4,85 |

8_ Screen Protector

| | | |
|---|---|---|
| | Quantity | 1 |
| | Dimensions (mm) | 97 x 55 x 0,5 |

9_Touchscreen

| | | |
|---|---|---|
|  | Quantity | 1 |
| | Type | 5- wide resistive |
| | Dimensions (mm) | 97 x 55 x 0,5 |

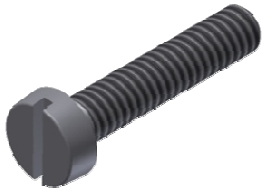
10_ Microcontroller

| | | |
|---|---|---|
| | Quantity | 1 |
| | Model | ATMEGA16L |

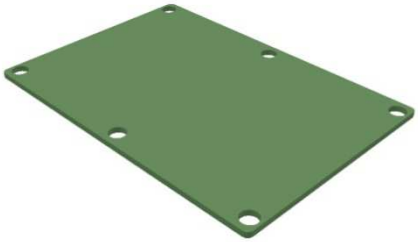
11_Strap

| | | |
|---|---|---|
|  | Quantity | 2 |
| | Type | Click buckle |
| | Length (mm) | 60 |

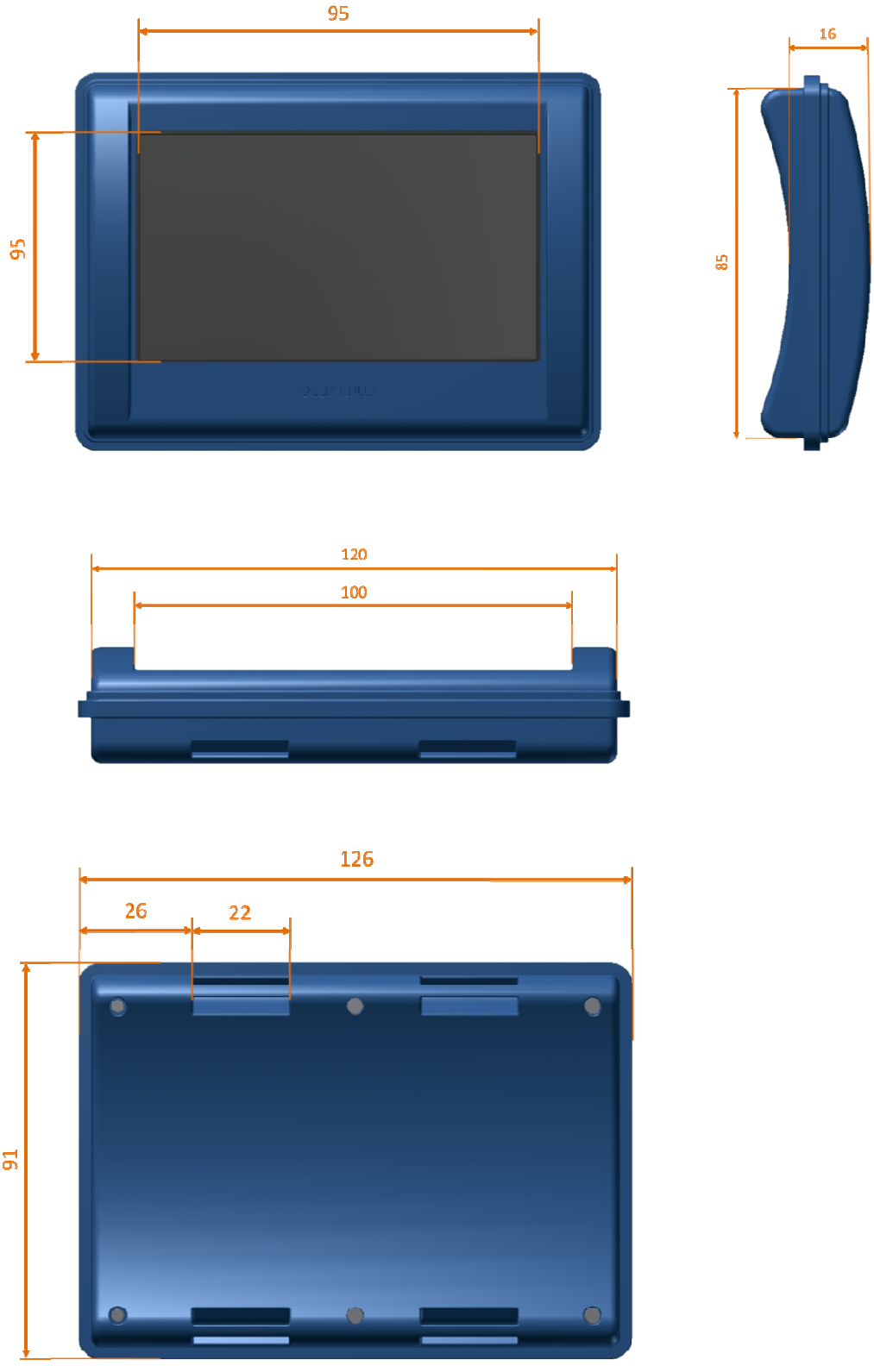
12_ Screw

| | | |
|---|---|---|
|  | Quantity | 6 |
| | Dimensions | M2x10 |
| | ISO rule | 1207 |

13_ Mainboard

| | | |
|---|---|---|
|  | Quantity | 1 |
| | Dimensions | 116 x 81 x 2 |

### 4.3.2 General dimensions



### 4.3.3 Logo

## 4.4 CE marking

*CE* is an acronym for the French phrase "Conformite Europeene" and is similar to the UL or CSA marks of North America. Unlike UL or CSA which require independent laboratory testing, the CE mark can be applied by the manufacturer through a "self certifying" procedure that verify that products are designed to the appropriate standards.

The European Union has issued 24 directives related to the CE mark.

Before manufacturers and exporters can CE-mark their products and legally sell them to, or within, the European common market, they must be in compliance with the applicable CE Marking Directive.

- The CE mark states that the manufacturer complies the product to be within applicable EU directives.

**Note!** The CE Marking is **not a safety mark** and must not be confused with a certificate. CE marking will never be granted by a third party test house or a certification body.[1)]

The manufacturer is responsible for non-compliance and liable for any damage caused by the product. If the manufacturer (or his authorized representative) is not based within the EU, the importer is responsible for the product in Europe.

If a product is not in compliance with the directives, it may be restricted, prohibited from sale or even withdrawn from the market.

Reference: (2010, http://www.engineeringtoolbox.com/ce-marking-d_453.html)

**General principles of the CE marking**

1. The CE marking shall be affixed only by the manufacturer or his authorized representative.

2. The CE marking shall be affixed only to products to which its affixing is provided for by specific Community harmonization legislation, and shall not be affixed to any other product.

3. By affixing or having affixed the CE marking, the manufacturer indicates that he takes responsibility for the conformity of the product with all applicable requirements set out in the relevant Community harmonization legislation providing for its affixing.

4. The CE marking shall be the only marking which attests the conformity of the product with the applicable requirements of the relevant Community harmonization legislation providing for its affixing.

5. The affixing to a product of markings, signs or inscriptions which are likely to mislead third parties regarding the meaning or form of the CE marking shall be prohibited. Any other marking may be affixed to the product provided that the visibility, legibility and meaning of the CE marking is not thereby impaired.

6. Member States shall ensure the correct implementation of the regime governing the CE marking and take appropriate action in the event of improper use of the marking. Member States shall also provide for penalties for infringements, which may include criminal sanctions for serious infringements. Those penalties shall be proportionate to the seriousness of the offence and constitute an effective deterrent against improper use.

Reference: (2010, http://www.ce-marking.org/what-is-ce-marking.html)

## 4.5 IP code

The IP Code (or International Protection Rating, sometimes also interpreted as Ingress Protection Rating) consists of the letters *IP* followed by two digits and an optional letter. As defined in international standard IEC 60529, it classifies the degrees of protection provided against the intrusion of solid objects (including body parts like hands and fingers), dust, accidental contact, and water in electrical enclosures. The standard aims to provide users more detailed information than vague marketing terms such as *waterproof*.

The digits (characteristic numerals) indicate conformity with the conditions summarized in the tables below. Where there is no protection rating with regard to one of the criteria, the digit is replaced with the letter *X*.

### 4.5.1 Solids, first digit

The first digit indicates the level of protection that the enclosure provides against access to hazardous parts (e.g., electrical conductors, moving parts) and the ingress of solid foreign objects.

| **Level** | **Object size protected against** | **Effective against** |
|---|---|---|
| **0** | — | No protection against contact and ingress of objects |
| **1** | >50 mm | Any large surface of the body, such as the back of a hand, but no protection against deliberate contact with a body part |
| **2** | >12.5 mm | Fingers or similar objects |
| **3** | >2.5 mm | Tools, thick wires, etc. |
| **4** | >1 mm | Most wires, screws, etc. |
| **5** | Dust protected | Ingress of dust is not entirely prevented, but it must not enter in |

| | | |
|---|---|---|
| | | sufficient quantity to interfere with the satisfactory operation of the equipment; complete protection against contact |
| **6** | Dust tight | No ingress of dust; complete protection against contact |

### 4.5.2 Liquids, second digit

Protection of the equipment inside the enclosure against harmful ingress of water.

| **Level** | **Protected against** | **Testing for** | **Details** |
|---|---|---|---|
| **0** | Not protected | — | — |
| **1** | Dripping water | Dripping water (vertically falling drops) shall have no harmful effect. | Test duration: 10 minutes<br>Water equivalent to 3-5mm rainfall per minute |
| **2** | Dripping water when tilted up to 15° | Vertically dripping water shall have no harmful effect when the enclosure is tilted at an angle up to 15° from its normal position. | Test duration: 10 minutes<br>Water equivalent to 3-5mm rainfall per minute |
| **3** | Spraying water | Water falling as a spray at any angle up to 60° from the vertical shall have no harmful effect. | Test duration: 5 minutes<br>Water Volume: 0.7 |

| | | | |
|---|---|---|---|
| | | | litres per minute<br>Pressure: 80-100kNm2 |
| **4** | Splashing water | Water splashing against the enclosure from any direction shall have no harmful effect. | Test duration: 5 minutes<br>Water volume: 10 litres per minute<br>Pressure: 80-100kNm2 |
| **5** | Water jets | Water projected by a nozzle (6.3mm) against enclosure from any direction shall have no harmful effects. | Test duration: at least 3 minutes<br>Water volume: 12.5 litres per minute<br>Pressure: 30kN/m2 at distance of 3meters |
| **6** | Powerful water jets | Water projected in powerful jets (12.5mm nozzle) against the enclosure from any direction shall have no harmful effects. | Test duration: at least 3 minutes<br>Water volume: 100 litres per minute<br>Pressure: 100kN/m2 at distance of 3meters |
| **7** | Immersion up to 1 m | Ingress of water in harmful quantity shall not be possible when the enclosure is immersed in water under defined conditions of pressure and | Test duration: 30 minutes<br>Immersion at depth of |

| | | | |
|---|---|---|---|
| | | time (up to 1 m of submersion). | 1meter |
| **8** | Immersion beyond 1 m | The equipment is suitable for continuous immersion in water under conditions which shall be specified by the manufacturer. Normally, this will mean that the equipment is hermetically sealed. However, with certain types of equipment, it can mean that water can enter but only in such a manner that produces no harmful effects. | Test duration: continuous immersion in water<br>Depth specified by manufacturer |

### 4.5.3 Additional letters

The standard defines additional letters that can be appended to classify only the level of protection against access to hazardous parts by persons:

| **Level** | **Protected against access to hazardous parts with** |
|---|---|
| **A** | Back of hand |
| **B** | Finger |
| **C** | Tool |
| **D** | Wire |

Further letters can be appended to provide additional information related to the protection of the device:

| Letter | Meaning |
|---|---|
| **H** | High voltage device |
| **M** | Device moving during water test |
| **S** | Device standing still during water test |
| **W** | Weather conditions |

### 4.5.4 Mechanical impact resistance

An additional number has sometimes been used to specify the resistance of equipment to mechanical impact. This mechanical impact is identified by the energy needed to qualify a specified resistance level, which is measured in joules (J). This has now been superseded by the separate *IK number* specified in EN 50102.

Although dropped from the 3rd edition of IEC 60529 onwards, and not present in the EN version, older enclosure specifications will sometimes be seen with an optional third IP digit denoting impact resistance. Newer products are likely to be given an IK rating instead. However there is not an exact correspondence of values between the old and new standards.

| Dropped IP level | Impact energy | Equivalent drop mass and height |
|---|---|---|
| **0** | — | — |
| **1** | 0.225 J | 150 g dropped from 15 cm |
| **2** | 0.375 J | 250 g dropped from 15 cm |
| **3** | 0.5 J | 250 g dropped from 20 cm |
| **5** | 2 J | 500 g dropped from 40 cm |

| | | |
|---|---|---|
| **7** | 6 J | 1.5 kg dropped from 40 cm |
| **9** | 20 J | 5.0 kg dropped from 40 cm |

| **IK number** | **Impact energy (joules)** | **Equivalent impact** |
|---|---|---|
| 00 | Unprotected | No test |
| 01 | 0.15 | Drop of 200 g object from 7.5 cm height |
| 02 | 0.2 | Drop of 200 g object from 10 cm height |
| 03 | 0.35 | Drop of 200 g object from 17.5 cm height |
| 04 | 0.5 | Drop of 200 g object from 25 cm height |
| 05 | 0.7 | Drop of 200 g object from 35 cm height |
| 06 | 1 | Drop of 500 g object from 20 cm height |
| 07 | 2 | Drop of 500 g object from 40 cm height |
| 08 | 5 | Drop of 1.7 kg object from 29.5 cm height |
| 09 | 10 | Drop of 5 kg object from 20 cm height |
| 10 | 20 | Drop of 5 kg object from 40 cm height |

Reference: (2010, http://en.wikipedia.org/wiki/IP_Code)

# 5 Display

## 5.1 Connection scheme

Figure 1.1 shows the main connections between ATMEGA16L and our display. Port B is used to send data (green). Some pins from port D (PD6..PD2) are connected to control signals in the display (brown). SDL and SDA are directly wired to the same pins in the display (red). And finally, TCLK signal (blue) is connected to DCLK pin in the display. This signal takes charge of the synchronism of the data transfer.

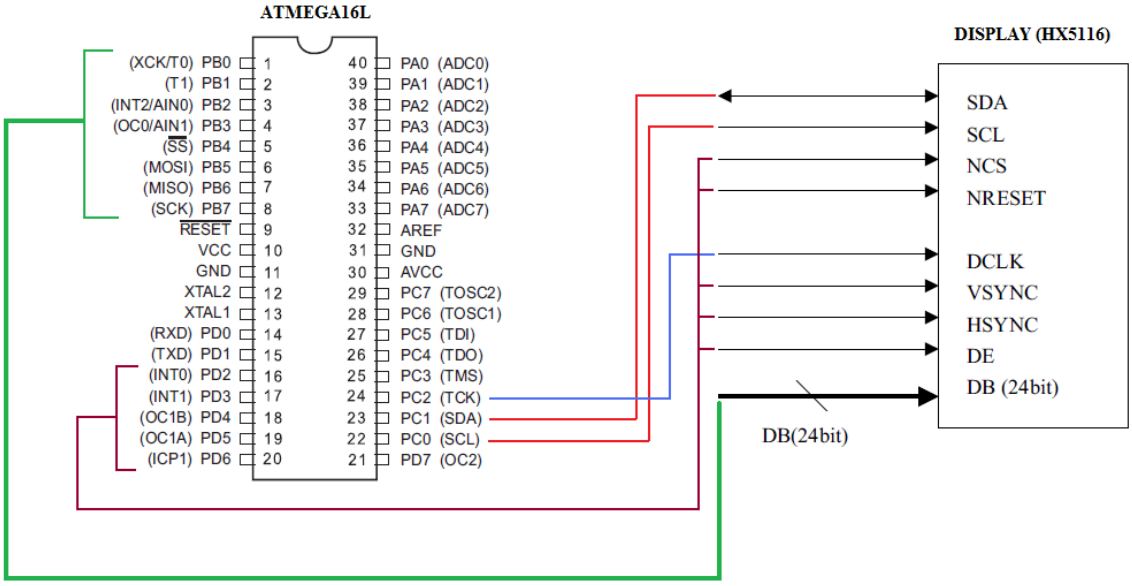



**Figure 5.1, Connections**

## 5.2 Codes

```
// ******* TEST.C ******* //
#define F_CPU 1000000L      // Clock Frequency
#include <avr/io.h>         // Input/Output Library
int main(void)
{
        DDRD = 0xFF;        // Set PORTD pins as outputs
        PORTD = 2;          // Pin PD1 set active
        PORTD = 0xAA;               // Pins PD7 PD5 PD3 PD1 active
        PORTD = 8;          // Pin PD3 active
        PINB = PORTD;               // PORTD loaded in PINB
}
```

This simple code introduces the use of the input and output ports in the microcontroller. In our case, we can use a similar one to create the general purpose signals, like NRESET, NCS and that kind.

```
// ********** TEST2.C (USART CONFIGURATION) ********** //
#include <avr/io.h>

#define FOSC 1000000        // Clock Speed
#define BAUD 9600           // Baud Rate
#define MYUBRR 6            // UBRR Register
void USART_Init( unsigned int ubrr)
{
        /* Set baud rate */
        UBRRH = (unsigned char)(ubrr>>8);
```

```
        UBRRL = (unsigned char)ubrr;
        /* Enable transmitter */
        UCSRB = (1<<TXEN);
        /* Set frame format: 8data, 1stop bit */
        UCSRC = (1<<URSEL)|(3<<UCSZ0);
}

void USART_Transmit( unsigned char data )
{
        /* Wait for empty transmit buffer */
        while ( !( UCSRA & (1<<UDRE)) );
        /* Put data into buffer, sends the data */
        UDR = data;
}

int main( void )
{
        USART_Init ( MYUBRR );
        DDRD = 0xFF;  //Port D outputs

        //Send data USART
        char data = 0x01;                   //Serial 8bit RGB (DE)
        PORTD = 0x0E;                               //Pin 14 Low Level --> NCS;NRESET, SCL
        USART_Transmit (data);              //SDA
        PORTD = 0x0F;                               //Pin 14 High Level --> NCS;
}
```

Last code is made to configure USART settings. As it was said in programming chapter, we used USART to fix the display mode. There, it is explained in detail.

**Display datasheet**. The attached file is called **displaySheet.pdf**. It contains **Bolymin bl043acrnb$** documentation.

**Connector datasheet**. The connector specifications are included in the document **fh26-71s-0.3shw.pdf**.

# 6 Process of making adaptor

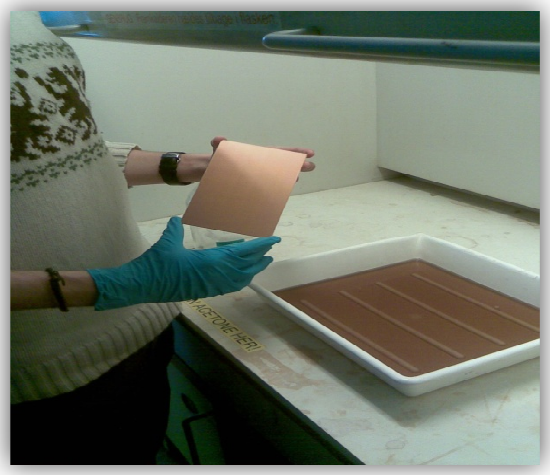
Our aim is to make a proper PCB with 71 small lines for OLED connector:

1. First step is to do a draw, and we did in INKSCAPE. INKSCAPE is a vector graphics editor application. It is distributed under a free software license, the GNU GPL.

2. Next we had to make a printout on transparent paper (we've had a big problems with resolution of printer) .

3. Than it should be exposed for 300 sec. on UV. Overexpose is better than underexpose. After that we could see yellowish color paths:

4. After that we put board to the bath with NaOH 1,5% for about 40s.:



5. The last step is to put it to pcb etching container with bubbles:

The hardest thing was to print 71 lines 0.12 mm thick and with distance between them 0,3mm. Our printers didn't have enough good resolution to make a satisfactory printout. Some of the lines with the same size in INKSCAPE were on the paper thicker than the others. There will be probably better if we used the plastic paper to print on it.

# 7 Software design

## 7.1 Applications used

We were programming in Microsoft Visual Studio 2010.

StarUML application was used to make UML diagrams.

### 7.1.1 Code of simulation application

We would like to present a code of simulation application, which can be wisely utilized. We won't give many comments here –it should be clear enough for those who know c# language. However we think it's not a good place to explain c# basis.

### 7.1.2 MainWindow.xaml file:

```
<Window x:Class="EPS.MainWindow"
    xmlns="http://schemas.microsoft.com/winfx/2006/xaml/presentation"
    xmlns:x="http://schemas.microsoft.com/winfx/2006/xaml"
    Title="EPS: Experimental State Diagram Simulation" Height="400" Width="600">
  <Grid>
                <Grid.ColumnDefinitions>
                        <ColumnDefinition Width="1*" />
                        <ColumnDefinition Width="3*" />
                </Grid.ColumnDefinitions>

                <Grid Name="ButtonGrid" Grid.Column="0">
                        <Grid.RowDefinitions>
                                <RowDefinition Height="1*" />
                                <RowDefinition Height="1*" />
                                <RowDefinition Height="1*" />
                                <RowDefinition Height="1*" />
                                <RowDefinition Height="1*" />
                                <RowDefinition Height="1*" />
                                <RowDefinition Height="1*" />
                                <RowDefinition Height="1*" />
                                <RowDefinition Height="1*" />
                                <RowDefinition Height="1*" />
                        </Grid.RowDefinitions>
```

```
                    <Label Name="stateName" Margin="3" Grid.Row="0" FontSize="11"
FontFamily="Times New Roman" FontWeight="Bold" Foreground="#FFFF8000"
VerticalAlignment="Center" HorizontalAlignment="Center"/>
                    <Label Name="simulateLabel" Margin="3" Grid.Row="1" FontSize="12"
FontFamily="Times New Roman" FontWeight="Bold" Foreground="#FF008080"
VerticalAlignment="Center" HorizontalAlignment="Center">Simulate</Label>
                    <Button Name="button1" Margin="5" Grid.Row="2"
Click="ButtonClick"></Button>
                    <Button Name="button2" Margin="5" Grid.Row="3"
Click="ButtonClick"></Button>
                    <Button Name="button3" Margin="5" Grid.Row="4"
Click="ButtonClick"></Button>
                    <Button Name="button4" Margin="5" Grid.Row="5"
Click="ButtonClick"></Button>
                    <Button Name="button5" Margin="5" Grid.Row="6"
Click="ButtonClick"></Button>
                    <Button Name="button6" Margin="5" Grid.Row="7"
Click="ButtonClick"></Button>
                    <Button Name="button7" Margin="5" Grid.Row="8"
Click="ButtonClick"></Button>
                    <Button Name="button8" Margin="5" Grid.Row="9"
Click="ButtonClick"></Button>
                </Grid>

                <Grid Name="DisplayGrid" Grid.Column="1" Margin="10"></Grid>
        </Grid>
</Window>
```

### 7.1.3 MainWindow.xaml.cs file:

```
using System.Collections.Generic;
using System.Windows;
using System.Windows.Controls;


namespace EPS
{
	public partial class MainWindow
	{
		public State State;
		public Dictionary<string, State> Transitions;
	// name of action available, name of destination state

		public MainWindow()
		{
			InitializeComponent();

			Transitions = new Dictionary<string, State>();

			FillTransitions();

			ProceedTransition("Init");
		}


		#region fill all transitions
		private void FillTransitions()
		{
			Transitions.Add("Init", new InitialState());
		// from the start

			Transitions.Add("Recover message", new RecoveringMessageState());
		// from InitialState

			Transitions.Add("Message found", new ReadyToReadState());
		// from RecoveringMessageState
			Transitions.Add("Message not found", new StandbyState());
		// from RecoveringMessageState

			Transitions.Add("Critical energy alert", new FinalState());
		// from StandbyState
			Transitions.Add("Receive message", new ReadyToReadState());
		// from StandbyState
			Transitions.Add("Danger signal", new AlertState());
		// from StandbyState & ReadyState
			Transitions.Add("S.O.S. signal", new AlertState());
		// from StandbyState & ReadyState
			Transitions.Add("Touch the screen", new ReadyState());
		// from StandbyState
```

```
                    Transitions.Add("Turn-off signal", new FinalState());
                // from StandbyState

                    Transitions.Add("Turn-off and save", new SavingMessageState());
                // from ReadyToReadState & ShowMessageState
                    Transitions.Add("Low energy - save", new SavingMessageState());
                // from ReadyToReadState & ShowMessageState
                    Transitions.Add("Allow to read", new ShowMessageState());
                // from ReadyToReadState

                    Transitions.Add("Close message", new ReadyState());
                    // from ShowMessageState

                    Transitions.Add("Turn-off", new FinalState());
                // from SavingMessageState & ReadyState & ChoosingASignState & ChoosingADiverState & ReadyToSendState

                    Transitions.Add("Sleep / timeout", new StandbyState());
                // from ReadyState
                    Transitions.Add("Interruption", new SavingState());
                // from ReadyState & ChoosingASignState & ChoosingADiverState & ReadyToSendState
                    Transitions.Add("Start sending", new ChoosingASignState());
                // from ReadyState
                    Transitions.Add("Low energy - sleep", new StandbyState());
                // from ReadyState & ChoosingASignState & ChoosingADiverState & ReadyToSendState

                    Transitions.Add("Choose sign", new ChoosingADiverState());
                // from ChoosingASignState
                    Transitions.Add("Cancel sending", new ReadyState());
                // from ChoosingASignState & ChoosingADiverState & ReadyToSendState

                    Transitions.Add("Choose diver", new ReadyToSendState());
                // from ChoosingADiverState

                    Transitions.Add("Confirm sending", new ReadyState());
                // from ReadyToSendState

                    Transitions.Add("Read after saving", new ReadyToReadState());
                // from SavingState

                    Transitions.Add("Cancel alert", new ReadyState());
                // from AlertState
                    Transitions.Add("Confirm alert", new ReadyState());
                // from AlertState

                    Transitions.Add("Start again", new InitialState());
                // from FinalState
                }
                #endregion
```

```
        #region buttonClick event handlers
        void ProceedTransition(string text)
        {
            State = Transitions[text];
            stateName.Content = State.GetType().Name;
            FillButtons(State.GetActionsAvailable());
            State.ChangeScreen(DisplayGrid);
        }


        private void ButtonClick(object sender, RoutedEventArgs e)
        {
            ProceedTransition(((Button)sender).Content.ToString());
        }
        #endregion


        #region filling buttons
        private static void FillButton(string s, Button btk)
        {
            if (string.IsNullOrEmpty(s))
            {
                btk.Content = "";
                btk.Visibility = Visibility.Hidden;
                return;
            }

            btk.Content = s;
            btk.Visibility = Visibility.Visible;
        }


        public void FillButtons(List<string> actions)
        {
            if (actions.Count < 1) MessageBox.Show("No actions found !");
            FillButton(actions.Count >= 1 ? actions[0] : null, button1);
            FillButton(actions.Count >= 2 ? actions[1] : null, button2);
            FillButton(actions.Count >= 3 ? actions[2] : null, button3);
            FillButton(actions.Count >= 4 ? actions[3] : null, button4);
            FillButton(actions.Count >= 5 ? actions[4] : null, button5);
            FillButton(actions.Count >= 6 ? actions[5] : null, button6);
            FillButton(actions.Count >= 7 ? actions[6] : null, button7);
            FillButton(actions.Count >= 8 ? actions[7] : null, button8);
            if (actions.Count >= 9) MessageBox.Show("Too less buttons !");
        }
        #endregion
    }
}
```

### 7.1.4 State.cs file:

```
using System.Collections.Generic;
using System.Windows.Controls;
using System.Windows.Media;


namespace EPS
{
	#region state
	public class State
	{
		protected List<string> ActionsAvailable = new List<string>();

		protected State()
		{
			ActionsAvailable.Clear();
		}

		public List<string> GetActionsAvailable()
		{
			return ActionsAvailable;
		}

		public virtual void ChangeScreen(Grid g)
		{
			//MessageBox.Show(this.GetType().Name);
			g.Background = new SolidColorBrush(Color.FromArgb(255, 255, 255,
255));
			g.Children.Clear();
		}
	}
	#endregion


	#region initial state
	public class InitialState : State
	{
		public InitialState()
			: base()
		{
			ActionsAvailable.Add("Recover message");
		}

		public override void ChangeScreen(Grid g)
		{
			base.ChangeScreen(g);
			g.Background = new SolidColorBrush(Color.FromArgb(255, 128, 128, 0));
		}
	}
	#endregion
```

```
#region recovering message state
public class RecoveringMessageState : State
{
        public RecoveringMessageState()
                : base()
        {
                ActionsAvailable.Add("Message found");
                ActionsAvailable.Add("Message not found");
        }
}
#endregion


#region standby state
public class StandbyState : State
{
        public StandbyState()
                : base()
        {
                ActionsAvailable.Add("Critical energy alert");
                ActionsAvailable.Add("Receive message");
                ActionsAvailable.Add("Danger signal");
                ActionsAvailable.Add("S.O.S. signal");
                ActionsAvailable.Add("Touch the screen");
                ActionsAvailable.Add("Turn-off signal");
        }
}
#endregion


#region ready to read state
public class ReadyToReadState : State
{
        public ReadyToReadState()
                : base()
        {
                ActionsAvailable.Add("Turn-off and save");
                ActionsAvailable.Add("Low energy - save");
                ActionsAvailable.Add("Allow to read");
        }
}
#endregion


#region show message state
public class ShowMessageState : State
{
        public ShowMessageState()
                : base()
```

```
        {
            ActionsAvailable.Add("Turn-off and save");
            ActionsAvailable.Add("Low energy - save");
            ActionsAvailable.Add("Close message");
        }
    }
    #endregion


    #region saving message state
    public class SavingMessageState : State
    {
        public SavingMessageState()
            : base()
        {
            ActionsAvailable.Add("Turn-off");
        }
    }
    #endregion


    #region ready state
    public class ReadyState : State
    {
        public ReadyState()
            : base()
        {
            ActionsAvailable.Add("Sleep / timeout");
            ActionsAvailable.Add("Danger signal");
            ActionsAvailable.Add("S.O.S. signal");
            ActionsAvailable.Add("Interruption");
            ActionsAvailable.Add("Start sending");
            ActionsAvailable.Add("Turn-off");
            ActionsAvailable.Add("Low energy - sleep");
        }
    }
    #endregion


    #region choosing a sign state
    public class ChoosingASignState : State
    {
        public ChoosingASignState()
            : base()
        {
            ActionsAvailable.Add("Interruption");
            ActionsAvailable.Add("Turn-off");
            ActionsAvailable.Add("Low energy - sleep");
            ActionsAvailable.Add("Cancel sending");
            ActionsAvailable.Add("Choose sign");
        }
```

```
}
#endregion


#region choosing a diver state
public class ChoosingADiverState : State
{
        public ChoosingADiverState()
                : base()
        {
                ActionsAvailable.Add("Interruption");
                ActionsAvailable.Add("Turn-off");
                ActionsAvailable.Add("Low energy - sleep");
                ActionsAvailable.Add("Cancel sending");
                ActionsAvailable.Add("Choose diver");
        }
}
#endregion


#region ready to send state
public class ReadyToSendState : State
{
        public ReadyToSendState()
                : base()
        {
                ActionsAvailable.Add("Interruption");
                ActionsAvailable.Add("Turn-off");
                ActionsAvailable.Add("Low energy - sleep");
                ActionsAvailable.Add("Cancel sending");
                ActionsAvailable.Add("Confirm sending");
        }
}
#endregion


#region saving state
public class SavingState : State
{
        public SavingState()
                : base()
        {
                ActionsAvailable.Add("Read after saving");
        }
}
#endregion


#region alert state
public class AlertState : State
{
```

```
		public AlertState()
			: base()
		{
			ActionsAvailable.Add("Cancel alert");
			ActionsAvailable.Add("Confirm alert");
		}
	}
	#endregion


	#region final state
	public class FinalState : State
	{
		public FinalState()
			: base()
		{
			ActionsAvailable.Add("Start again");
		}
	}
	#endregion
}
```

Document No.:

# Tentative Product Specification

## Module name: BL043ACRNB$

## Issue date: 2008/07/21

## Version: 1.3

| Customer | | |
|---|---|---|
| | | |
| **Approved by Customer** | | |
| | | |
| **Approved by BOLYMIN** | | |
| **PD Division** | **ENG Division** | **QA Dept** |
| | | |

**Note:**

1. The information contained herein may be change without prior notice. It is therefore advisable to contact BOLYMIN before designed your product based on this specification.
2. This tentative product specification is for reference, some item or setting maybe changed for evaluation.

**Reversion History**

| Version | Date | Page | Description |
|---|---|---|---|
| Ver.1.0 | 2007/12/26 | All | Tentative specification was first issued |
| Ver.1.1 | 2008/03/19 | 10,11,12 | Add IC Initial Register Setting |
| | | 15,16,17 | Modify Pin Assignment |
| | | 18 | Change External Dimension |
| Ver.1.2 | 2008/04/08 | 10 | Change Typical Luminance |
| | | 14 | Add System Diagram |
| | | 19 | Add Reliability Test |
| | | 20 | Add Package Drawing |
| Ver.1.3 | 2008/07/21 | 9,10,11 | Modify Electro-Optical Characteristic |

## 1. Purpose:

This documentation defines general product specification for OLED module supplied by BOLYMIN. The information described in this technical specification is tentative. Please Contact BOLYMIN's representative while your product is modified.

## 2. General Description:

- Driving Mode: Active Matrix
- Color Mode: Full Color (16M color)
- Driver IC: HX5116, COG Assembly
- Interface:
  8bit serial RGB and 24bit parallel RGB interface
- Application: Portable DVD, PMP, GPS, Photo Frame etc.

## 3. Mechanical Data:

| No. | Items | Specification | Unit |
|---|---|---|---|
| 1 | **Diagonal Size** | 4.3 | Inch |
| 2 | **Resolution** | 480 RGB x 272 | |
| 3 | **Pixel Pitch** | H: 0.198 V: 0.198 | um |
| 4 | **Active Area** | 95.0 x 53.8 | mm |
| 5 | **Outline Area** | 103.5 x 67 | mm |
| 6 | **Thickness** | 2.05 | mm |
| 7 | **Weight** | TBD | g |

## 4. Maximum ratings:

| Symbol | Parameter | Value | Unit |
|---|---|---|---|
| VCC | Logic Supply Voltage | -0.3 to +3.6 | V |
| VCI | Analog Supply Voltage | -0.3 to +3.6 | V |
| Tstg | Storage Temperature | -40 to +85 | ℃ |

Table 7.1 Maximum ratings

Maximum ratings are those values beyond which damages to the device may occur. Functional operation should be restricted to the limits in the Electrical Characteristics tables or Pin Description section. Unused outputs must be left open.

# 5. Electrical Characteristic:

## 5.1 DC Characteristic

### DC Characteristics

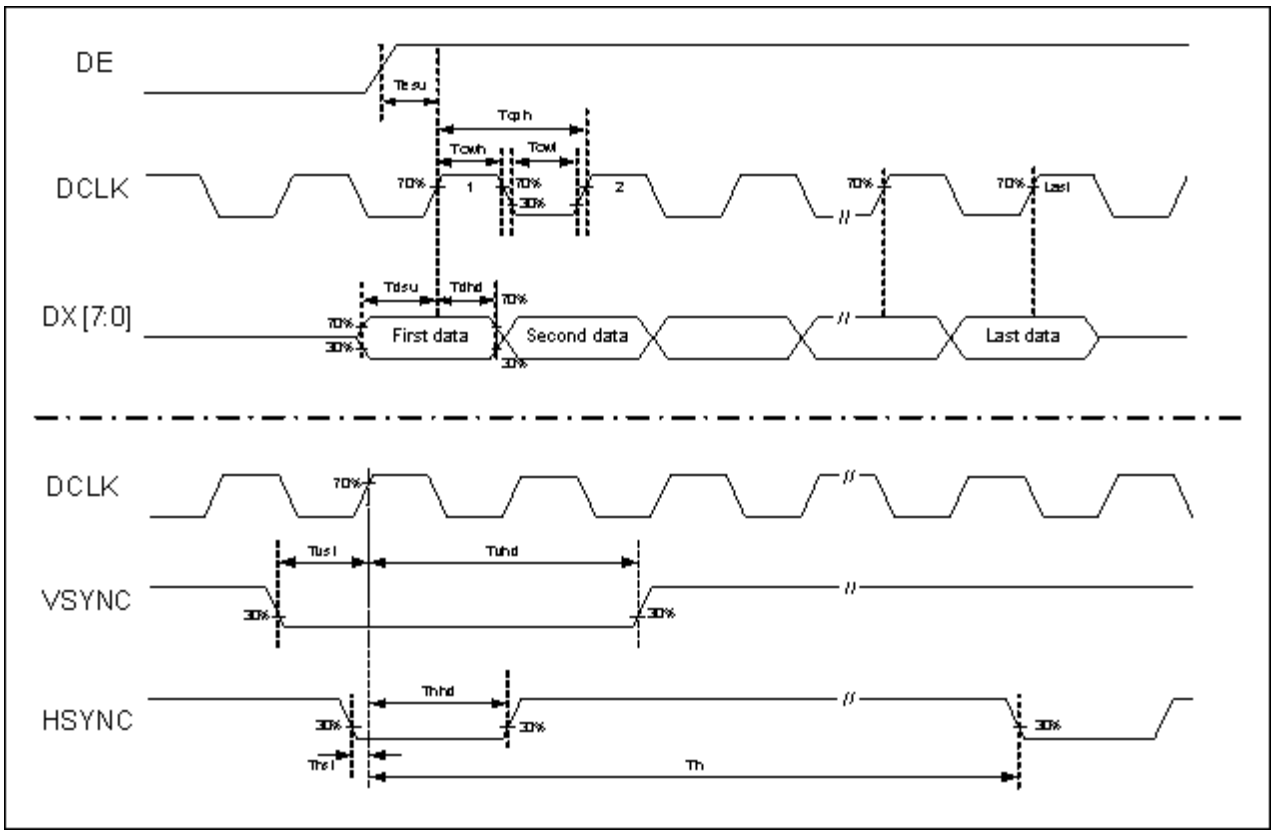
(Unless otherwise specified, Voltage Referenced to VSS = 0V, VCC = 1.5 to 3.6V, $T_A$ = -20 to 70C)

| Parameter | Symbol | Test condition | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| System power supply pins of the logic block | VCC | - | 1.5 | - | 3.6 | V |
| Booster Reference Supply Voltage Range | VCI | - | 3.0 | - | 3.6 | V |
| DDVDH Output Voltage 1 | DDVDH | Set CP1X=0 | 4.9 | 5.1 | 5.3 | V |
| DDVDH Output Voltage 2 | DDVDH | Set CP1X=1 | 5.8 | 6.0 | 6.2 | V |
| VGAM1OUT Output Voltage 1 | VGAM1OUT | Set CP1X=0 | 4.7 | 4.8 | 4.9 | V |
| VGAM1OUT Output Voltage 2 | VGAM1OUT | Set CP1X=1 | 5.7 | 5.8 | 5.9 | V |
| Gate driver High Output Voltage | VGH | - | +3 | - | +8 | V |
| Gate driver Low Output Voltage | VGL | - | -8 | - | -3 | V |
| OLED Diode Refer Voltage | ARREF | - | -8 | - | +8 | V |
| Logic High Output Voltage | VOH | Iout=-400μA | 0.8 * VCC | - | VCC | V |
| Logic Low Output Voltage | VOL | Iout=400μA | 0 | - | 0.2 * VCC | V |
| Logic High Input voltage | VIH | - | 0.8 * VCC | - | VCC | V |
| Logic Low Input voltage | VIL | | 0 | - | 0.2 * VCC | V |
| Logic Input Current | IIL/IIH | No pull up or pull low | -1 | - | 1 | μA |
| Pull high resistance | RH | Pull up pins | 600 | 900 | 1200 | KΩ |
| Pull low resistance | RL | Pull low pins | 600 | 900 | 1200 | KΩ |
| High Output Current | IOH | S1~S107, Vo=4.9V vs. 4V | 50 | - | - | μA |
| Low Output Current | IOL | S1~S107, Vo=0.1V vs. 1V | - | - | -50 | μA |
| Output leakage Current | IOZ | - | -1 | - | 1 | μA |
| Output voltage offset | VOS | S1~S107, Vo=0.1V~DDVDH-0.1V | | ±10 | | mV |
| Output voltage deviation | VOD | S1~S107, Vo=0.1V~DDVDH-0.1V | | ±10 | | mV |
| Analog standby current | ISTB | VCI=3.0V, Stand by mode | | - | 10 | uA |
| Analog operating current | IVCI | VCI=3.0V, S1~S160 no load | | - | 20 | mA |
| Logic Pins Input Capacitance | CIN | - | - | 5 | 7.5 | pF |

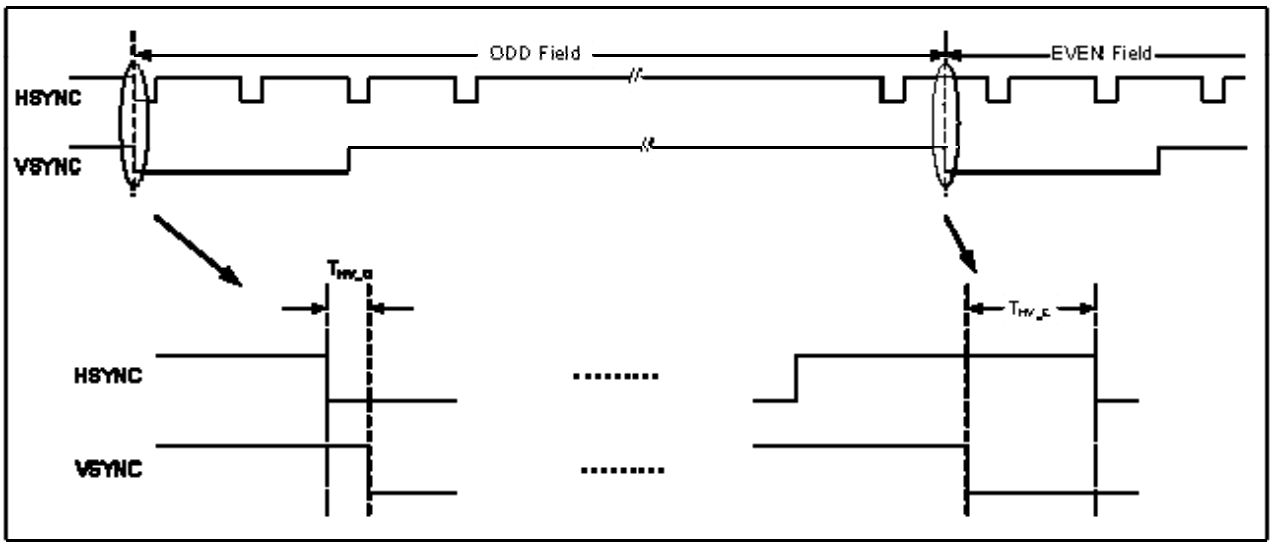
## 5.2 AC Characteristic

### 5.2.1 AC Electrical Characteristics

| PARAMETER | Symbol | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|
| HSYNC setup time | $T_{hst}$ | 10 | - | - | ns |
| HSYNC hold time | $T_{hhd}$ | 10 | - | - | ns |
| VSYNC setup time | $T_{vst}$ | 10 | - | - | ns |
| VSYNC hold time | $T_{vhd}$ | 10 | - | - | ns |
| Data setup time | $T_{dsu}$ | 10 | - | - | ns |
| Data hold time | $T_{dhd}$ | 10 | - | - | ns |
| DE setup time | $T_{esu}$ | 10 | - | - | ns |
| VSYNC falling to HSYNC falling time on odd field @ RGB mode | $T_{HV\_O}$ | -4 | 0 | +4 | $T_{CPH}$ |
| VSYNC falling to HSYNC falling time on even field @ RGB mode | $T_{HV\_E}$ | 0.4 | 0.5 | 0.6 | $T_H$ |
| Source output settling time | $T_{ST}$ | - | 3 | - | µs |
| Source output loading R | $R_{SL}$ | - | 25 | - | K ohm |
| Source output loading C | $C_{SL}$ | - | 16 | - | pF |
| Gate signals settling time (90%) | $T_{GL}$ | - | 0.5 | - | µs |
| Gate signals loading R | $R_{GL}$ | - | 5.6 | - | K ohm |
| Gate signals loading C | $C_{GL}$ | - | 30 | - | pF |
| SW signals settling time (90%) | $T_{SW}$ | - | 0.6 | - | µs |
| SW signals loading R | $R_{SW}$ | - | 1.4 | - | K ohm |
| SW signals loading C | $C_{SW}$ | - | 85.5 | - | pF |




**Clock and Data input waveforms**



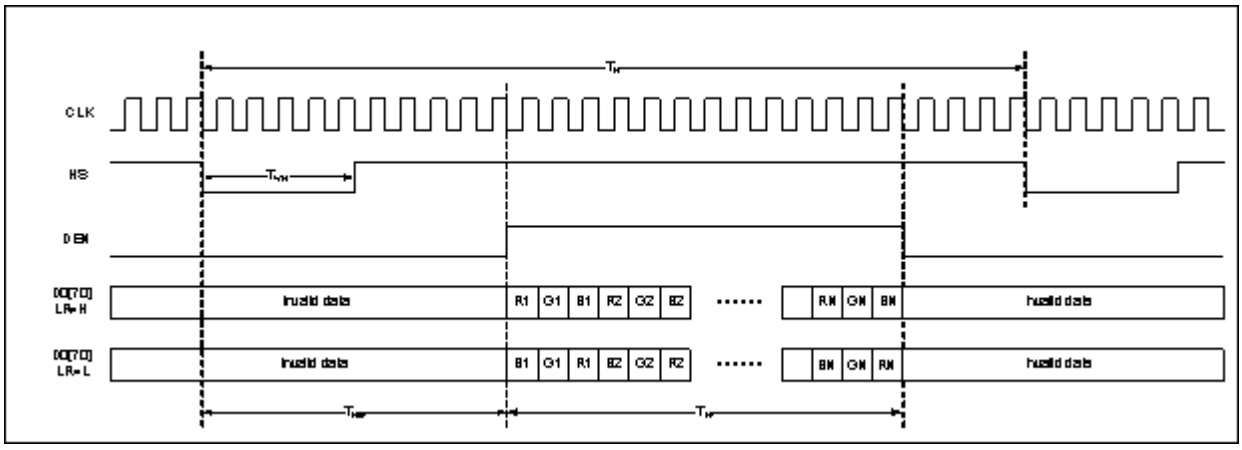

**Define the HSYNC to VSYNC timing for RGB mode**

5.2.2 480RGB X 272 serial RGB interface

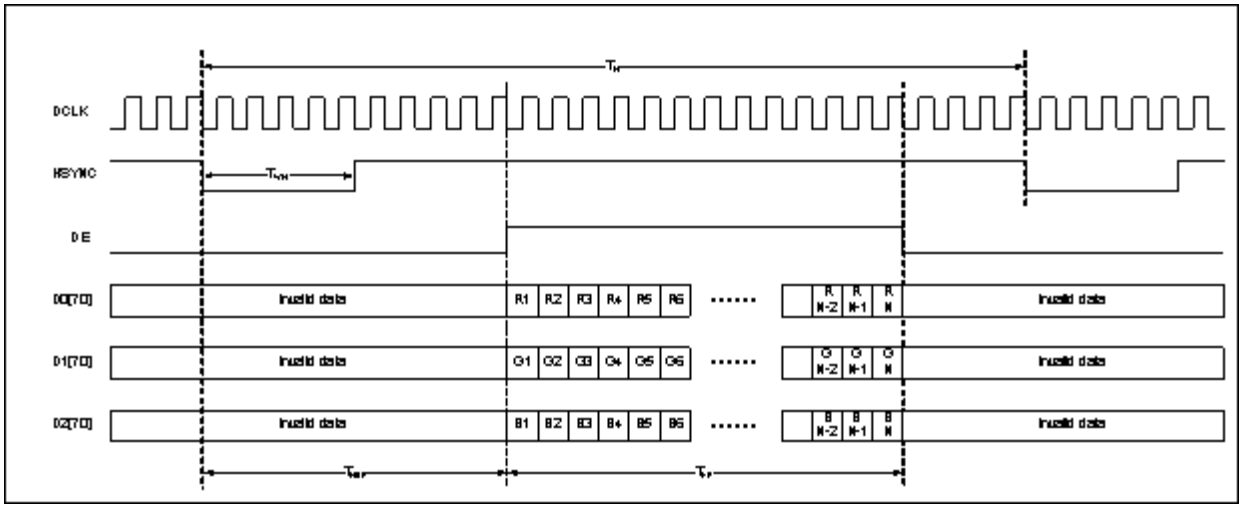
| PARAMETER | Symbol | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|
| DCLK frequency | $F_{CPH}$ | 33.3 | - | - | MHz |
| DCLK period | $T_{CPH}$ | - | - | 30 | ns |
| DCLK pulse duty | $T_{CWH}$ | 40 | 50 | 60 | % |
| HSYNC period | $T_H$ | - | 1836 | - | $T_{CPH}$ |
| HSYNC pulse width | $T_{WH}$ | 5 | 90 | - | $T_{CPH}$ |
| HSYNC-first horizontal data time | $T_{HBP}$ | 274 | 306 | 337 | $T_{CPH}$ |
| DE pulse width | $T_{EP}$ | - | 1440 | - | $T_{CPH}$ |
| VSYNC pulse width | $T_{WV}$ | 1 | 3 | 5 | $T_H$ |
| VSYNC-1st Data input (DE) time | $T_{VBP}$ | 4 | 20 | 35 | $T_H$ |
| VSYNC period | $T_V$ | 302 | - | - | $T_H$ |

5.2.2 480RGB X 272 parallel RGB interface

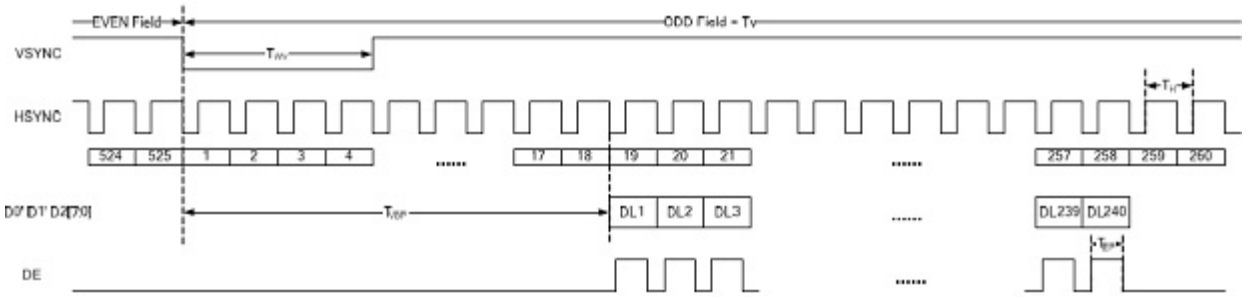
| PARAMETER | Symbol | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|
| DCLK frequency | $F_{CPH}$ | 11.1 | - | - | MHz |
| DCLK period | $T_{CPH}$ | - | - | 90 | ns |
| DCLK pulse duty | $T_{CWH}$ | 40 | 50 | 60 | % |
| HSYNC period | $T_H$ | - | 612 | - | $T_{CPH}$ |
| HSYNC pulse width | $T_{WH}$ | 5 | 30 | - | $T_{CPH}$ |
| HSYNC-first horizontal data time | $T_{HBP}$ | 70 | 102 | 133 | $T_{CPH}$ |
| DE pulse width | $T_{EP}$ | - | 480 | - | $T_{CPH}$ |
| VSYNC pulse width | $T_{WV}$ | 1 | 3 | 5 | $T_H$ |
| VSYNC-1st Data input (DE) time | $T_{VBP}$ | 4 | 20 | 35 | $T_H$ |
| VSYNC period | $T_V$ | 302 | - | - | $T_H$ |




**Serial RGB Horizontal Data Format**




**Parallel RGB Horizontal Data Format**




**Digital RGB Vertical Data Format**

## 6. Electro-Optical Characteristic:

| Items | Symbol | Min | Typ. | Max | Unit | Remark |
|---|---|---|---|---|---|---|
| Operating Luminance | L | 170 | 200 | 230 | $Cd/m^2$ | (1)(5) |
| Power Consumption | Pon | | 700 | 950 | mW | 30% pixels on (1) |
| Maximum Current | Icc | | 220 | 302 | mA | (1) |
| Response Time | Tres | | | 50 | uS | (2) |
| CIEx (White) | Wx | 0.26 | 0.31 | 0.36 | - | (5) |
| CIEy (White) | Wy | 0.28 | 0.33 | 0.38 | - | (5) |
| CIEx (Red) | Rx | 0.62 | 0.66 | 0.70 | - | (5) |
| CIEy( Red) | Ry | 0.30 | 0.34 | 0.38 | - | (5) |
| CIEx (Green) | Gx | 0.25 | 0.29 | 0.33 | - | (5) |
| CIEy( Green) | Gy | 0.62 | 0.66 | 0.70 | - | (5) |
| CIEx (Blue) | Bx | 0.11 | 0.15 | 0.19 | - | (5) |
| CIEy( Blue) | By | 0.12 | 0.16 | 0.20 | - | (5) |
| Viewing Angle | VA | 160 | 170 | | Degree | (3) |
| Contrast | CR | 5000:1 | 10000:1 | | | (4) |
| Operation Lifetime | LTop | 20000 | | | Hrs | (1)(6) |

Note:

Measuring surrounding: dark room

Surrounding temperature: 25°C

1. Test condition:

a. AR_VDD= 5.2V +/-0.03V, AR_VSS= -4.8V +/-0.03V

b. IC Initial Register Setting:

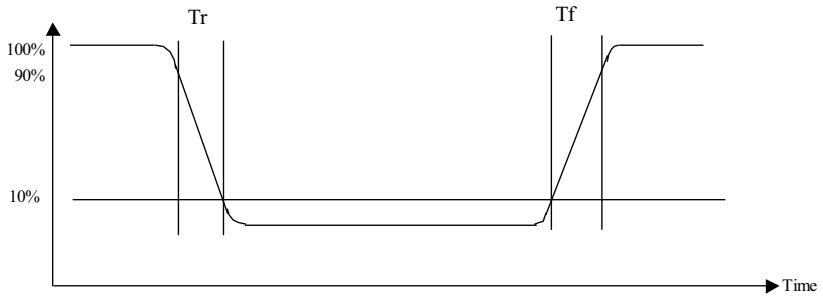
| 24-bit parallel RGB (DE) | |
|---|---|
| Index_out(0x04); | Parameter_out(0x23); //set display mode 24-bit parallel RGB (DE) |
| Index_out(0x05); | Parameter_out(0x82); //set display mode |
| Index_out(0x07); | Parameter_out(0x0F); //set driver capability |
| Index_out(0x34); | Parameter_out(0x18); //set display timing |
| Index_out(0x35); | Parameter_out(0x28); //set display timing |
| Index_out(0x36); | Parameter_out(0x16); //set display timing |
| Index_out(0x37); | Parameter_out(0x01); //set display timing |
| Index_out(0x02); | Parameter_out(0x02); //OTP On |
| Index_out(0x0A); | Parameter_out(0x79); //VGHVGL=+/-6V |

| |
|---|
| Index_out(0x09); Parameter_out(0x26); //VGAM1OUT=5.0V |
| Index_out(0x10); Parameter_out(0x07); //set R slop |
| Index_out(0x11); Parameter_out(0x08); //set G slop |
| Index_out(0x12); Parameter_out(0x07); //set B slop |
| Index_out(0x13); Parameter_out(0x00); //set R_0 |
| Index_out(0x14); Parameter_out(0x01); //set R_10 |
| Index_out(0x15); Parameter_out(0x02); //set R_36 |
| Index_out(0x16); Parameter_out(0x01); //set R_80 |
| Index_out(0x17); Parameter_out(0x02); //set R_124 |
| Index_out(0x18); Parameter_out(0x02); //set R_168 |
| Index_out(0x19); Parameter_out(0x03); //set R_212 |
| Index_out(0x1A); Parameter_out(0x06); //set R_255 |
| Index_out(0x1B); Parameter_out(0x00); //set G_0 |
| Index_out(0x1C); Parameter_out(0x02); //set G_10 |
| Index_out(0x1D); Parameter_out(0x00); //set G_36 |
| Index_out(0x1E); Parameter_out(0x01); //set G_80 |
| Index_out(0x1F); Parameter_out(0x02); //set G_124 |
| Index_out(0x20); Parameter_out(0x03); //set G_168 |
| Index_out(0x21); Parameter_out(0x03); //set G_212 |
| Index_out(0x22); Parameter_out(0x05); //set G_255 |
| Index_out(0x23); Parameter_out(0x00); //set G_0 |
| Index_out(0x24); Parameter_out(0x03); //set B_10 |
| Index_out(0x25); Parameter_out(0x06); //set B_36 |
| Index_out(0x26); Parameter_out(0x07); //set B_80 |
| Index_out(0x27); Parameter_out(0x06); //set B_124 |
| Index_out(0x28); Parameter_out(0x05); //set B_168 |
| Index_out(0x29); Parameter_out(0x05); //set B_212 |
| Index_out(0x2A); Parameter_out(0x08); //set B_255 |
| Index_out(0x06); Parameter_out(0x03); //set display on |
| AR_VDD= +5.2V |
| AR_VSS= -4.8V |

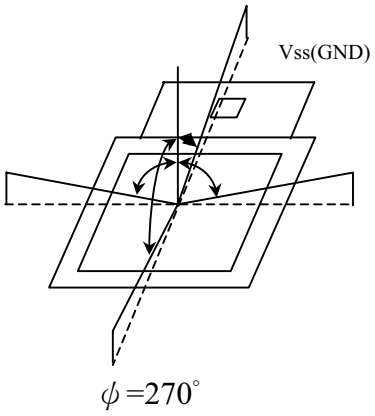
| **8-bit serial RGB (DE)** |
|---|
| Index_out(0x04); Parameter_out(0x21); //set display mode 8-bit serial RGB (DE) |
| Index_out(0x05); Parameter_out(0x82); //set display mode |
| Index_out(0x07); Parameter_out(0x0F); //set driver capability |
| Index_out(0x34); Parameter_out(0x48); //set display timing |
| Index_out(0x35); Parameter_out(0x78); //set display timing |

| |
|---|
| Index_out(0x36); Parameter_out(0x42); //set display timing |
| Index_out(0x37); Parameter_out(0x01); //set display timing |
| Index_out(0x02); Parameter_out(0x02); //OTP On |
| Index_out(0x0A); Parameter_out(0x79); //VGHVGL=+/-6V |
| Index_out(0x09); Parameter_out(0x26); //VGAM1OUT=5.0V |
| Index_out(0x10); Parameter_out(0x07); //set R slop |
| Index_out(0x11); Parameter_out(0x08); //set G slop |
| Index_out(0x12); Parameter_out(0x07); //set B slop |
| Index_out(0x13); Parameter_out(0x00); //set R_0 |
| Index_out(0x14); Parameter_out(0x01); //set R_10 |
| Index_out(0x15); Parameter_out(0x02); //set R_36 |
| Index_out(0x16); Parameter_out(0x01); //set R_80 |
| Index_out(0x17); Parameter_out(0x02); //set R_124 |
| Index_out(0x18); Parameter_out(0x02); //set R_168 |
| Index_out(0x19); Parameter_out(0x03); //set R_212 |
| Index_out(0x1A); Parameter_out(0x06); //set R_255 |
| Index_out(0x1B); Parameter_out(0x00); //set G_0 |
| Index_out(0x1C); Parameter_out(0x02); //set G_10 |
| Index_out(0x1D); Parameter_out(0x00); //set G_36 |
| Index_out(0x1E); Parameter_out(0x01); //set G_80 |
| Index_out(0x1F); Parameter_out(0x02); //set G_124 |
| Index_out(0x20); Parameter_out(0x03); //set G_168 |
| Index_out(0x21); Parameter_out(0x03); //set G_212 |
| Index_out(0x22); Parameter_out(0x05); //set G_255 |
| Index_out(0x23); Parameter_out(0x00); //set G_0 |
| Index_out(0x24); Parameter_out(0x03); //set B_10 |
| Index_out(0x25); Parameter_out(0x06); //set B_36 |
| Index_out(0x26); Parameter_out(0x07); //set B_80 |
| Index_out(0x27); Parameter_out(0x06); //set B_124 |
| Index_out(0x28); Parameter_out(0x05); //set B_168 |
| Index_out(0x29); Parameter_out(0x05); //set B_212 |
| Index_out(0x2A); Parameter_out(0x08); //set B_255 |
| Index_out(0x06); Parameter_out(0x03); //set display on |
| AR_VDD= +5.2V |
| AR_VSS= -4.8V |

2. Response Time test condition




3. Viewing angle test condition:



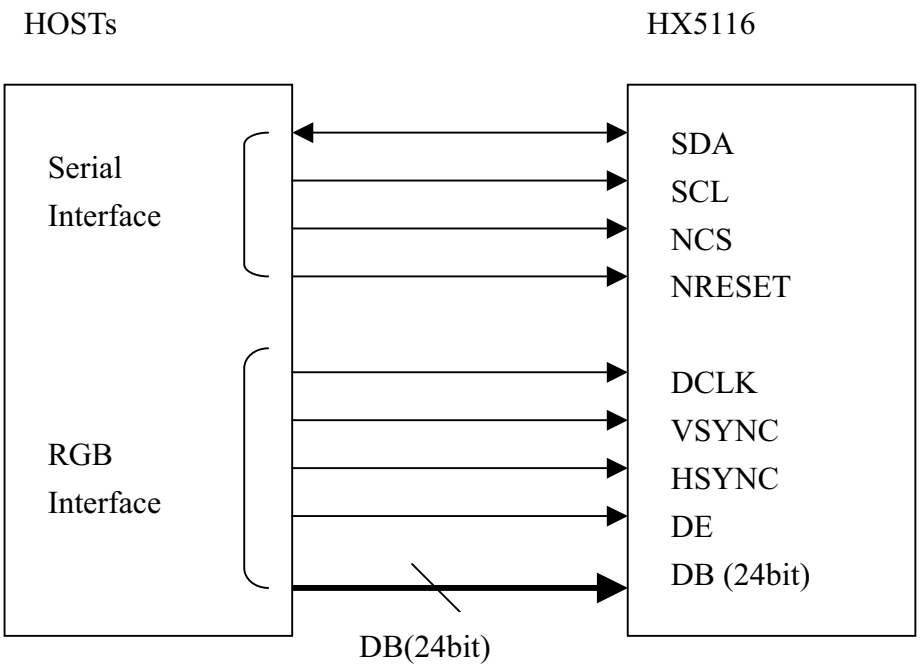

4. Contrast

$$CR = \frac{\text{Luminance with all pixels white}}{\text{Luminance with all pixels black}}$$

5. Optical tester: CA210

6. Brightness of 30% power consumption. Operating Life Time is defined when the luminance has decayed to less than 50% of the initial measured luminance before life test.

## 7. System Diagram:



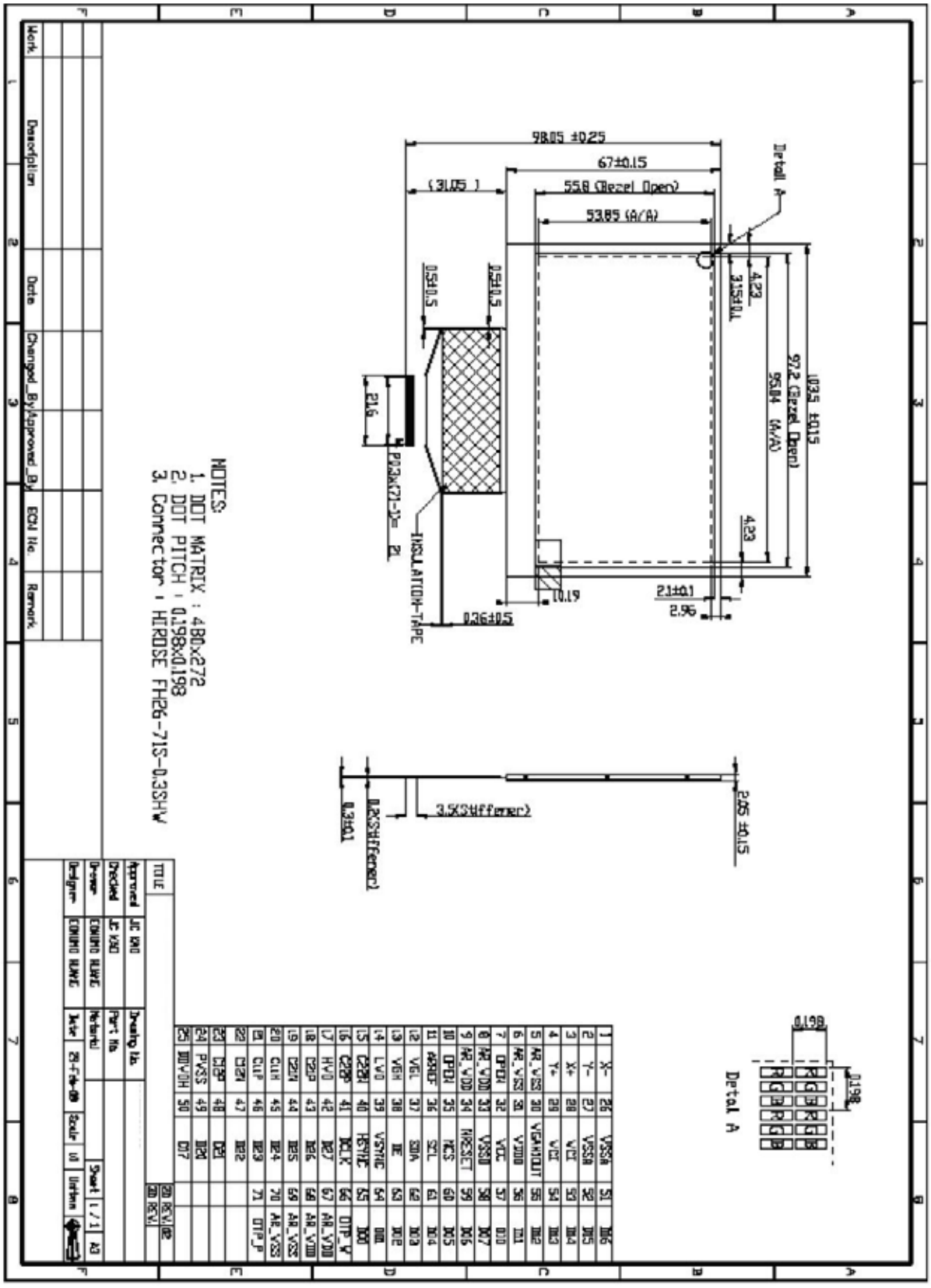
## 8. Pin Assignment:

| PIN | Symbol | I/O | Description | Remarks |
|---|---|---|---|---|
| 1 | TP1 | I | Touch panel P1 | |
| 2 | TP2 | I | Touch panel P2 | |
| 3 | TP3 | I | Touch panel P3. | |
| 4 | TP4 | I | Touch panel P4 | |
| 5 | AR_VSS | I | Negative voltage for OLED | |
| 6 | AR_VSS | I | Negative voltage for OLED | |
| 7 | TEST1_VS | **open** | **Test pin, it must be open.** | |
| 8 | AR_VDD | I | Positive voltage for OLED | |
| 9 | AR_VDD | I | Positive voltage for OLED | |
| 10 | TEST2_VD | **open** | **Test pin, it must be open.** | |
| 11 | ARREF | I/O | Panel refers voltage of the regulator ARREF or external input voltage. (-8V~+8V) | |
| 12 | VGL | I/O | Low Voltage output of regulator VGL or external input voltage. (-3V~-8V) | |
| 13 | VGH | I/O | High Voltage output of regulator VGH or external input voltage. (+3V~+8V) | |
| 14 | LVO | I/O | **Negative output voltage of the booster2. (-8.5V)** | |
| 15 | C22N | I/O | Connect to the step-up circuit, capacitors according to the step-up factor. Leave this pin open if the internal step-up circuit is not used. | |
| 16 | C22P | | | |
| 17 | HVO | I/O | Positive output voltage of the booster2. (8.5V) | |
| 18 | C21P | I/O | Connect to the step-up circuit, capacitors according to the step-up factor. Leave this pin open if the internal step-up circuit is not used. | |
| 19 | C21N | | | |
| 20 | C11N | I/O | Connect to the step-up circuit, 4capacitors according to the step-up factor. Leave this pin open if the internal step-up circuit is not used. | |
| 21 | C11P | | | |
| 22 | C12N | | | |
| 23 | C12P | | | |
| 24 | PVSS | P | Charge pump ground pin, it must connect to external ground. | |
| 25 | DDVDH | I/O | Output voltage of the booster1. (5.1V/6.0V) | |
| 26 | VSSA | P | **Analog ground pin. It must connect to external ground.** | |
| 27 | VSSA | P | **Analog ground pin. It must connect to external ground.** | |
| 28 | VCI | P | **A power supply for the Analog circuit. (3.0V~3.6V)** | |
| 29 | VCI | P | **A power supply for the Analog circuit. (3.0V~3.6V)** | |
| 30 | VGAM1OUT | I/O | Output voltage of the VGAM1OUT regulator and used positive power of source driver. (4.8V/5.8V) | |
| 31 | VDDD | I/O | Internal logic voltage input or output pin<br>VDC_ENB=0, VDDD is output, please connect to 1uF capacitor.<br>VDC0 / VDDD / Status<br>0 / 1.8V / Normal display | |

| | | | | |
|---|---|---|---|---|
| | | | 1 \| 2.5V \| OTP program<br>**VDC_ENB=1, VDDD is input. (Input range = 1.6V~2.75V)** | |
| **32** | VCC | P | **A power supply for the Digital circuit. (1.5V~3.6V)** | |
| **33** | VSSD | P | **Digital ground pin. It must connect to external ground.** | |
| **34** | NRESET | I | **Reset pin. Setting either pin low initializes the LSI. Must be reset after power is supplied.** (Normally pull high) | |
| **35** | NCS | I | **Serial Interface chip enable pin.** (Normally pull high) | |
| **36** | SCL | I | **Serial Interface clock input pin.** (Normally pull high) | |
| **37** | SDA | I | **Serial Interface data line.** (Normally pull high) | |
| **38** | DE | I | Data enable:<br>When VSYNC+HSYNC+DE mode,<br>DE=H: Data enable, DE=L: Data disable (Black). **(Normally pull low)** | |
| **39** | VSYNC | I | Frame synchronizing signal.<br>If VSPL=0: Active low.<br>If VSPL=1: Active high. | |
| **40** | HSYNC | I | Line synchronizing signal.<br>If HSPL=0: Active low.<br>**If HSPL=1: Active high.** | |
| **41** | DCLK | I | Dot clock signal.<br>If DPL=0: Data are input on the rising edge of DOTCLK.<br>**If DPL=1: Data are input on the falling edge of DOTCLK.** | |
| **42** | D27 | I | Digital data input. DX0 is LSB and DX7 is MSB. **(Normally pull low)**<br>1. If parallel RGB input mode is used, D0X, D1X, and D2X indicate R, G, and B data in turn.<br>2. If serial RGB or RGBD or CCIR601 or CCIR656 input mode is selected, only D07~D00 are used, and others short to GND.<br>**DX7~DX0 has 8-bit width, respectively to compose 16,777,216 color and 256 gray scale of 1 pixel.** | |
| **43** | D26 | | | |
| **44** | D25 | | | |
| **45** | D24 | | | |
| **46** | D23 | | | |
| **47** | D22 | | | |
| **48** | D21 | | | |
| **49** | D20 | | | |
| **50** | D17 | | | |
| **51** | D16 | | | |
| **52** | D15 | | | |
| **53** | D14 | | | |
| **54** | D13 | | | |
| **55** | D12 | | | |
| **56** | D11 | | | |
| **57** | D10 | | | |
| **58** | D07 | | | |
| **59** | D06 | | | |

| | | | | |
|---|---|---|---|---|
| **60** | D05 | | | |
| **61** | D04 | | | |
| **62** | D03 | | | |
| **63** | D02 | | | |
| **64** | D01 | | | |
| **65** | D00 | | | |
| **66** | **TEST3_W** | **open** | **Test pin, it must be open.** | |
| **67** | **AR_VDD** | I | Positive voltage for OLED | |
| **68** | **AR_VDD** | I | Positive voltage for OLED | |
| **69** | **AR_VSS** | I | Negative voltage for OLED | |
| **70** | **AR_VSS** | I | Negative voltage for OLED | |
| **71** | **TEST4_P** | **open** | **Test pin, it must be open.** | |

## 9. External Dimension:



**10. Reliability Test:**

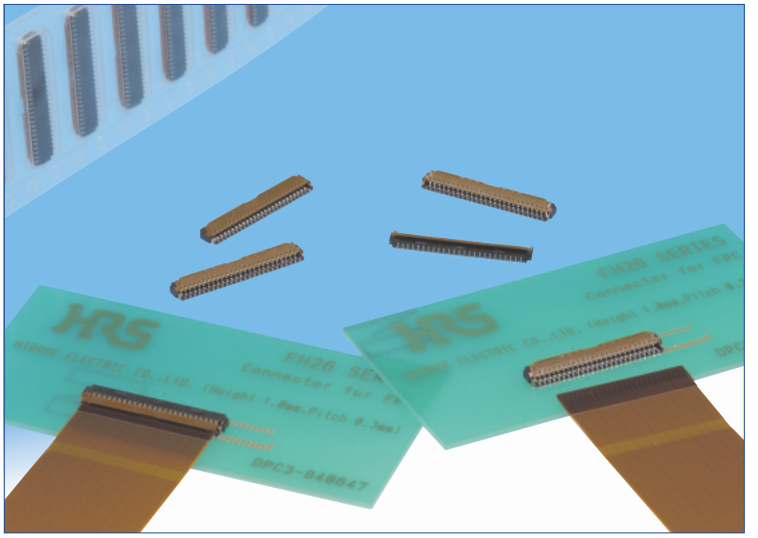
| No | Item | Specification |
|---|---|---|
| 1 | High Temp. Storage | 85℃, 240hr |
| 2 | Low Temp. Storage | -40℃, 240hr |
| 3 | High Temp. Operation | 60℃, 240hr |
| 4 | Low Temp. Operation | -40℃, 240hr |
| 5 | High Temp./ High Hum. Storage | 85℃, 85 % RH, 120 hr |
| 6 | High Temp./ High Hum. Operation | 60℃, 90 % RH, 240hr |
| 7 | Thermal Shock storage | -40℃, 30 min. --> 85℃, 30 min., 100 cycles |
| 8 | ESD | (1) Contact discharge mode: +/- 2kV, 3 times/FPC pin |
| | | (2) Air discharge mode: +/- 8 kV, 10 times/central area |
| 9 | Packing Test | Drop 1 corner, 3 sides, 6 faces, 1 time for each; Height: follow ISTA standard. |
| | | Frequency: 5~50HZ, 0.5G |
| | | Scan rate: 1 oct/min |
| | | Time: 2 hrs/axis |
| | | Test axis: X, Y, Z |

**Evaluation Criteria**

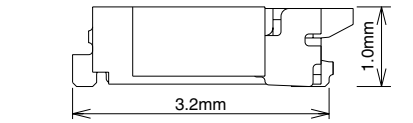
- No damage to glass or encapsulation
- No drastic change to display
- Defects / Mura follow product specification
- Luminance: Within +/-50% of initial value
- Current consumption: within +/-50% of initial value

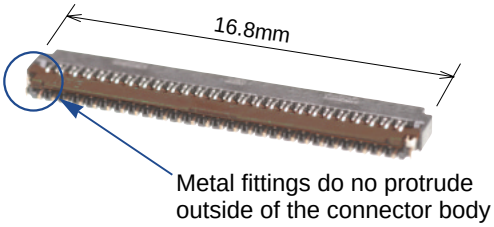
# 0.3mm Contact Pitch, 1mm above the board, Flexible Printed Circuit ZIF Connectors

## FH26 Series



●Space saving(51 pos. shown)




## ■Features

### 1. Extremely light weight

The typical version, with all 51 contacts loaded, weights only 0.1 grams.

### 2. Easy solderability on the PC board

The soldering leads are on 0.6 mm pitch, exiting on front and back of the connector.

### 3. Conductive traces on the PCB can run under the connector

No exposed contacts on the bottom of the connector.

### 4. Easy FPC insertion and reliable electrical connection

Proven Flip LockR actuator allows easy insertion of FPC. Tactile sensation when fully closed confirms complete electrical and mechanical connection.

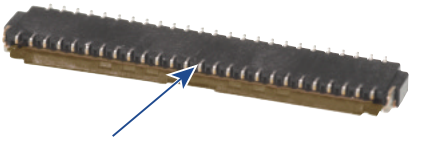
### 5. Accepts standard thickness FPC

0.2mm thick standard Flexible Printed Circuit board can be used.
This is the only ultra-low profile ZIF connector allowing the use of standard FPC.

### 6. Board placement with automatic equipment

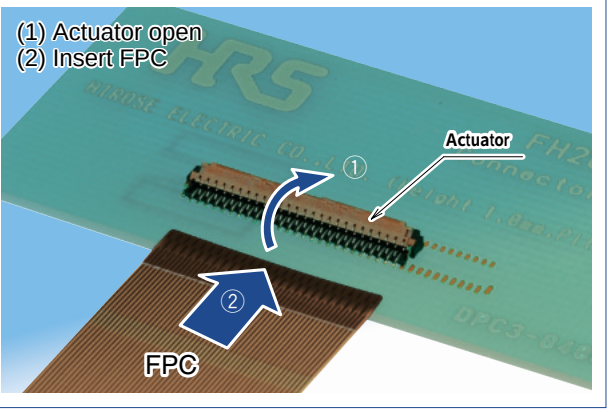
Flat top surface and packaging on the tape-and-reel allows use of vacuum nozzles.
Standard reel contains 5,000 connectors.

●Can be mounted over conductive traces.



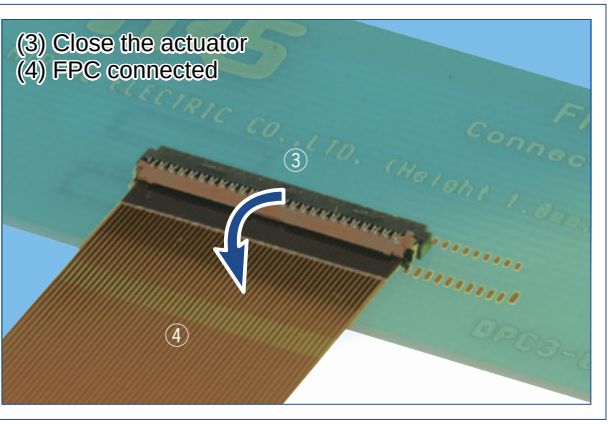
No exposed contacts on the bottom
of the connector

●Operation




## ■Applications

Mobile phones, PDA's, digital cameras, digital video cameras, LCD connections, plasma displays (PDP), camera modules and other compact devices requiring Flexible Printed Circuit connections using high reliability ultra-small profile connectors.



## ■Specifications

| | | | |
|---|---|---|---|
| Rating | Current rating 0.2A DC<br>Voltage rating 30V AC | Operating temperature range -55℃ to +85℃ (Note 1)<br>Operating humidity range Relative humidity 90% max. (No condensation) | Storage temperature range -10℃ to +50℃ (Note 2)<br>Storage humidity range Relative humidity 90% max. |

| | |
|---|---|
| Recommended FPC : | Thickness: = 0.2±0.03mm tin-lead plated (Note 3) |

| Item | Specification | Conditions |
|---|---|---|
| 1. Insulation resistance | 50 M ohms min. | 100 V DC |
| 2. Withstanding voltage | No flashover or insulation breakdown. | 90 V AC /one minute |
| 3. Contact resistance | 100 m ohms max.<br>∗ Including FPC conductor resistance | 1 mA |
| 4. Durability (Insertion/ withdrawal) | Contact resistance: 100 m ohms max.<br>No damage, cracks, or parts dislocation. | 10 cycles |
| 5. Vibration | No electrical discontinuity of 1μs or more.<br>Contact resistance: 100 m ohms max.<br>No damage, cracks, or parts dislocation. | Frequency: 10 to 55 Hz, single amplitude of 0.75 mm, 10 cycles, 3 directions. |
| 6. Shock | No electrical discontinuity of 1μs. min.<br>Contact resistance: 100 m ohms max.<br>No damage, cracks, or parts dislocation. | Acceleration of 981 m/s², 6 ms duration, sine half-wave waveform, 3 cycles in each of the 3 axis |
| 7. Humidity (Steady state) | Contact resistance: 100 m ohms max.<br>Insulation resistance: 50 M ohms min.<br>No affect on appearance or performance. | 96 hours at temperature of 40±2℃ and humidity of 90% to 95%. |
| 8. Temperature cycle | Contact resistance: 100 m ohms max.<br>Insulation resistance: 50 M ohms min.<br>No damage, cracks, or parts looseness. | Temperature: -55 ℃→+15℃ to +35℃→+85℃→+15℃ to +35℃<br>Time: 30 → 2 to 3 → 30 → 2 to 3 (Minutes)<br>5 cycles |
| 9. Resistance to soldering heat | No deformation of components affecting performance. | Reflow: At the recommended temperature profile<br>Manual soldering: 350℃ +/-10℃ for 5±1 seconds |

Note 1: Includes temperature rise caused by current flow.
Note 2: The term "storage" refers to products stored for long period of time prior to mounting and use. Operating Temperature Range and Humidity range covers non- conducting condition of installed connectors in storage, shipment or during transportation.
Note 3: When FPC is gold plated, the connector contacts must be also gold plated: Specify the (05) plating code.

## ■Materials

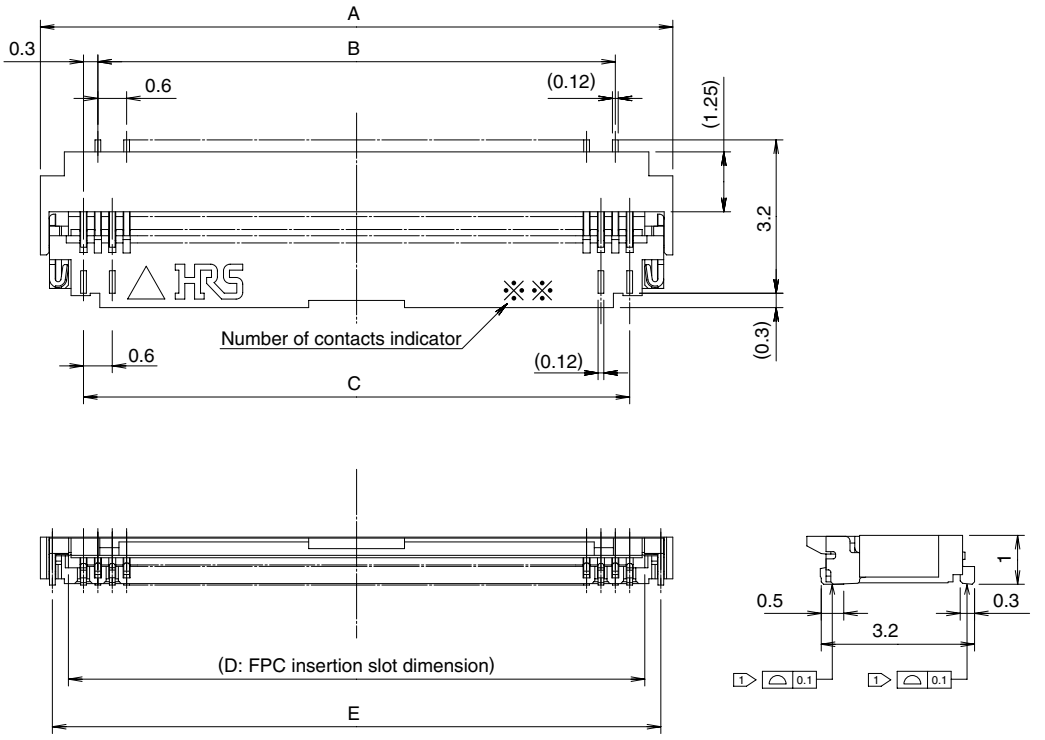
| Part | Material | Finish | Remarks |
|---|---|---|---|
| Insulator | LCP | Color: Black | UL94V-0 |
| Actuator | PA | Color: Dark brown | |
| Contacts | Phosphor bronze | Tin-lead plated (Note 3) | ——— |
| Metal fitting | | Tin plated (Lead free) | ——— |

## ■Ordering information

**FH26 - 51S - 0.3 SHW (05)**
❶ ❷ ❸ ❹ ❺

| | |
|---|---|
| ❶ Series name: FH26 | ❹ Terminal type: SHW(SMT horizontal mounting) |
| ❷ No. of contacts: 13, 21, 23, 25, 27, 33, 35, 39, 41, 45, 51, 57, 71 | ❺ Plating specifications<br>Blank: Tin-lead plated<br>(05) : Gold flash plated |
| ❸ Contact pitch: 0.3mm | |

## ■Connector Dimensions



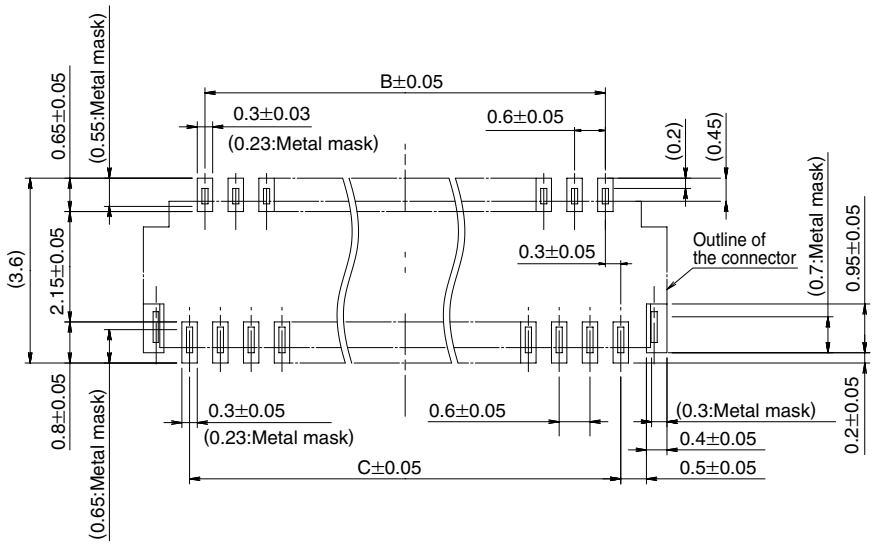

Notes 1 The coplanarity of each terminal lead within specified dimension is ± 0.1 mm.
2 Packaged on tape and reel only. Check packaging specification.

All dimensions: mm

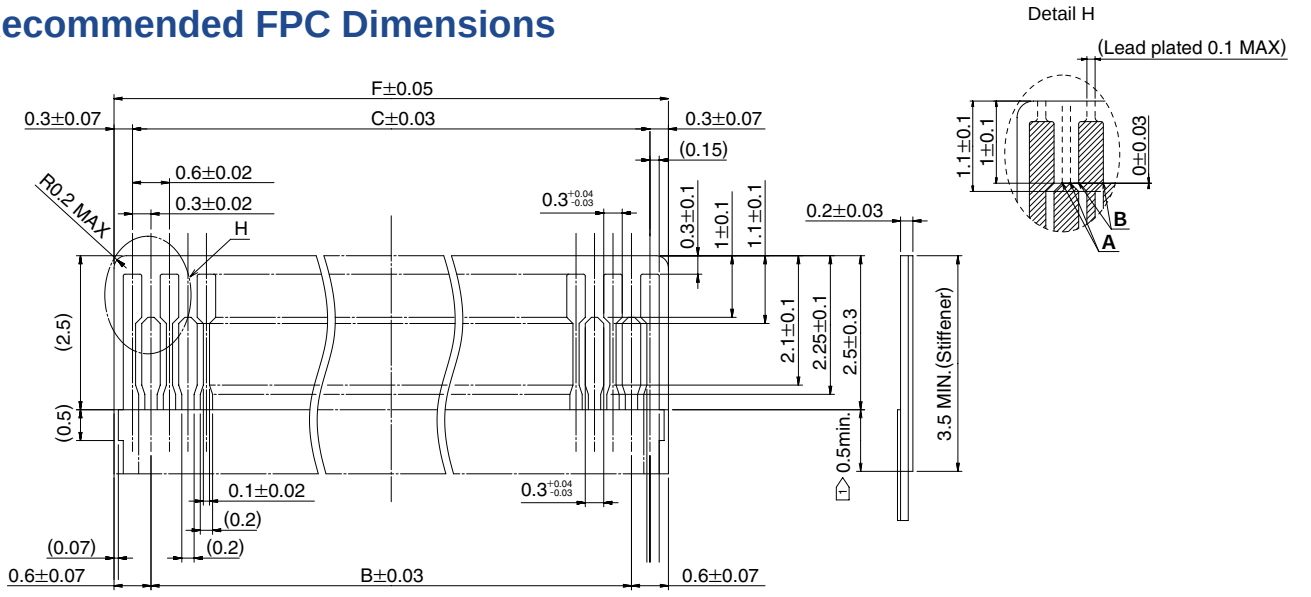
| Part Number | CL No. | Number of Contacts | A | B | C | D | E |
|---|---|---|---|---|---|---|---|
| FH26-13S-0.3SHW | CL580-0209-3 | 13 | 5.4 | 3.0 | 3.6 | 4.23 | 4.9 |
| FH26-21S-0.3SHW | CL580-0207-8 | 21 | 7.8 | 5.4 | 6.0 | 6.63 | 7.3 |
| FH26-23S-0.3SHW | CL580-0203-7 | 23 | 8.4 | 6.0 | 6.6 | 7.23 | 7.9 |
| FH26-25S-0.3SHW | CL580-0208-0 | 25 | 9.0 | 6.6 | 7.2 | 7.83 | 8.5 |
| FH26-27S-0.3SHW | CL580-0204-0 | 27 | 9.6 | 7.2 | 7.8 | 8.43 | 9.1 |
| FH26-33S-0.3SHW | CL580-0210-2 | 33 | 11.4 | 9.0 | 9.6 | 10.23 | 10.9 |
| FH26-35S-0.3SHW | CL580-0205-2 | 35 | 12.0 | 9.6 | 10.2 | 10.83 | 11.5 |
| FH26-39S-0.3SHW | CL580-0201-1 | 39 | 13.2 | 10.8 | 11.4 | 12.03 | 12.7 |
| FH26-41S-0.3SHW | CL580-0206-5 | 41 | 13.8 | 11.4 | 12.0 | 12.63 | 13.3 |
| FH26-45S-0.3SHW | CL580-0211-5 | 45 | 15.0 | 12.6 | 13.2 | 13.83 | 14.5 |
| FH26-51S-0.3SHW | CL580-0200-9 | 51 | 16.8 | 14.4 | 15.0 | 15.63 | 16.3 |
| FH26-57S-0.3SHW | CL580-0212-8 | 57 | 18.6 | 16.2 | 16.8 | 17.43 | 18.1 |
| FH26-71S-0.3SHW | CL580-0202-4 | 71 | 22.8 | 20.4 | 21.0 | 21.63 | 22.3 |

Embossed tape reel packaging (5,000 pieces/reel).
Order by number of reels.

## Recommended PCB mounting pattern and metal mask dimensions




## Recommended FPC Dimensions



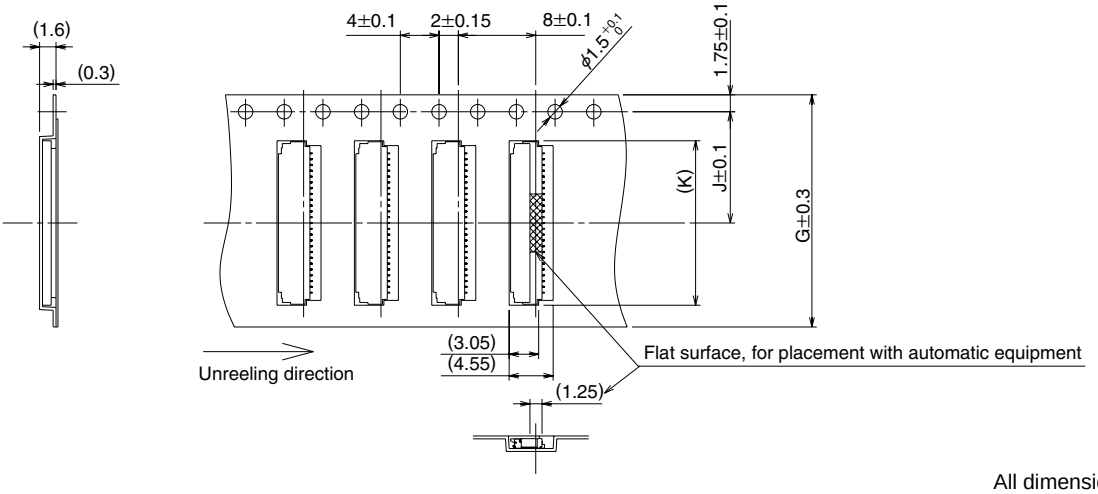

1 Overlap between covering film layer and stiffener.

All dimensions: mm

| Part Number | CL No. | Number of Contacts | B | C | F |
|---|---|---|---|---|---|
| FH26-13S-0.3SHW | CL580-0209-3 | 13 | 3.0 | 3.6 | 4.2 |
| FH26-21S-0.3SHW | CL580-0207-8 | 21 | 5.4 | 6.0 | 6.6 |
| FH26-23S-0.3SHW | CL580-0203-7 | 23 | 6.0 | 6.6 | 7.2 |
| FH26-25S-0.3SHW | CL580-0208-0 | 25 | 6.6 | 7.2 | 7.8 |
| FH26-27S-0.3SHW | CL580-0204-0 | 27 | 7.2 | 7.8 | 8.4 |
| FH26-33S-0.3SHW | CL580-0210-2 | 33 | 9.0 | 9.6 | 10.2 |
| FH26-35S-0.3SHW | CL580-0205-2 | 35 | 9.6 | 10.2 | 10.8 |
| FH26-39S-0.3SHW | CL580-0201-1 | 39 | 10.8 | 11.4 | 12.0 |
| FH26-41S-0.3SHW | CL580-0206-5 | 41 | 11.4 | 12.0 | 12.6 |
| FH26-45S-0.3SHW | CL580-0211-5 | 45 | 12.6 | 13.2 | 13.8 |
| FH26-51S-0.3SHW | CL580-0200-9 | 51 | 14.4 | 15.0 | 15.6 |
| FH26-57S-0.3SHW | CL580-0212-8 | 57 | 16.2 | 16.8 | 17.4 |
| FH26-71S-0.3SHW | CL580-0202-4 | 71 | 20.4 | 21.0 | 21.6 |

# ◆Packaging Specification

## ●Embossed Carrier Tape Dimensions (Tape width of 24mm max.)

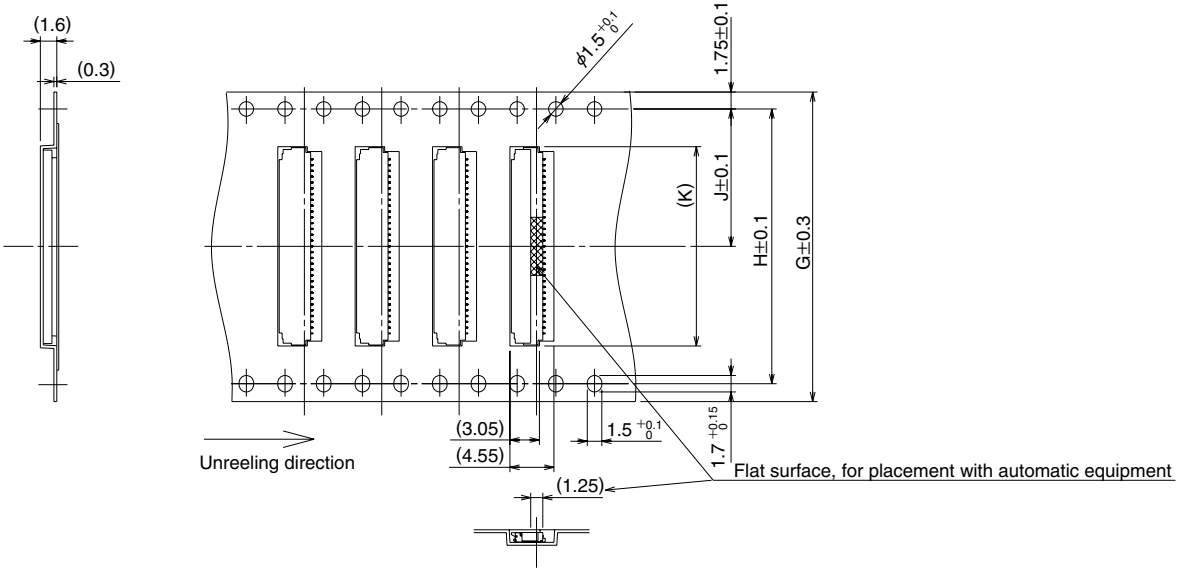



All dimensions: mm

| Part Number | CL No. | Number of Contacts | G | J | K | L |
|---|---|---|---|---|---|---|
| FH26-13S-0.3SHW | CL580-0209-3 | 13 | 16 | 7.5 | 5.6 | 16.5 |
| FH26-21S-0.3SHW | CL580-0207-8 | 21 | 16 | 7.5 | 8.0 | 16.5 |
| FH26-23S-0.3SHW | CL580-0203-7 | 23 | 16 | 7.5 | 8.6 | 16.5 |
| FH26-25S-0.3SHW | CL580-0208-0 | 25 | 16 | 7.5 | 9.2 | 16.5 |
| FH26-27S-0.3SHW | CL580-0204-0 | 27 | 16 | 7.5 | 9.8 | 16.5 |
| FH26-33S-0.3SHW | CL580-0210-2 | 33 | 24 | 11.5 | 11.6 | 24.5 |
| FH26-35S-0.3SHW | CL580-0205-2 | 35 | 24 | 11.5 | 12.2 | 24.5 |
| FH26-39S-0.3SHW | CL580-0201-1 | 39 | 24 | 11.5 | 13.4 | 24.5 |
| FH26-41S-0.3SHW | CL580-0206-5 | 41 | 24 | 11.5 | 14.0 | 24.5 |
| FH26-45S-0.3SHW | CL580-0211-5 | 45 | 24 | 11.5 | 15.2 | 24.5 |
| FH26-51S-0.3SHW | CL580-0200-9 | 51 | 24 | 11.5 | 17.0 | 24.5 |

5, 000 pieces per reel.

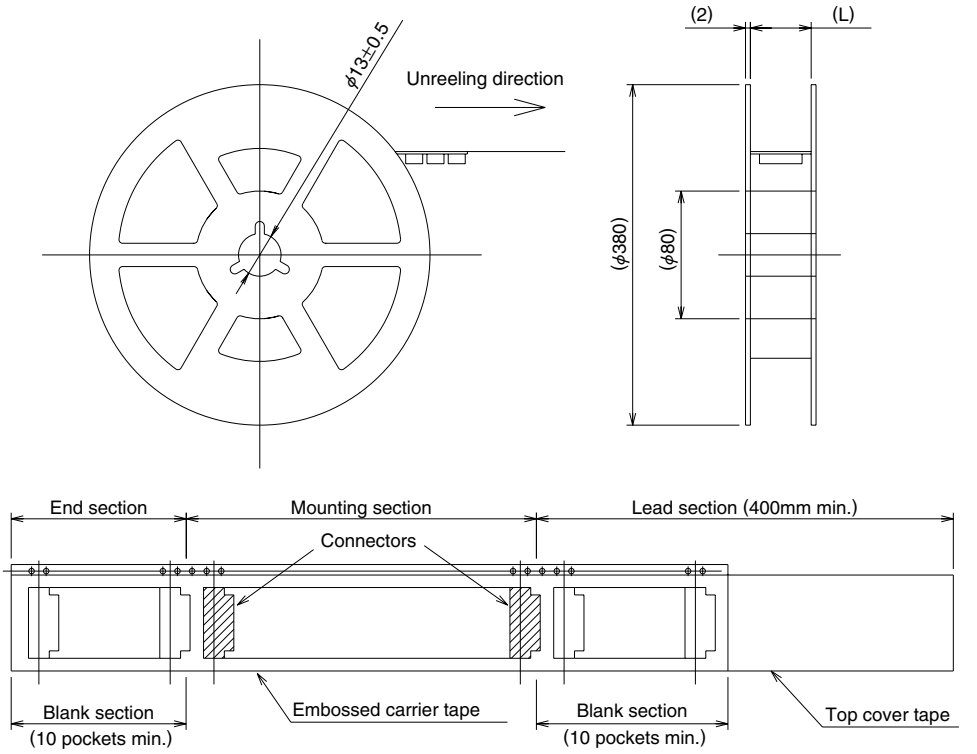
## ●Embossed Carrier Tape Dimensions (Tape width of 32mm min.)




All dimensions: mm

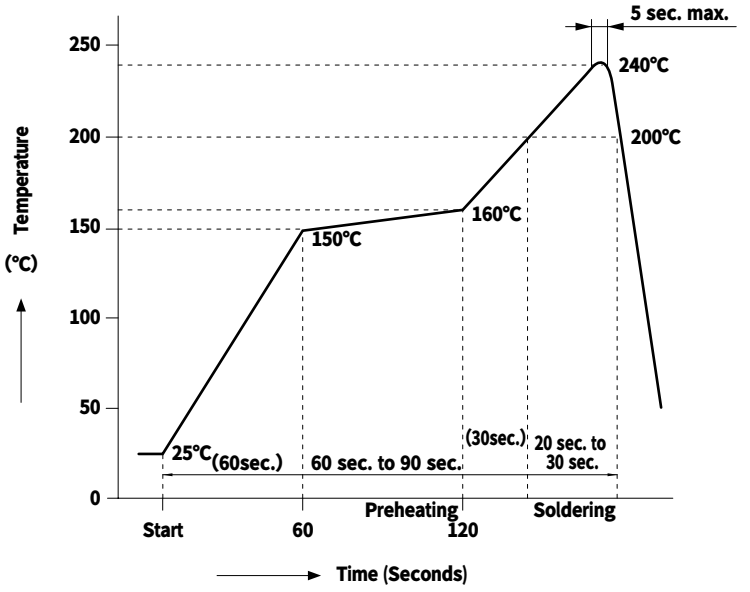
| Part Number | CL No. | Number of Contacts | G | H | J | K | L |
|---|---|---|---|---|---|---|---|
| FH26-57S-0.3SHW | CL580-0212-8 | 57 | 32 | 28.4 | 14.2 | 18.8 | 32.5 |
| FH26-71S-0.3SHW | CL580-0202-4 | 71 | 44 | 40.4 | 20.2 | 23.0 | 44.5 |

## ●Reel Dimensions



## ◆Recommended Temperature Profile

### ●Using Typical Solder Paste

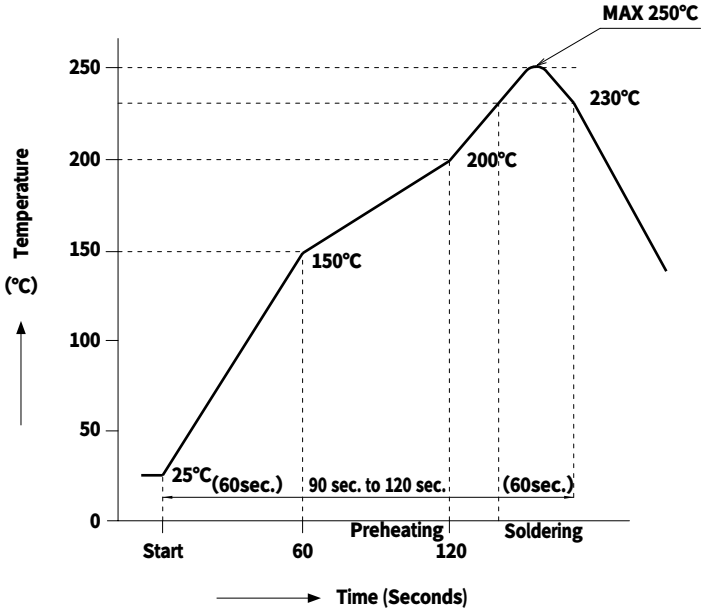



**HRS test conditions**

| | |
|---|---|
| Solder method | :Reflow, IR/hot air<br>(Nihon Den-netsu Co., Ltd.'s<br>Part Number: SENSBY NR-Ⅱ) |
| Environment: | :Room air |
| Solder composition: | :Paste, 63%Sn/37%Pb<br>(Senju Metal Industry, Co., Ltd.'s<br>Part Number: OZ63-201C-50-9) |
| Test board | :Glass epoxy 25mm×50mm×0.8mm thick |
| Land dimensions | :0.3mm×0.65mm,0.3mm×0.8mm |
| Metal mask | :0.23×0.55×0.1mm thick,<br>0.23×0.65×0.1mm thick |

The temperature profiles are based on the above conditions. In individual applications the actual temperature may vary,depending on solder paste type, volume/thickness and board size/thickness. Consult your solder paste and equipment manufacturer for specific recommendations.

### ●Using Lead-free Solder Paste




**HRS test conditions**

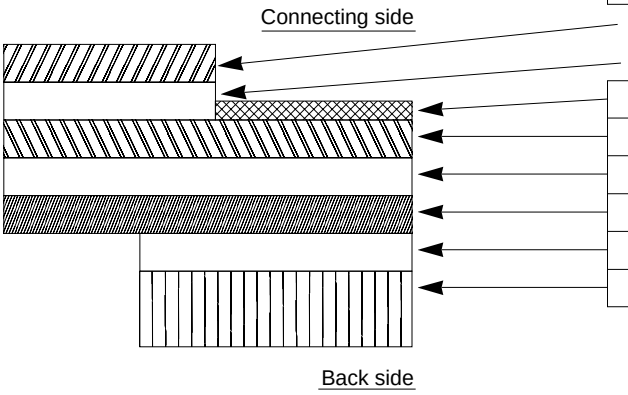
| | |
|---|---|
| Solder method | :Reflow, IR/hot air<br>(Nihon Den-netsu Co., Ltd.'s<br>Part Number: SENSBY NR-NR-Ⅱ) |
| Environment | :Room air |
| Solder composition | :Paste, 96.5%Sn/3.0%Ag/0.5%Cu<br>(Senju Metal Industry, Co., Ltd.'s<br>Part Number: M705-221CM5-42-10.5) |
| Test board | :Glass epoxy 25mm×50mm×0.8mm thick |
| Land dimensions | :0.3mm×0.65mm, 0.3mm×0.8mm |
| Metal mask | :0.23×0.55×0.1mm thick,<br>0.23×0.65×0.1mm thick |

The temperature profiles are based on the above conditions. In individual applications the actual temperature may vary, depending on solder paste type, volume/thickness and board size/thickness. Consult your solder paste and equipment manufacturer for specific recommendations.

## ◆Recommended FPC Construction

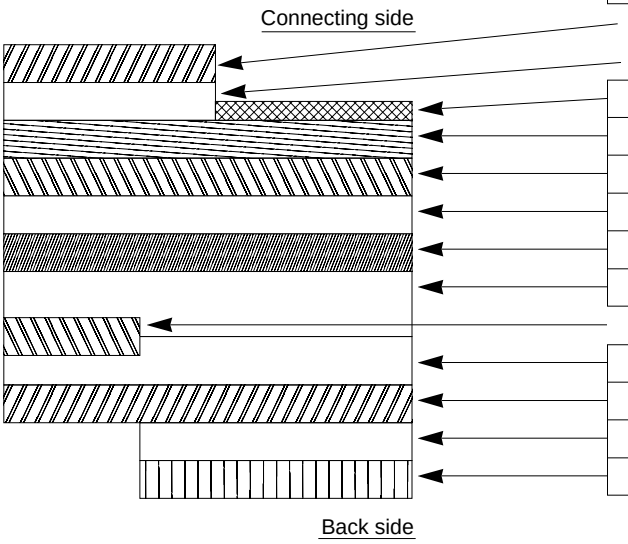
**●Contact FPC manufacturer for specific details.**

### 1. Using Single-sided FPC




| Material Name | Material | Thickness (µm) |
|---|---|---|
| Covering film layer. | Polyamide 1 mil thick. | 25 |
| Cover adhesive | | 25 |
| Surface treatment | Tin-lead plated | 5 |
| Copper foil | Cu 1/2oz | 35 |
| Base adhesive | Thermosetting adhesive | 25 |
| Base film | Polyamide 1 mil thick | 25 |
| Reinforcement material adhesive | Thermosetting adhesive | 40 |
| Stiffener | Polyamide 3 mil thick | 75 |
| | Total | 205 |

### 2. Using Double-sided FPC




| Material Name | Material | Thickness (µm) |
|---|---|---|
| Covering layer film | Polyamide 1 mil thick | 25 |
| Cover adhesive | | 25 |
| Surface treatment | Tin-lead plated | 5 |
| Through-hole copper | Cu | 15 |
| Copper foil | Cu 1/2oz | 18 |
| Base adhesive | Thermosetting adhesive | 18 |
| Base film | Polyamide 1 mil thick | 25 |
| Base adhesive | Thermosetting adhesive | 18 |
| Copper foil | Cu 1/2oz | 18 |
| Cover adhesive | Thermosetting adhesive | 25 |
| Covering layer film | Polyamide 1 mil thick | 25 |
| Reinforcement material adhesive | Thermosetting adhesive | 25 |
| Stiffener | Polyamide 1 mil thick | 25 |
| | Total | 199 |

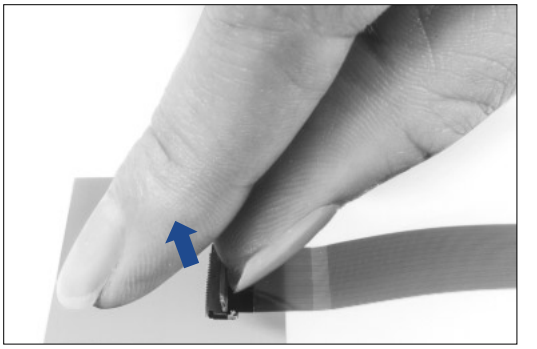
●To prevent release of the FPC due to it's bending, use of double sided FPC with copper foil on the back side is NOT RECOMMENDED.

## ◆Operation and Precautions

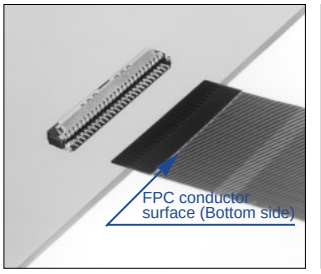
**Operation**

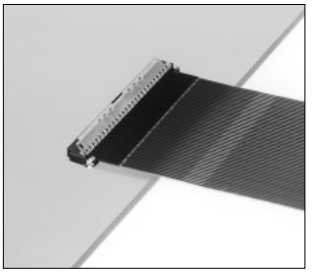
### 1.FPC insertion procedure. Connector installed on the board.

❶ Lift up the actuator. Use thumb or index finger.

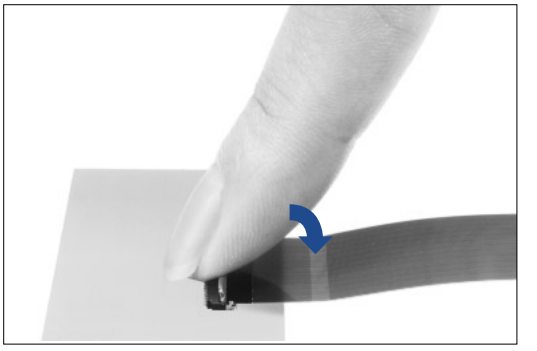


❷ Fully insert the FPC in the connector parallel to mounting surface, with the exposed conductive traces facing down.



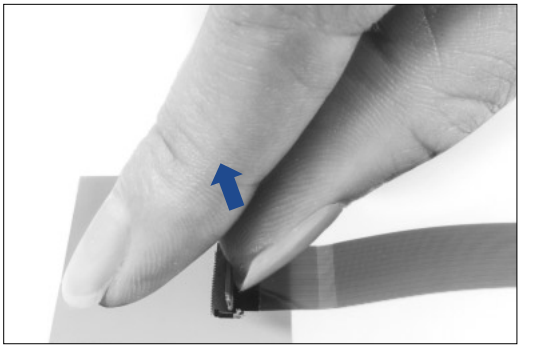



❸ Rotate down the actuator until firmly closed. It is critical that the inserted FPC is not moved and remains fully inserted.



### 2.FPC removal

❶ Lift up the actuator. Carefully withdraw the FPC.



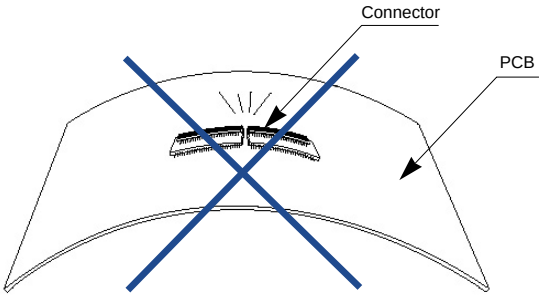
## Exercise care when handling connectors. Follow recommendations given below.

### PC board flexing

◆PC board connector mounting area
The connectors are straight within 0.1 mm max.
Make sure that the PC board connector mounting area flatness can accept the connector terminals without causing any failure of the solder joints.

◆Handling before mounting on PCB
Insertion of the FPC or operation of the actuator prior to mounting on the PCB is NOT RECOMMENDED.

◆PC Board handling
Exercise caution when handling boards with the connectors installed. Do not apply any forces affecting soldered joints.

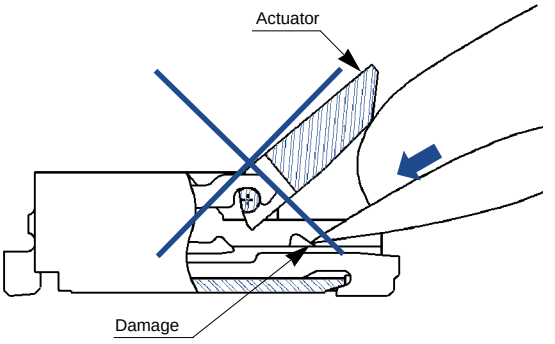


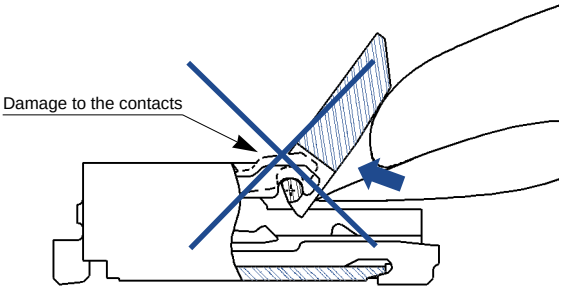

### Precautions When Inserting or Coupling FPC

**Pay attention to the following points when inserting FPC.**

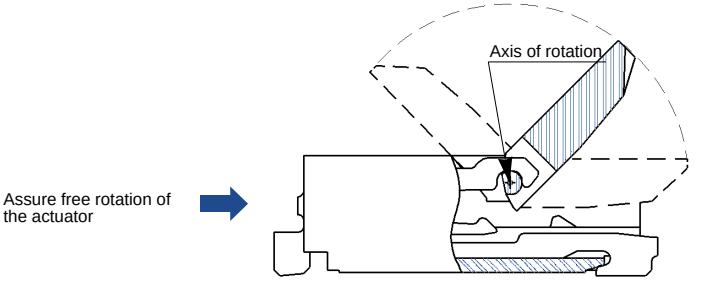
◆Actuator operation

❶Do not apply excessive force when opening the actuator prior to FPC insertion. When opening make sure that the force is applied only to the actuator itself, avoiding touching of the contacts.

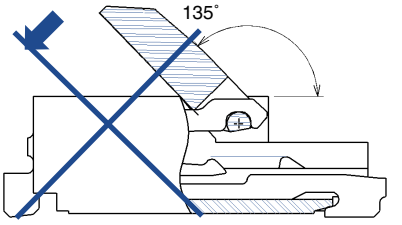


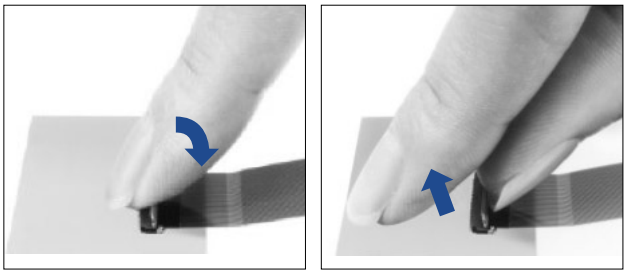

❷Axis of rotation



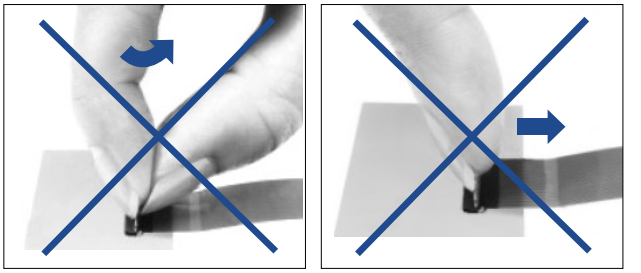
❸The actuator will rotate 135 degrees maximum. Do not apply force to rotate further.




❹When operating the actuator, do so at the center portion.

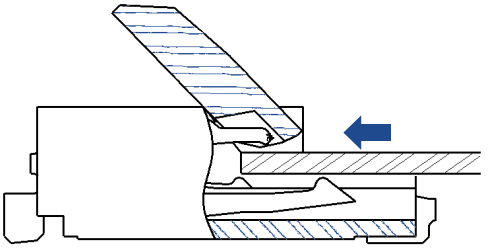


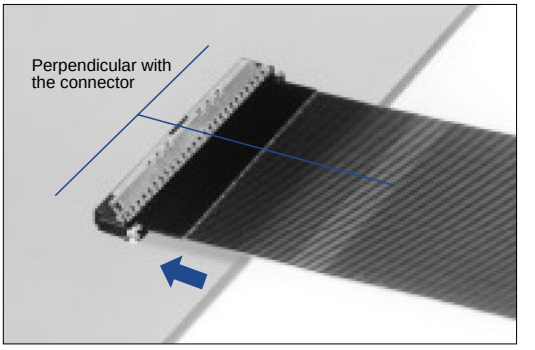
❺As illustrated, do not attempt removal or re-positioning of the actuator.



◆ FPC Insertion①

The FPC should be aligned parallel with the board surface and perpendicular with the connector (as shown), then completely inserted.



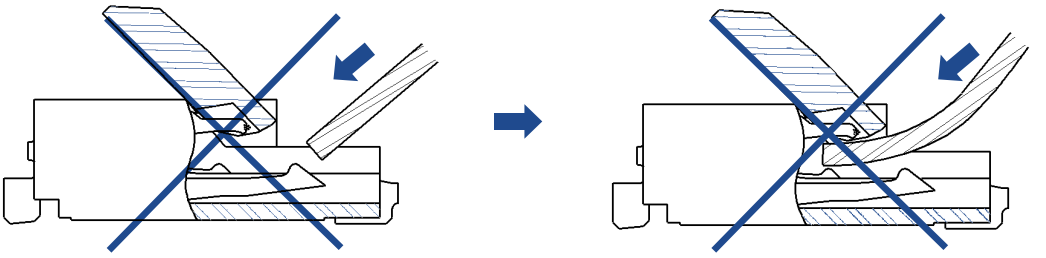



To assure correct electrical and mechanical connection do not insert FPC at angle. It must be fully inserted.

Make sure that the FPC is NOT MOVED during the closing of the actuator.

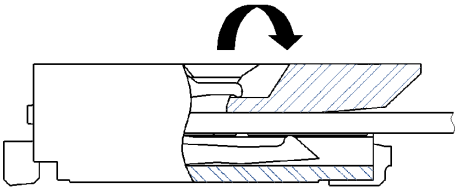
◆FPC Insertion②
Do not insert the FPC at any angle from above.

As illustrated, angle insertion may cause electrical discontinuity when the FPC is deflected in use.



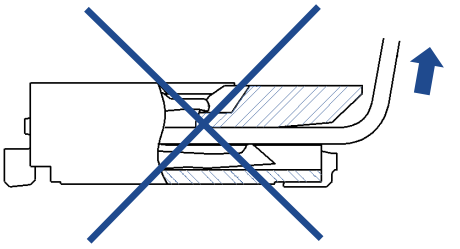
✻To avert insertion of the FPC on an angle, consideration should be given to securing FPC insertion space at the time of board layout. Insertion will be difficult when the FPC is too short.
✻Contact the FPC manufacturer for information about the bending specifications.

◆Verification of the fully closed actuator.
The actuator should be fully closed (as illustrated) and the FPC held firmly in the connector.
Do not press against the actuator when is fully closed. Max force applied to the fully closed actuator should not exceed 1 N.



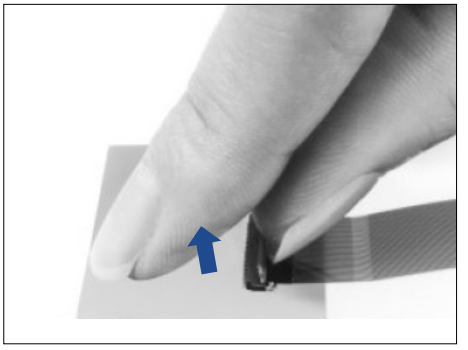
## Routing the FPC (FPC fully inserted/ actuator closed)

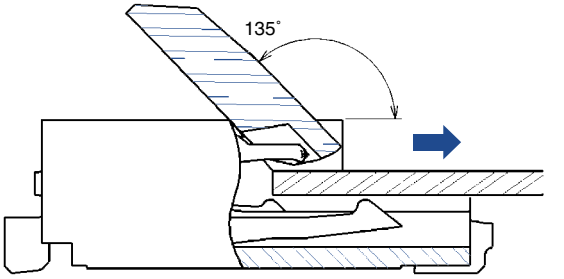
◆FPC Load
Do not apply force in excess of 0.05N/pin max. in the upward direction (as illustrated). Do not bend the FPC too close to the actuator.



## Removing the FPC

Rotate the actuator to the open position (maximum open angle of 135°). Carefully withdraw the FPC.






## Other Precautions

◆Hand Soldering Precautions

When hand soldering:

❶Do not perform reflow or hand soldering with the FPC inserted in the connector.

❷Do not apply excessive heat or touch the soldering iron anywhere other than the connector leads.

❸Do not use excessive amount of solder or flux compounds.
Operation of the actuator and contacts may be affected by excessive amounts of solder or flux compounds.

## NOTES :

## NOTES :

## NOTES :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## Description

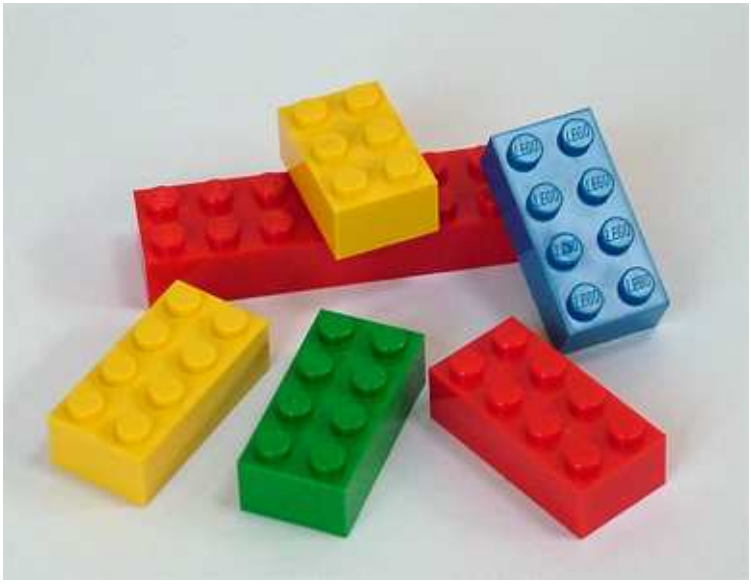
### The material

ABS (Acrylonitrile-butadiene-styrene) is tough, resilient, and easily molded. It is usually opaque, although some grades can now be transparent, and it can be given vivid colors. ABS-PVC alloys are tougher than standard ABS and, in self-extinguishing grades, are used for the casings of power tools.

### Composition (summary)

(CH2-CH-C6H4)n

### Image



### Caption

The picture says a lot: ABS allows detailed moldings, accepts color well, and is non-toxic and tough enough to survive the worst that children can do to it.

## General properties

| | | | | |
|---|---|---|---|---|
| Density | 1.01e3 | - | 1.21e3 | kg/m^3 |
| Price | 1.47 | - | 1.79 | EUR/kg |

## Mechanical properties

| | | | | |
|---|---|---|---|---|
| Young's modulus | 1.1 | - | 2.9 | GPa |
| Shear modulus | 0.319 | - | 1.03 | GPa |
| Bulk modulus | 3.8 | - | 4 | GPa |
| Poisson's ratio | 0.391 | - | 0.422 | |
| Yield strength (elastic limit) | 18.5 | - | 51 | MPa |
| Tensile strength | 27.6 | - | 55.2 | MPa |
| Compressive strength | 31 | - | 86.2 | MPa |
| Elongation | 1.5 | - | 100 | % strain |
| Hardness - Vickers | 5.6 | - | 15.3 | HV |
| Fatigue strength at 10^7 cycles | 11 | - | 22.1 | MPa |
| Fracture toughness | 1.19 | - | 4.29 | MPa.m^0.5 |
| Mechanical loss coefficient (tan delta) | 0.0138 | - | 0.0446 | |

## Thermal properties

| | | | | |
|---|---|---|---|---|
| Glass temperature | 87.9 | - | 128 | ℃ |
| Maximum service temperature | 61.9 | - | 76.9 | ℃ |
| Minimum service temperature | -123 | - | -73.2 | ℃ |
| Thermal conductor or insulator? | Good insulator | | | |

| | | | | |
|---|---|---|---|---|
| Thermal conductivity | 0.188 | - | 0.335 | W/m.℃ |
| Specific heat capacity | 1.39e3 | - | 1.92e3 | J/kg.℃ |
| Thermal expansion coefficient | 84.6 | - | 234 | µstrain/℃ |

## Electrical properties

| | | | | |
|---|---|---|---|---|
| Electrical conductor or insulator? | Good insulator | | | |
| Electrical resistivity | 3.3e21 | - | 3e22 | µohm.cm |
| Dielectric constant (relative permittivity) | 2.8 | - | 3.2 | |
| Dissipation factor (dielectric loss tangent) | 0.003 | - | 0.007 | |
| Dielectric strength (dielectric breakdown) | 13.8 | - | 21.7 | 1000000 V/m |

## Optical properties

| | | | | |
|---|---|---|---|---|
| Transparency | Opaque | | | |
| Refractive index | 1.53 | - | 1.54 | |

## Processability

| | | | | |
|---|---|---|---|---|
| Castability | 1 | - | 2 | |
| Moldability | 4 | - | 5 | |
| Machinability | 3 | - | 4 | |
| Weldability | 5 | | | |

## Durability: water and aqueous solutions

| | |
|---|---|
| Water (fresh) | Excellent |
| Water (salt) | Excellent |
| Soils, acidic (peat) | Excellent |
| Soils, alkaline (clay) | Excellent |
| Wine | Excellent |

## Durability: acids

| | |
|---|---|
| Acetic acid (10%) | Excellent |
| Acetic acid (glacial) | Unacceptable |
| Citric acid (10%) | Excellent |
| Hydrochloric acid (10%) | Excellent |
| Hydrochloric acid (36%) | Limited use |
| Hydrofluoric acid (40%) | Limited use |
| Nitric acid (10%) | Excellent |
| Nitric acid (70%) | Unacceptable |
| Phosphoric acid (10%) | Excellent |
| Phosphoric acid (85%) | Excellent |
| Sulfuric acid (10%) | Excellent |
| Sulfuric acid (70%) | Excellent |

## Durability: alkalis

| | |
|---|---|
| Sodium hydroxide (10%) | Excellent |
| Sodium hydroxide (60%) | Excellent |

## Durability: fuels, oils and solvents

| | |
|---|---|
| Amyl acetate | Unacceptable |
| Benzene | Unacceptable |
| Carbon tetrachloride | Unacceptable |
| Chloroform | Unacceptable |
| Crude oil | Excellent |
| Diesel oil | Excellent |
| Lubricating oil | Excellent |

| | |
|---|---|
| Paraffin oil (kerosene) | Excellent |
| Petrol (gasoline) | Excellent |
| Silicone fluids | Excellent |
| Toluene | Unacceptable |
| Turpentine | Unacceptable |
| Vegetable oils (general) | Excellent |
| White spirit | Excellent |

## Durability: alcohols, aldehydes, ketones

| | |
|---|---|
| Acetaldehyde | Unacceptable |
| Acetone | Unacceptable |
| Ethyl alcohol (ethanol) | Unacceptable |
| Ethylene glycol | Excellent |
| Formaldehyde (40%) | Excellent |
| Glycerol | Excellent |
| Methyl alcohol (methanol) | Unacceptable |

## Durability: halogens and gases

| | |
|---|---|
| Chlorine gas (dry) | Unacceptable |
| Fluorine (gas) | Excellent |
| O2 (oxygen gas) | Unacceptable |
| Sulfur dioxide (gas) | Unacceptable |

## Durability: built environments

| | |
|---|---|
| Industrial atmosphere | Acceptable |
| Rural atmosphere | Excellent |
| Marine atmosphere | Excellent |
| UV radiation (sunlight) | Poor |

## Durability: flammability

| | |
|---|---|
| Flammability | Highly flammable |

## Durability: thermal environments

| | |
|---|---|
| Tolerance to cryogenic temperatures | Unacceptable |
| Tolerance up to 150 C (302 F) | Acceptable |
| Tolerance up to 250 C (482 F) | Unacceptable |
| Tolerance up to 450 C (842 F) | Unacceptable |
| Tolerance up to 850 C (1562 F) | Unacceptable |
| Tolerance above 850 C (1562 F) | Unacceptable |

## Geo-economic data for principal component

| | | | | |
|---|---|---|---|---|
| Annual world production | * 5.6e6 | - | 5.7e6 | tonne/yr |
| Reserves | * 1.48e8 | - | 1.5e8 | tonne |

## Primary material production: energy, CO2 and water

| | | | | |
|---|---|---|---|---|
| Embodied energy, primary production | * 91 | - | 102 | MJ/kg |
| CO2 footprint, primary production | * 3.27 | - | 3.62 | kg/kg |
| Water usage | * 108 | - | 324 | l/kg |
| Eco-indicator 95 | 400 | | | millipoints/kg |
| Eco-indicator 99 | 352 | | | millipoints/kg |

## Material processing: energy

| | | | | |
|---|---|---|---|---|
| Polymer molding energy | * 21.8 | - | 26.2 | MJ/kg |
| Polymer extrusion energy | * 8.43 | - | 10.1 | MJ/kg |

| | | | | |
|---|---|---|---|---|
| Polymer machining energy (per unit wt removed) | * 1.99 | - | 2.19 | MJ/kg |

## Material processing: CO2 footprint

| | | | | |
|---|---|---|---|---|
| Polymer molding CO2 | * 1.74 | - | 2.1 | kg/kg |
| Polymer extrusion CO2 | * 0.675 | - | 0.808 | kg/kg |
| Polymer machining CO2 (per unit wt removed) | * 0.159 | - | 0.176 | kg/kg |

## Material recycling: energy, CO2 and recycle fraction

| | | | | |
|---|---|---|---|---|
| Recycle | ✓ | | | |
| Embodied energy, recycling | * 38 | - | 43 | MJ/kg |
| CO2 footprint, recycling | * 1.39 | - | 1.5 | kg/kg |
| Recycle fraction in current supply | 0.5 | - | 1 | % |
| Downcycle | ✓ | | | |
| Combust for energy recovery | ✓ | | | |
| Heat of combustion (net) | * 37.6 | - | 39.5 | MJ/kg |
| Combustion CO2 | * 3.06 | - | 3.22 | kg/kg |
| Landfill | ✓ | | | |
| Biodegrade | ✗ | | | |
| Toxicity rating | Non-toxic | | | |
| A renewable resource? | ✗ | | | |

**Environmental notes**

The acrylonitrile monomer is nasty stuff, almost as poisonous as cyanide. Once polymerized with styrene it becomes harmless. ABS is FDA compliant, can be recycled, and can be incinerated to recover the energy it contains.

**Recycle mark**


## Supporting information

**Design guidelines**

ABS has the highest impact resistance of all polymers. It takes color well. Integral metallics are possible (as in GE Plastics' Magix.) ABS is UV resistant for outdoor application if stabilizers are added. It is hygroscopic (may need to be oven dried before thermoforming) and can be damaged by petroleum-based machining oils. ASA (acrylic-styrene-acrylonitrile) has very high gloss; its natural color is off-white but others are available. It has good chemical and temperature resistance and high impact resistance at low temperatures. UL-approved grades are available. SAN (styrene-acrylonitrile) has the good processing attributes of polystyrene but greater strength, stiffness, toughness, and chemical and heat resistance. By adding glass fiber the rigidity can be increased dramatically. It is transparent (over 90% in the visible range but less for UV light) and has good color, depending on the amount of acrylonitrile that is added this can vary from water white to pale yellow, but without a protective coating, sunlight causes yellowing and loss of strength, slowed by UV stabilizers. All three can be extruded, compression molded or formed to sheet that is then vacuum thermo-formed. They can be joined by ultrasonic or hot-plate welding, or bonded with polyester, epoxy, isocyanate or nitrile-phenolic adhesives.

**Technical notes**

ABS is a terpolymer - one made by copolymerizing 3 monomers: acrylonitrile, butadiene and styrene. The acrylonitrile gives thermal and chemical resistance, rubber-like butadiene gives ductility and strength, the styrene gives a glossy surface, ease of machining and a lower cost. In ASA, the butadiene component (which gives poor UV resistance) is replaced by an acrylic ester. Without the addition of butyl, ABS becomes, SAN - a similar material with lower impact resistance or toughness. It is the stiffest of the thermoplastics and has excellent resistance to acids, alkalis, salts and many solvents.

### Typical uses

Safety helmets; camper tops; automotive instrument panels and other interior components; pipe fittings; home-security devices and housings for small appliances; communications equipment; business machines; plumbing hardware; automobile grilles; wheel covers; mirror housings; refrigerator liners; luggage shells; tote trays; mower shrouds; boat hulls; large components for recreational vehicles; weather seals; glass beading; refrigerator breaker strips; conduit; pipe for drain-waste-vent (DWV) systems.

### Tradenames

Claradex, Comalloy, Cycogel, Cycolac, Hanalac, Lastilac, Lupos, Lustran ABS, Magnum, Multibase, Novodur, Polyfabs, Polylac, Porene, Ronfalin, Sinkral, Terluran, Toyolac, Tufrex, Ultrastyr

## Links

Reference

ProcessUniverse

Producers

# Polyethylene (PE)

## Description

### The material

POLYETHYLENE, (-CH2-)n, first synthesized in 1933, looks like the simplest of molecules, but the number of ways in which the - CH2 - units can be linked is large. It is the first of the polyolefins, the bulk thermoplastic polymers that account for a dominant fraction of all polymer consumption. Polyethylene is inert, and extremely resistant to fresh and salt water, food, and most water-based solutions. Because of this it is widely used in household products, food containers like Tupperware and chopping boards. Polyethylene is cheap, and particularly easy to mold and fabricate. It accepts a wide range of colors, can be transparent, translucent or opaque, has a pleasant, slightly waxy feel, can be textured or metal coated, but is difficult to print on.

### Composition (summary)

(-CH2-CH2-)n

### Image


### Caption

PE is widely used for containers and packaging.

## General properties

| | | | | |
|---|---|---|---|---|
| Density | 939 | - | 960 | kg/m^3 |
| Price | 1.13 | - | 1.24 | EUR/kg |

## Mechanical properties

| | | | | |
|---|---|---|---|---|
| Young's modulus | 0.621 | - | 0.896 | GPa |
| Shear modulus | * 0.218 | - | 0.314 | GPa |
| Bulk modulus | 2.15 | - | 2.25 | GPa |
| Poisson's ratio | * 0.418 | - | 0.434 | |
| Yield strength (elastic limit) | 17.9 | - | 29 | MPa |
| Tensile strength | 20.7 | - | 44.8 | MPa |
| Compressive strength | 19.7 | - | 31.9 | MPa |
| Elongation | 200 | - | 800 | % strain |
| Hardness - Vickers | 5.4 | - | 8.7 | HV |
| Fatigue strength at 10^7 cycles | 21 | - | 23 | MPa |
| Fracture toughness | * 1.44 | - | 1.72 | MPa.m^0.5 |
| Mechanical loss coefficient (tan delta) | * 0.0446 | - | 0.0644 | |

## Thermal properties

| | | | | |
|---|---|---|---|---|
| Melting point | 125 | - | 132 | ℃ |
| Glass temperature | -25.2 | - | -15.2 | ℃ |
| Maximum service temperature | * 90 | - | 110 | ℃ |
| Minimum service temperature | * -123 | - | -73.2 | ℃ |

| | | | | | |
|---|---|---|---|---|---|
| Thermal conductor or insulator? | | Good insulator | | | |
| Thermal conductivity | | 0.403 | - | 0.435 | W/m.℃ |
| Specific heat capacity | * | 1.81e3 | - | 1.88e3 | J/kg.℃ |
| Thermal expansion coefficient | | 126 | - | 198 | µstrain/℃ |

## Electrical properties

| | | | | | |
|---|---|---|---|---|---|
| Electrical conductor or insulator? | | Good insulator | | | |
| Electrical resistivity | | 3.3e22 | - | 3e24 | µohm.cm |
| Dielectric constant (relative permittivity) | | 2.2 | - | 2.4 | |
| Dissipation factor (dielectric loss tangent) | * | 3e-4 | - | 6e-4 | |
| Dielectric strength (dielectric breakdown) | | 17.7 | - | 19.7 | 1000000 V/m |

## Optical properties

| | | | | | |
|---|---|---|---|---|---|
| Transparency | | Translucent | | | |
| Refractive index | | 1.5 | - | 1.52 | |

## Processability

| | | | | |
|---|---|---|---|---|
| Castability | 1 | - | 2 | |
| Moldability | 4 | - | 5 | |
| Machinability | 3 | - | 4 | |
| Weldability | 5 | | | |

## Durability: water and aqueous solutions

| | |
|---|---|
| Water (fresh) | Excellent |
| Water (salt) | Excellent |
| Soils, acidic (peat) | Excellent |
| Soils, alkaline (clay) | Excellent |
| Wine | Excellent |

## Durability: acids

| | |
|---|---|
| Acetic acid (10%) | Excellent |
| Acetic acid (glacial) | Excellent |
| Citric acid (10%) | Excellent |
| Hydrochloric acid (10%) | Excellent |
| Hydrochloric acid (36%) | Excellent |
| Hydrofluoric acid (40%) | Excellent |
| Nitric acid (10%) | Excellent |
| Nitric acid (70%) | Acceptable |
| Phosphoric acid (10%) | Excellent |
| Phosphoric acid (85%) | Excellent |
| Sulfuric acid (10%) | Excellent |
| Sulfuric acid (70%) | Excellent |

## Durability: alkalis

| | |
|---|---|
| Sodium hydroxide (10%) | Excellent |
| Sodium hydroxide (60%) | Excellent |

## Durability: fuels, oils and solvents

| | |
|---|---|
| Amyl acetate | Excellent |
| Benzene | Acceptable |
| Carbon tetrachloride | Acceptable |
| Chloroform | Limited use |
| Crude oil | Acceptable |
| Diesel oil | Excellent |

| | |
|---|---|
| Lubricating oil | Excellent |
| Paraffin oil (kerosene) | Excellent |
| Petrol (gasoline) | Excellent |
| Silicone fluids | Acceptable |
| Toluene | Acceptable |
| Turpentine | Excellent |
| Vegetable oils (general) | Excellent |
| White spirit | Excellent |

## Durability: alcohols, aldehydes, ketones

| | |
|---|---|
| Acetaldehyde | Excellent |
| Acetone | Acceptable |
| Ethyl alcohol (ethanol) | Excellent |
| Ethylene glycol | Excellent |
| Formaldehyde (40%) | Excellent |
| Glycerol | Excellent |
| Methyl alcohol (methanol) | Excellent |

## Durability: halogens and gases

| | |
|---|---|
| Chlorine gas (dry) | Acceptable |
| Fluorine (gas) | Limited use |
| O2 (oxygen gas) | Unacceptable |
| Sulfur dioxide (gas) | Excellent |

## Durability: built environments

| | |
|---|---|
| Industrial atmosphere | Excellent |
| Rural atmosphere | Excellent |
| Marine atmosphere | Excellent |
| UV radiation (sunlight) | Fair |

## Durability: flammability

| | |
|---|---|
| Flammability | Highly flammable |

## Durability: thermal environments

| | |
|---|---|
| Tolerance to cryogenic temperatures | Unacceptable |
| Tolerance up to 150 C (302 F) | Acceptable |
| Tolerance up to 250 C (482 F) | Unacceptable |
| Tolerance up to 450 C (842 F) | Unacceptable |
| Tolerance up to 850 C (1562 F) | Unacceptable |
| Tolerance above 850 C (1562 F) | Unacceptable |

## Geo-economic data for principal component

| | | | | |
|---|---|---|---|---|
| Annual world production | 6.8e7 | - | 6.9e7 | tonne/yr |
| Reserves | * 1.66e9 | - | 1.88e9 | tonne |

## Primary material production: energy, CO2 and water

| | | | | |
|---|---|---|---|---|
| Embodied energy, primary production | 76.9 | - | 85 | MJ/kg |
| CO2 footprint, primary production | 1.95 | - | 2.16 | kg/kg |
| Water usage | * 38.1 | - | 114 | l/kg |
| Eco-indicator 95 | 330 | | | millipoints/kg |
| Eco-indicator 99 | 287 | | | millipoints/kg |

## Material processing: energy

| | | | | |
|---|---|---|---|---|
| Polymer molding energy | * 13.4 | - | 14.8 | MJ/kg |

| | | | | |
|---|---|---|---|---|
| Polymer extrusion energy | * 5.28 | - | 5.82 | MJ/kg |
| Polymer machining energy (per unit wt removed) | * 1.98 | - | 2.18 | MJ/kg |

## Material processing: CO2 footprint

| | | | | |
|---|---|---|---|---|
| Polymer molding CO2 | * 1.07 | - | 1.18 | kg/kg |
| Polymer extrusion CO2 | * 0.422 | - | 0.465 | kg/kg |
| Polymer machining CO2 (per unit wt removed) | * 0.158 | - | 0.174 | kg/kg |

## Material recycling: energy, CO2 and recycle fraction

| | | | | |
|---|---|---|---|---|
| Recycle | ✓ | | | |
| Embodied energy, recycling | 32.3 | - | 35.7 | MJ/kg |
| CO2 footprint, recycling | 0.819 | - | 0.907 | kg/kg |
| Recycle fraction in current supply | 7.5 | - | 9.5 | % |
| Downcycle | ✓ | | | |
| Combust for energy recovery | ✓ | | | |
| Heat of combustion (net) | * 44 | - | 46.2 | MJ/kg |
| Combustion CO2 | * 3.06 | - | 3.22 | kg/kg |
| Landfill | ✓ | | | |
| Biodegrade | ✗ | | | |
| Toxicity rating | Non-toxic | | | |
| A renewable resource? | ✗ | | | |

**Environmental notes**

PE is FDA compliant - indeed it is so non-toxic that it can be embedded in the human body (heart valves, hip-joint cups, artificial artery). PE, PP and PVC are made by processes that are relatively energy-efficient, making them the least energy-intensive of commodity polymers. The ethylene from which it is made at present is an oil derivative, but PE can be produced from renewable resources - from alcohol derived from the fermentation of sugar or starch, for instance. Its utility per kilogram far exceeds that of gasoline or fuel-oil (and its energy is stored and still accessible), so that production from oil will not disadvantage it in the near future. Polyethylene is readily recyclable if it has not been coated with other materials, and - if contaminated - it can be incinerated to recover the energy it contains.

### Recycle mark


## Supporting information

**Design guidelines**

PE is commercially produced as film, sheet, rod, foam and fiber. Drawn PE fiber has exceptional mechanical stiffness and strength, exploited in geo-textile and structural uses. PE is a good electrical insulator with low dielectric loss, so suitable for containers for microwave cooking. It has poor resistance to aromatics and chlorine; it is slow burning in fire. PE is cheap, easy to form, biologically inert and recyclable; it is one of the materials of the next 20 years.

**Technical notes**

Low density polyethylene (LDPE), used for film and packaging, has branched chains which do not pack well, making it less dense than water. Medium (MDPE) and High (HDPE) density polyethylenes have longer, less branched chains, making them stiffer and stronger; they are used for containers and pipes. Modern catalysis allows side-branching to be suppressed and molecular length to be controlled precisely, permitting precise tailoring both of the processing properties critical for drawing, blow molding, injection molding or extrusion and the use-properties of softening temperature, flexibility and toughness. Linear low-density polyethylene (LLPDE) is an example. In its pure form it is less resistant to organic solvents, but even this can be overcome by converting its surface to a fluoro-polymer by exposing it to fluorine gas. Treated in this way (when it known is known as 'Super PE') it can be used for petrol tanks in cars and copes with oil, cleaning fluid, cosmetics and that most corrosive of substances: cola concentrate. Very low density polyethylene (VDLPE) is similar to EVA and plasticized PVC.

### Typical uses

Oil container, street bollards, milk bottles, toys, beer crate, food packaging, shrink wrap, squeeze tubes, disposable clothing, plastic bags, paper coatings, cable insulation, artificial joints, and as fibers - low cost ropes and packing tape reinforcement.

### Tradenames

Alathon, Aquathene, Bapolene, Dowlex, Eltex, Empee, Eraclene, Ferrene, Fortiflex, HiVal, Hid, Kemcor, Lacqtene, Lupolen, Marlex, Nortuff, Novapol, Paxon, Petrothene, Polyfort, Rigidex, Sclair, Stamylyn, Statoil, Unival, Zemid

## Links

Reference

ProcessUniverse

Producers

# Description

## The material

Silicones are high-performance, high cost materials. Silicone and fluoro-silicone elastomers have long chains of linked O-Si-O-Si- groups (replacing the -C-C-C-C- chains in carbon-based elastomers), with methyl (CH3) or fluorine (F) side chains. They have poor strength, but can be used over an exceptional range of temperature (-100 C to + 300 C), have great chemical stability, and an unusual combination of properties (Silly Putty is a silicone elastomer - it bounces when dropped but flows if simple left on the desk).

## Composition (summary)

Most common version: ( O-Si(CH3)2 )n

## Image

| | | | | |
|---|---|---|---|---|
| Eco-indicator 99 | 207 | | | millipoints/kg |

## Material processing: energy

| | | | | |
|---|---|---|---|---|
| Polymer molding energy | * 12.7 | - | 14.9 | MJ/kg |

## Material processing: CO2 footprint

| | | | | |
|---|---|---|---|---|
| Polymer molding CO2 | * 1.02 | - | 1.19 | kg/kg |

## Material recycling: energy, CO2 and recycle fraction

| | | | | |
|---|---|---|---|---|
| Recycle | ✗ | | | |
| Recycle fraction in current supply | 0.1 | | | % |
| Downcycle | ✓ | | | |
| Combust for energy recovery | ✓ | | | |
| Heat of combustion (net) | * 13.1 | - | 14.2 | MJ/kg |
| Combustion CO2 | * 1.3 | - | 1.37 | kg/kg |
| Landfill | ✓ | | | |
| Biodegrade | ✗ | | | |
| Toxicity rating | Non-toxic | | | |
| A renewable resource? | ✗ | | | |

**Environmental notes**

Silicones are energy intensive - although they are not oil-derivatives. They cannot be recycled.

## Supporting information

**Design guidelines**

Silicone resins are the most expensive thermosetting resin to use in composite materials and they are difficult to process. They feel like natural rubber, but have a completely different structure. Glass fibers and other fillers are commonly used as reinforcement. The resulting parts are relatively low in strength but have high heat resistance. For glass fiber composites, the mechanical properties are better with a phenolic or melamine resin, but the electrical properties are better with silicone. Electrical and high temperature applications dominate their use. They are chemically inert, do not absorb water and can be used in surgical or food processing equipment and seals. Silicones can be produced as fluids, adhesives, coatings, elastomers, molding resins and release agents. But each suffers from a short shelf life (3-6 months). Silicone fluids were the earliest commercial silicones, used as lubricants over a wide range of temperature (-75 C to 450 C). Silicone adhesives can be made as liquids or pastes, they can be non-curing, self-curing or heat-curing. RTV silicone was first developed for its rapid mold filling - a few seconds at high temperatures. Silicone elastomers can be air-curing, cold-curing by the addition of a catalyst or heat-curing; they may be pure or loaded with carbon black to give conductivity. Silicone molding resins are compounded with inert fillers to allow the production of flexible parts with high heat resistance. Silicones are the most chemically stable of all elastomers, with useful properties from -110 C to +310 C, good electrical properties, but relatively low strength (8MPa).

**Technical notes**

Silicone and fluoro-silicone elastomers have long chains of linked O-Si-O-Si- groups (replacing the -C-C-C-C- chains in carbon-based elastomers), with methyl (CH3) or fluorine (F) side chains. Silicones are based on the repetition of silicon and oxygen in the polymer chain; it can be used as an elastomer or a thermoset.

**Typical uses**

Wire and cable insulation, mold release agents and flexible molds, lens cleaning tissue coatings, seals, gaskets, adhesives, o-rings, insulation, encapsulation and potting of electronic circuitry, surgical and food processing equipment, baby bottle tips, breast implants.

## Links

Reference

ProcessUniverse

Producers

## Description

**The material**

Think of polyurethanes and you think of the soft, the stretchy, materials and fabrics (Lycra or Spandex). Like PVC, polyurethanes have thermoplastic, elastomeric and thermosetting grades. They are easily foamed; some 40% of all PU is made into foam by mixing it with a blowing agent. The foams can be open- or closed-cell, microcellular or filter grades. They are the strongest of elastomers.

**Composition (summary)**

(CO-NH-R-NH-CO-O-R-O)n

**Image**

## General properties

| | | | | | |
|---|---|---|---|---|---|
| Density | | 1.02e3 | - | 1.25e3 | kg/m^3 |
| Price | * | 3.6 | - | 3.95 | EUR/kg |

## Mechanical properties

| | | | | | |
|---|---|---|---|---|---|
| Young's modulus | | 0.002 | - | 0.03 | GPa |
| Shear modulus | | 7e-4 | - | 0.008 | GPa |
| Bulk modulus | | 1.5 | - | 1.6 | GPa |
| Poisson's ratio | | 0.49 | - | 0.498 | |
| Yield strength (elastic limit) | | 25 | - | 51 | MPa |
| Tensile strength | | 25 | - | 51 | MPa |
| Compressive strength | | 50 | - | 100 | MPa |
| Elongation | | 380 | - | 720 | % strain |
| Fatigue strength at 10^7 cycles | * | 18.8 | - | 38.3 | MPa |
| Fracture toughness | | 0.2 | - | 0.4 | MPa.m^0.5 |
| Mechanical loss coefficient (tan delta) | * | 0.51 | - | 1.2 | |

## Thermal properties

| | | | | | |
|---|---|---|---|---|---|
| Glass temperature | | -73.2 | - | -23.2 | ℃ |
| Maximum service temperature | | 66.9 | - | 86.9 | ℃ |
| Minimum service temperature | * | -73.2 | - | -23.2 | ℃ |
| Thermal conductor or insulator? | | Good insulator | | | |
| Thermal conductivity | | 0.28 | - | 0.3 | W/m.℃ |
| Specific heat capacity | | 1.65e3 | - | 1.7e3 | J/kg.℃ |
| Thermal expansion coefficient | | 150 | - | 165 | µstrain/℃ |

## Electrical properties

| | |
|---|---|
| Electrical conductor or insulator? | Good insulator |

| | | | | |
|---|---|---|---|---|
| Electrical resistivity | 1e18 | - | 1e22 | µohm.cm |
| Dielectric constant (relative permittivity) | 5 | - | 9 | |
| Dissipation factor (dielectric loss tangent) | 0.003 | - | 0.009 | |
| Dielectric strength (dielectric breakdown) | 16 | - | 22 | 1000000 V/m |

## Optical properties

| | |
|---|---|
| Transparency | Translucent |

## Processability

| | | | |
|---|---|---|---|
| Castability | 4 | - | 5 |
| Moldability | 4 | - | 5 |
| Machinability | 2 | - | 3 |
| Weldability | 1 | | |

## Durability: water and aqueous solutions

| | |
|---|---|
| Water (fresh) | Excellent |
| Water (salt) | Excellent |
| Soils, acidic (peat) | Unacceptable |
| Soils, alkaline (clay) | Limited use |
| Wine | Limited use |

## Durability: acids

| | |
|---|---|
| Acetic acid (10%) | Unacceptable |
| Acetic acid (glacial) | Unacceptable |
| Citric acid (10%) | Excellent |
| Hydrochloric acid (10%) | Limited use |
| Hydrochloric acid (36%) | Unacceptable |
| Hydrofluoric acid (40%) | Unacceptable |
| Nitric acid (10%) | Limited use |
| Nitric acid (70%) | Unacceptable |
| Phosphoric acid (10%) | Limited use |
| Phosphoric acid (85%) | Unacceptable |
| Sulfuric acid (10%) | Limited use |
| Sulfuric acid (70%) | Unacceptable |

## Durability: alkalis

| | |
|---|---|
| Sodium hydroxide (10%) | Limited use |
| Sodium hydroxide (60%) | Unacceptable |

## Durability: fuels, oils and solvents

| | |
|---|---|
| Amyl acetate | Unacceptable |
| Benzene | Unacceptable |
| Carbon tetrachloride | Unacceptable |
| Chloroform | Unacceptable |
| Crude oil | Limited use |
| Diesel oil | Limited use |
| Lubricating oil | Acceptable |
| Paraffin oil (kerosene) | Excellent |
| Petrol (gasoline) | Acceptable |
| Silicone fluids | Excellent |
| Toluene | Limited use |
| Turpentine | Unacceptable |
| Vegetable oils (general) | Excellent |
| White spirit | Unacceptable |

## Durability: alcohols, aldehydes, ketones

| | |
|---|---|
| Acetaldehyde | Unacceptable |
| Acetone | Unacceptable |
| Ethyl alcohol (ethanol) | Unacceptable |
| Ethylene glycol | Unacceptable |
| Formaldehyde (40%) | Unacceptable |
| Glycerol | Excellent |
| Methyl alcohol (methanol) | Unacceptable |

## Durability: halogens and gases

| | |
|---|---|
| Chlorine gas (dry) | Unacceptable |
| Fluorine (gas) | Limited use |
| O2 (oxygen gas) | Unacceptable |
| Sulfur dioxide (gas) | Excellent |

## Durability: built environments

| | |
|---|---|
| Industrial atmosphere | Excellent |
| Rural atmosphere | Excellent |
| Marine atmosphere | Excellent |
| UV radiation (sunlight) | Fair |

## Durability: flammability

| | |
|---|---|
| Flammability | Highly flammable |

## Durability: thermal environments

| | |
|---|---|
| Tolerance to cryogenic temperatures | Unacceptable |
| Tolerance up to 150 C (302 F) | Acceptable |
| Tolerance up to 250 C (482 F) | Unacceptable |
| Tolerance up to 450 C (842 F) | Unacceptable |
| Tolerance up to 850 C (1562 F) | Unacceptable |
| Tolerance above 850 C (1562 F) | Unacceptable |

## Primary material production: energy, CO2 and water

| | | | | |
|---|---|---|---|---|
| Embodied energy, primary production | * 109 | - | 120 | MJ/kg |
| CO2 footprint, primary production | * 4.47 | - | 4.94 | kg/kg |
| Water usage | * 167 | - | 502 | l/kg |
| Eco-indicator 99 | 386 | | | millipoints/kg |

## Material processing: energy

| | | | | |
|---|---|---|---|---|
| Polymer molding energy | * 15.5 | - | 18 | MJ/kg |

## Material processing: CO2 footprint

| | | | | |
|---|---|---|---|---|
| Polymer molding CO2 | * 1.24 | - | 1.44 | kg/kg |

## Material recycling: energy, CO2 and recycle fraction

| | | | | |
|---|---|---|---|---|
| Recycle | ✗ | | | |
| Recycle fraction in current supply | 0.5 | - | 1 | % |
| Downcycle | ✓ | | | |
| Combust for energy recovery | ✓ | | | |
| Heat of combustion (net) | * 21.8 | - | 22.9 | MJ/kg |
| Combustion CO2 | * 2 | - | 2.1 | kg/kg |
| Landfill | ✓ | | | |
| Biodegrade | ✗ | | | |
| Toxicity rating | | | | |

| | Non-toxic |
|---|---|
| A renewable resource? | ✗ |

**Environmental notes**

Polyurethane elastomers are thermosets, and thus cannot be recycled. Their disposal creates an environmental problem.

## Supporting information

**Design guidelines**

Urethanes have exceptional strength (up to 48 MPa) and abrasion resistance, low compression set and good fuel resistance. They have useful properties from -55 C to 90 C

**Technical notes**

Urethane elastomers (elPU) are co-polymers of diisocyanate and polyester.

**Typical uses**

Cushioning; packaging; shoe soles; tires; fuel hoses; gears; bearings; car bumpers; adhesives; fabric-coating.

## Links

Reference

ProcessUniverse

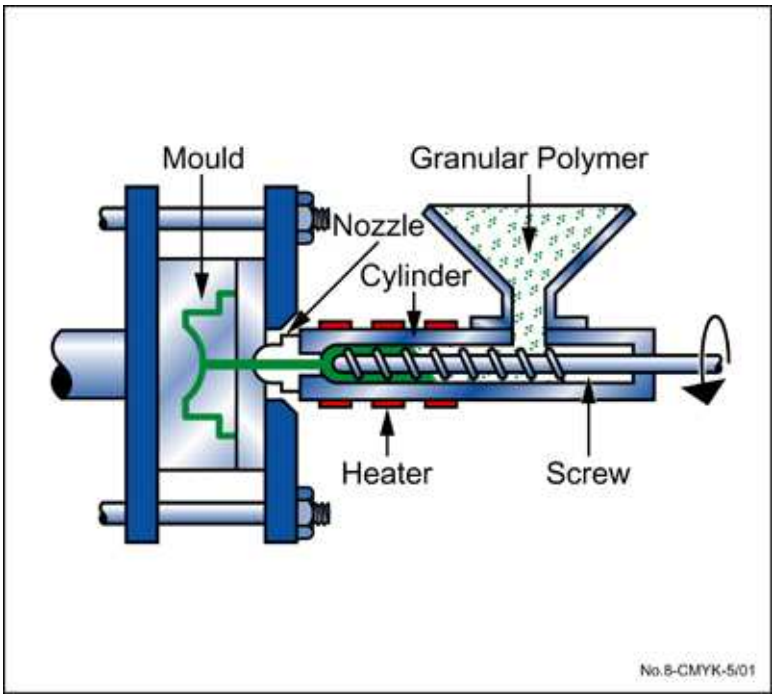
Producers

## Description

### The process

No other process has changed product design more than INJECTION MOLDING. Injection molded products appear in every sector of product design: consumer products, business, industrial, computers, communication, medical and research products, toys, cosmetic packaging and sports equipment. The most common equipment for molding thermoplastics is the reciprocating screw machine, shown schematically in the figure. Polymer granules are fed into a spiral press where they mix and soften to a dough-like consistency that can be forced through one or more channels ('sprues') into the die. The polymer solidifies under pressure and the component is then ejected. Thermoplastics, thermosets and elastomers can all be injection molded. Co-injection allows molding of components with different materials, colors and features. Injection foam molding allows economical production of large molded components by using inert gas or chemical blowing agents to make components that have a solid skin and a cellular inner structure.

### Process schematic




### Figure caption

Injection molding: polymer granules are heated and forced by the screw through a nozzle into the die.

## Shape

| | |
|---|---|
| Circular prismatic | ✓ |
| Non-circular prismatic | ✓ |
| Solid 3-D | ✓ |
| Hollow 3-D | ✓ |

## Physical attributes

| | | | | |
|---|---|---|---|---|
| Mass range | 0.001 | - | 25 | kg |
| Range of section thickness | 0.4 | - | 6.3 | mm |
| Tolerance | 0.07 | - | 1 | mm |
| Roughness | 0.2 | - | 1.6 | µm |
| Surface roughness (A=v. smooth) | A | | | |

## Process characteristics

| | |
|---|---|
| Primary shaping processes | ✓ |

| | | | | |
|---|---|---|---|---|
| Discrete | ✓ | | | |

## Economic attributes

| | | | | |
|---|---|---|---|---|
| Relative tooling cost | very high | | | |
| Relative equipment cost | high | | | |
| Labor intensity | low | | | |
| Economic batch size (units) | 1e4 | - | 1e6 | |

## Cost modeling

| | | | | |
|---|---|---|---|---|
| Relative cost index (per unit) | * 13.5 | - | 36.9 | |

Parameters: Material Cost = 7.41EUR/kg, Component Mass = 1kg, Batch Size = 1e3, Overhead Rate = 81.5EUR/hr,

| | | | | |
|---|---|---|---|---|
| Capital cost | * 2.43e4 | - | 5.47e5 | EUR |
| Material utilization fraction | * 0.6 | - | 0.9 | |
| Production rate (units) | * 60 | - | 1e3 | /hr |
| Tooling cost | * 2.43e3 | - | 2.43e4 | EUR |
| Tool life (units) | * 1e4 | - | 1e6 | |

## Supporting information

### Design guidelines

Injection molding is the best way to mass-produce small, precise, polymer components with complex shapes. The surface finish is good; texture and pattern can be easily altered in the tool, and fine detail reproduces well. Decorative labels can be molded onto the surface of the component (see In-mold Decoration). The only finishing operation is the removal of the sprue.

### Technical notes

Most thermoplastics can be injection molded, although those with high melting temperatures (e.g. PTFE) are difficult. Thermoplastic-based composites (short fiber and particulate filled) can be processed providing the filler loading is not too large. Large changes in section area are not recommended. Small re-entrant angles and complex shapes are possible, though some features (e.g. undercuts, screw threads, inserts) may result in increased tooling costs. The process may also be used with thermosets and elastomers. The most common equipment for molding thermoplastics is the reciprocating screw machine, shown schematically in the figure. Polymer granules are fed into a spiral press where they mix and soften to a dough-like consistency that can be forced through one or more channels ('sprues') into the die. The polymer solidifies under pressure and the component is then ejected.

### Typical uses

Extremely varied. Housings, containers, covers, knobs, tool handles, plumbing fittings, lenses, etc.

### The economics

Capital cost are medium to high, tooling costs are usually high - making injection molding economic only for large batch sizes. Production rate can be high particularly for small moldings. Multi-cavity molds are often used. Prototype moldings can be made using single cavity molds of cheaper materials. Typical products. Housings, containers, covers, knobs, tool handles, plumbing fittings, lenses.

### The environment

Thermoplastic sprues can be recycled. Extraction fans may be required for volatile fumes. Significant dust exposures may occur in the formulation of the resins. Thermostatic controller malfunctions can be hazardous.

## Links

Reference

MaterialUniverse

## Description

### The process

Structural adhesives are those that are used to perform some mechanical function, though they may have a secondary role as a sealant. Many are rigid, giving a stiff bond (see the record for Rigid Adhesives); but flexible adhesives also play an important role in design. They are classified by their chemical composition.

Flexible adhesives are typified by polyurethanes include and isocyanate-based adhesives, with lap shear strengths of about 8 MPa. They bond well to a wide range of materials, are tough and flexible, have good resistance to water and solvents, and perform well from -50 ℃ to 80 ℃.

Silicones (SIL) are synthetic polymers in which silicon replaces carbon as the major chain element. Most are two-part systems, their chemistry gives them exceptional flexibility and chemical stability. They are flexible, have useful properties from -115℃- 260 ℃, good resistance to water and UV and IR radiation.

### Process schematic

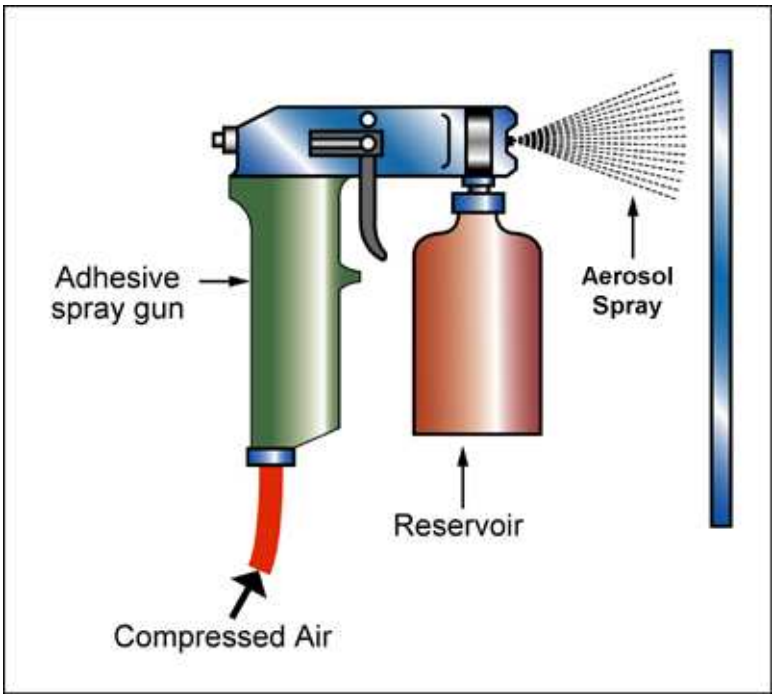



**Figure caption**

Adhesives are applied by spraying or with a dispenser

## Materials to be joined

| | |
|---|---|
| Metals | ✓ |
| Polymers | ✓ |
| Composites | ✓ |
| Glasses | ✓ |
| Ceramics | ✓ |
| Natural materials | ✓ |
| Dissimilar materials | ✓ |

## Joint geometry

| | |
|---|---|
| Lap | ✓ |
| Sleeve | ✓ |
| Scarf | ✓ |

## Physical attributes

| | | | | |
|---|---|---|---|---|
| Range of section thicknesses | 0.01 | - | 10 | mm |
| Unequal thicknesses | ✓ | | | |

## Function

| | |
|---|---|
| Electrically conductive | ✗ |
| Thermally conductive | ✗ |
| Watertight/airtight | ✓ |
| Demountable | ✓ |

## Economic attributes

| | |
|---|---|
| Relative tooling cost | low |
| Relative equipment cost | low |
| Labor intensity | low |

## Supporting information

**Typical uses**

Flexible adhesives are widely used in the aerospace, automotive, construction, furniture and footwear industries, in packaging, and in the refrigeration industry (due to their excellent properties at low temperatures).

## Links

Reference

MaterialUniverse