Navigation Devices for Mobile Phones

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Sony Ericsson

Preface

This master thesis has been performed during the autumn of 2006 at SEMC, Sony Ericsson Mobile Communications AB, in Lund and is the final part of the Master of Science Education in Mechanical Engineer/Technical Design at Lund University. The title of this master thesis is *Navigation Devices for Mobile Phones* and the objective has been to perform a pre-study on the next generation of navigation devices for mobile phones.

We would like to thank our supervisor at Lund University, Karl-Axel Andersson, Visiting Senior Lecturer – Division of Industrial Design, and our examiner, Robert Bjärnemo, Professor – Division of Machine Design, for their engagement, valuable comments and discussions regarding our work.

We would like to thank our supervisor and manager at SEMC, Ulf Liedholm, Manager – Mechanical Component section, for his engagement and support during this master thesis. We would also like to thank him for giving us the opportunity to perform this master thesis in such an interesting and front edge technology area. Then we would like to thank the employees at the Mechanical Component section for their guidance and support by answering our questions and helping us to complete this master thesis. We are also very grateful for all the help from other employees at SEMC that have contributed to our work by answering questions and giving valuable inputs.

Last but not least we would like to thank all the component manufacturers that have participated in this master thesis for sharing their information and making it possible to complete this master thesis.

Lund, December, 2006

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Abstract

Title

Navigation Devices for Mobile Phones

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Problem statement

This thesis work was initiated since there are problems with the navigation devices currently used by SEMC, Sony Ericsson Mobile Communications AB. The problems with the currently used navigation devices are lack of ability to keep dust out and they don't meet the demands from future applications like scrolling through large amounts of data, image editing and advanced web browsing.

Purpose

The purpose of this master thesis was to perform a pre-study on the next generation navigation devices for mobile phones and based on that give recommendations to SEMC of which navigation devices suitable to be used in the future.

Method

A state of the art was conducted to establish the needs, survey components among different manufacturers and existing products on the market. Initial target specifications were established based on the information from the state of the art. The components from the different manufacturers were rated and ranked according to the initial target specifications and six components were selected for further work. These six were evaluated according to technical target specifications and demo kits from the different manufacturers were used to conduct a usability study. Finally the components were evaluated using the result from the initial target specifications, technical target specifications and usability study to select two components to be recommended to SEMC. Recommendations of further work are also given.

Conclusions

The usability study showed that there is no need to select a fully analogue navigation device in front of an 8-way navigation device. The 8-way navigation is accurate enough for future applications. When comparing the results from the usability study with the result from technical evaluation it was difficult to find components that offered both good usability and a good technical construction. Some of the components performed well in the usability study but not so well in the technical evaluation, and some the other way around. It's important to understand that both aspects are important in order to have a successful product on the market. The technical area of navigation devices is constantly changing meaning that the components are continuously being developed and improved. It's therefore important to stay updated on what the market has to offer.

Key Words

Navigation device, input device, rocker key, joystick, mobile phone, cell phone, component manufacturers, usability study, analogue behaviour

Terminology

The terms and abbreviations used in this document are described below:

A/D	Analogue to Digital. An A/D converter is an electronic circuit that converts continuous signals to discrete digital numbers. (Wikipedia 2006-12-05a)
CCW	Counter Clockwise.
CDC	Creative Design Center. An organisation within SEMC.
CTO	Chief Technology Office. An organisation within SEMC.
CW	Clockwise.
DK	Demo Kit.
DU	Development Unit.
FPC	Flexible Printed Circuit. FPC is a technology for building electronic circuits by depositing electronic devices on flexible substrates such as plastic. (Wikipedia 2006-12-05b)
I/O	Input/Output. I/O is the collection of interfaces that different functional units (sub-systems) of an information processing system use to communicate with each other, or the signals (information) sent through those interfaces. (Wikipedia 2006-12-05c)
I^2C	Inter-Integrated Circuit. I^2C is a serial computer bus invented by Philips that is used to attach low-speed peripherals to a motherboard, embedded system, or cell phone. (Wikipedia 2006-12-05d)
IC	Integrated Circuit. A monolithic integrated circuit is a miniaturized electronic circuit (consisting mainly of semiconductor devices, as well as passive components) that has been manufactured in the surface of a thin substrate of semiconductor material. (Wikipedia 2006-12-05e)
LED	Light Emitting Diode.
LDO	Low Dropout. A LDO regulator is a DC linear voltage regulator which has a very small input-output differential voltage. (Wikipedia 2006-12-05f)
M2M	Machine to Machine. Data communications between machines.
Metal Dome	A small dome made of metal, is momentary switch contacts that, when used in conjunction with a printed circuit board, flex circuit, or membrane, become normally-open tactile switches. (Wikipedia 2006-12-05g)
MUX	Multiplexer. A multiplexer has multiple inputs and a selector that connects a specific input to the single output. (Wikipedia 2006-12-05h)
N/A	Not Applicable.
PCB	Printed Circuit Board.
PP	Product Planning. An organisation within SEMC.
R&D	Research and Development. An organisation within SEMC.

RF	Radio Frequency. RF refers to that portion of the electromagnetic spectrum in which electromagnetic waves can be generated by alternating current fed to an antenna. (Wikipedia 2006-12-05i)
RH	Relative Humidity.
Rocker Key	4-way switch key with a centre select.
SEMC	Sony Ericsson Mobile Communications AB.
TBI	To be Investigated.
UI	Usability and Interaction Design. An organisation within SEMC.

Table of Contents

1 Introduction

1.1 Background

A mobile phone has several buttons/keys e.g. numerical keys, side keys, camera buttons and navigation keys. SEMC, Sony Ericsson Mobile Communications AB, has mainly used the joystick, see figure 1.1, and the rocker key, see figure 1.2, as their navigation devices since they released their first phone in 2002. These technologies are used in all their phones except smart phones, e.g. W950 and P990. During the years SEMC has experienced some quality problems with their navigation devices, mainly with the joystick, because of the lack of ability to keep dust out.

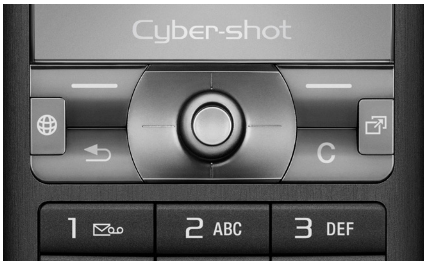


Figure 1.1: Joystick

Figure 1.2: Rocker key

As the development of mobile phones progress, with more functions and larger quantity of data to go through, the need of a navigation device with more possibilities arise. The Mechanical Component section at SEMC in Lund is the responsible section for all switches and input devices used in the mobile phones produced by DU Central, Development Unit Central. Their mission is to develop, maintain and search new opportunities for mechanical standard components and electro-mechanical components. This thesis work was initiated by Ulf Liedholm, Manager at the Mechanical Component section, to accelerate the search for new navigation devices to be used in future mobile phones.

1.2 Company Description

SEMC is a global provider of mobile multimedia devices, including phones and accessories, PC cards and M2M, machine to machine, solutions.

SEMC was established in 2001 by Telefonaktiebolaget LM Ericsson and Sony Corporation. The company is owned equally by Ericsson and Sony and announced its first joint products in March 2002.

SEMC employs approximately 5 000 employees worldwide, of which approximately 2 000 are placed in Lund. The company undertakes product research, design and development, marketing, sales, distribution and customer services. Global management is in London, and Research and Development is in Sweden, Japan, China, the US and UK. (Sony Ericsson 2006-08-28)

1.3 Objective and Constrains

The objective of this master thesis is to perform a pre-study on the next generation of navigation devices for mobile phones. This includes the following:

- Investigate state of the art
- Select the most interesting navigation devices for further work
- Build mock-ups
- Perform a usability study
- Present the result in form of a written report with recommendations to SEMC which navigation devices suitable to use in future mobile phones

The constrains in this master thesis are as follows:

- The navigation device shall be finger manoeuvred
- The navigation device is not meant to be used in smart phones but in entry, mid and high segment phones, i.e. the same segments where the joystick and rocker key is used today
- The economic aspects should not be considered
- The timeframe for this master thesis is 20 weeks

2 Methodology

This chapter describes the steps performed throughout this thesis work.

First of all are the objectives and constrains is drawn up to have a foundation for the work. Then a survey starts by making interviews, searching the web and contacting component manufacturers to gather information about state of the art. The initial target specifications are then established based on the information from the state of the art. The next step is component screening where the components are rated according to the criteria in the initial target specifications and the highest ranked components are selected for further work. When some components have been selected the preliminary design, i.e. a deeper technical survey of the selected components starts, and a technical target specifications is established. The next step is to test the components by building mock-ups of the different components and conduct a usability study. After that the components are evaluated once again using the initial target specifications, technical target specifications and the result from the usability study to get down to one or two components that can be recommended to SEMC as potential replacements for the current navigation devices. The final step is to reflect over the work, make conclusions of the result and give recommendations of further work.

To get a better view of the steps performed throughout this thesis work a figure representing the different steps is presented in figure 2.1.

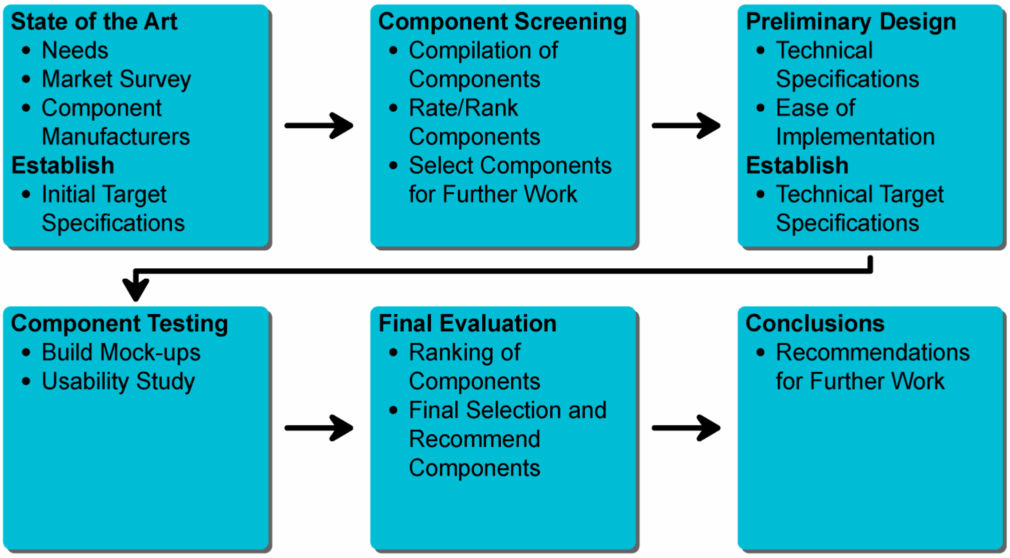


Figure 2.1: Work process steps

A time plan was established to estimate when in time the different steps should occur. The original time plan, a final revision and comments to it can be found in appendix A.

3 State of the Art

To get an apprehension of the state of the art for navigation devices a survey in three parts was conducted. The first part was to find the different needs, the second part was to find out what's available in existing products and the third part was what different component manufactures has to offer.

3.1 Needs

This is a technology push project and therefore the different needs have been collected from SEMC vision of future trends and their demands.

The technology awareness is in today's society very high, meaning that most people know about computers, internet, mobile phones, music players, digital cameras, video cameras and so on. And most important, they know how to use the technology and the benefits of it. This has created needs that didn't exist before, making people dependent on having these products with them at all times.

Today mobile phones have many features, like internet, music player, camera functions. The features in a mobile phone are not as advanced as in every separate original product, i.e. a computer, mp3-player or digital camera, but they are approaching the same level.

All these features increase the demand on the input devices since the number of functions to control increases. The problem can be solved in two ways; one is to increase the number of input devices and the other is to have multifunctional devices. It's a challenge to balance the contradictions between usability, the number of devices and the number of functions per device. One trend that limits increasing the number of input devices is that the screen on mobile phones is getting larger without any enlargement of the phone itself; if there is any size change it's reduction. This means that the space available for the input devices is reduced.

Since the navigation device is one of the most crucial input devices to get an efficient and easy to use phone the demands are high and increasing with all new features mentioned above. These features create the following demands:

- In an easy way scroll through long lists of music or pictures
- Move around on the web page and select links more easily i.e. like the mouse on a computer
- Crop and edit images

3.2 Market Survey

To find out which different types of navigation devices available in existing products a market survey focusing on competitor phones and other consumer products, with components that have a similar task as the navigation device on mobile phones, were carried out. A summary of the survey is presented in table 3.1.

Table 3.1: Market survey

	**Apple iPod Nano** The iPod Nano has a capacitive ring. Navigation through lists is made by moving the finger along the capacitive ring. There isn't any tactile feedback but instead there is a sound that can be turned on. Underneath the ring there is push buttons in four directions, up, down, left and right.
	**Apple Mighty mouse** The Apple Mighty Mouse has a scroll ball instead of a classic scroll wheel. This scroll ball offers full 360° scrolling.
	**Bang & Olufsen Serene** The Serene phone has a rotating disc in the centre of the key pad. The rotating disc can be rotated either CW, clockwise, or CCW, counter clockwise. In addition to the rotation the disc has push buttons up, down, left and right. The rotating disc is just a flat disc without any knops making it easier to rotate, and there is no tactile feedback when rotating the wheel. All this makes it hard to know if the wheel rotates or not. The quality of the disc rotation didn't live up to the known B&O quality sensation.
	**Creative Zen** The Creative Zen has a touch pad that has a 2-way scroll function. The function of the touch pad could not be tested since the test product only was a non functional display model.

cont. Table 3.1

	**LG KG 800 (Chocolate)** The touch buttons on the front of the phone are capacitive. This means that there isn't any tactile feedback when pressing a button i.e. it's hard to know if a button has been pressed or not. Sometimes there were very big problems to push the buttons on the test phone. Attempts had to be made with another finger and so on.
	**Nokia 7280** The Nokia 7280 has a mechanical wheel with a centre button as navigation device. The wheel can also be pushed down in four directions, up, down, left and right. When the wheel spin there is a feeling of small clicks giving a tactile feedback that feels good. The wheel has a rubber surface giving good friction and feeling.
	**Nokia 9300 Communicator** The Nokia Communicator has a floating button which can be freely moved in 360˚. It offers both 4-way navigation and a mouse function, which works well. The floating button only allows a movement of 0.5 mm in each direction. That doesn't sound much but can be an advantage because it doesn't need big movements while navigating through menus. But with this advantage there comes a big disadvantage; it's easy to get a disturbing flicker when changing between horizontal and vertical navigation in the 4-way navigation mode. The button itself could have a better design since it's very easy for the finger to slip of and lose contact with the button.
	**Nikon CoolPix S6** The camera has a mechanical wheel with a centre button as navigation device. The wheel can also be pushed down in four directions, up, down, left and right. When spinning the wheel there is a feeling of small clicks. This feels good but can be a problem if a long list should be scrolled trough very fast. The design of the wheel with its long and narrow knobs and concave shape makes it comfortably to spin.

cont. Table 3.1

	**Olympus m:robe MR-100** This music player has some kind of touch control. The function of the touch control could not be tested since the test product only was a non functional display model.
	**Philips HDD1420** This music player is equipped with what Philips calls Super Scroll. It's some kind of a sensory touch plate. The function of the Super Scroll could not be tested since the test product only was a non functional display model.
	**Samsung SGH-i300** This navigation device is a mechanical wheel that can be rotated CW and CCW. In addition to rotating there are push sensors up, down, left, right and centre. On the wheel there is only one knob which makes it hard to get hold of the wheel. There is no tactile feedback due to the smooth rotation of the wheel i.e. no click feel. It was strenuous for the thumb to scroll through long list due to the resolution of the sensor. A list of 7 to 15 positions is optimal for this wheel, in shorter list the wheel loose advantage over the normal arrow key.
	**Samsung SCH-S310** This mobile phone has touch buttons and a motion sensor. The motion sensor detects motion of the phone and interprets it as a number or letter. The function of the touch buttons and the motion sensor could not be tested because there was no power in the test product.
	**Sky IM 8500 (June)** This navigation device is a mechanical wheel that can be rotated CW and CCW. In addition to rotating there are push sensors up, down, left, right and centre. The wheel has small knobs in the peripheral making it easier to rotate. But the peripheral knobs make the motion path circle very big and the finger comes in contact with the other buttons on the phone when turning the wheel. The quality impression of the wheel was loose, wobbly and had no distinct click feel. A positive thing is the large amount of knops on the wheel. This means that there is always a knob to get hold of when starting rotating the wheel.

cont. Table 3.1

	**Sony PSP** The navigation key looked at was the floating button on the left hand side. The function of the button could unfortunately not be tested since the PSP was uncharged. Only the mechanical aspect of the button could be tested. The button is spring loaded so it always returns to the centre, but the springs are very hard.
	**Sony Ericsson A1404S** The navigation key is a cylinder with pushbutton function and one arrow key on each side of the cylinder. Scrolling in menus and lists is done by rolling the cylinder up/down, and confirming by pressing the whole cylinder.
	**Q-tek 8010** The navigation key is a spring loaded cylinder with three pushbuttons, centre push and side push at the ends of the cylinder. It's intuitive how to use it and long lists are easily scrolled through by tilting the cylinder up/down. The force needed for the centre and side push is very high.

3.3 Component Manufacturers

After searching the internet for information about component manufacturers, without any luck, a series of interviews were conducted with people from different departments at SEMC. The input from the interviews resulted in a list of manufacturers to contact and, most important, which person at each company appropriate to contact.

Most of the manufacturers were positive to participate in this thesis work. Meetings were arranged with many of them there they visited SEMC and held a presentation of the navigation devices in their portfolios, both existing components and the ones under development. Unfortunately some of the manufacturers chose to participate by only sending information about their components. A few manufacturers chose to not participate at all, and the information about their components is gathered from their websites.

The manufacturers that visited SEMC for a presentation of their components are:

- **Alps**
- **Avago Technologies**
- **IEE**
- **ITT Electronic Components**
- **Mitsumi**
- **Omron**
- **Panasonic**
- **Tyco**

The manufacturers that have sent information are:

- **Atmel**
- **Atrua**
- **AuthenTec (**Note: AuthenTec visited Per Holmberg, Senior Manager – Chief Technology Office, in November 2005 to give a presentation about their components)
- **SMK**

And the manufacturers where the information is gathered from their websites are:

- **Fujitsu**
- **Hosiden**
- **Idex**

A complete list of manufacturers, what components they offer and a brief description of the components can be found in appendix B.

In addition to the components from external manufacturers five internal components from SEMC have been included in this work. Information and specifications about the components have been available throughout this thesis work and used to evaluate them against the others. Unfortunately can't that information be included in this report since the components are under development and not yet patented. These internal components are referred to as Component A-E from SEMC.

3.4 Technical Principles

There are many different ways of movement detection used in sensors today. This section gives a brief explanation of different techniques used in navigation devices. What they all have in common is that they give a change in a signal, and this signal is then interpreted as some kind of action e.g. movement in one direction.

3.4.1 Capacitive Sensor

A capacitive sensor is a proximity sensor that detects non-contact and nearby objects by their effect on the electrical field created by the sensor. The electrical field is affected by the variation in capacitance between the sensor and the object, which means that the object can be both metallic and non-metallic e.g. fluids, plastic or wood. (Planet Analog 2006-09-12)

3.4.2 Hall Element

The Hall Effect is the result of the interaction between a magnetic field and an electrical current. When an electrical current is in presence of a magnetic field a force, called Lorentz Force, affects the electrical current, generating an electrical potential between the two ends of the current. The Hall Element is the sensor used to detect change in potential generated by the Hall Effect. (Wikipedia 2006-09-12a)

3.4.3 Optical Sensor

Optical sensing is a method by which information that occurs as variations in the intensity, or some other property, of light is translated into an electric signal. This is usually accomplished by the use of a photoelectric device i.e. optical sensor. (Infoplease 2006-09-19)

3.4.4 Radio Frequency Sensor

The technology used in a RF sensor, radio frequency sensor, is a low intensity radio wave which is reflected by the rugged surface of the object touching the sensor. By measuring the reflection the distance between the ridges and valleys of the rugged surface can be detected. This technology can be compared with sonar. (Atmel 2006-10-18)

3.4.5 Resistive Sensor

The resistive sensor is a film coated with a thin metallic electrically conductive and resistive layer that causes a change in the electrical current when touched. (Wikipedia 2006-09-12b)

3.4.6 Thermal Sensor

Thermal sensing is a method that measures the temperature differential between the ridges and valleys on a rugged surface. This sensor has the requirement that the surface has a thermal radiation. (Atmel 2006-10-18)

4 Initial Target Specifications

The initial target specifications are a list of overall requirements for a navigation device. The requirements are an interpretation of on one hand information and opinions gathered through interviews and meetings with people within SEMC, all with a wide range of expertise and knowledge representing different organisations e.g.

- CDC, Creative Design Center
- CTO, Chief Technology Office
- PP, Product Planning
- UI, Usability and Interaction Design
- R&D, Research and Development

and on the other hand the demands from SEMC. These requirements will be used to make the first evaluation of all the components.

The overall requirements are as follows:

Commercial property
- The navigation device should have novelty value

Usability
- Familiarity with already known navigation devices
- Easy to use for different user groups e.g. basic or advanced users
- Good semiotics

Size
- Minimal thickness and footprint without deterioration of usability

Freedom of design
- Different design solutions possible with respect to shape, material and looks

Tactile feedback
- Force perceived by the user indicating that the system has recognized an event

Analogue behaviour
- The user should perceive the motion as analogue and not digital i.e. on/off

Single hand operation
- The navigation device shall be manoeuvred with the fingers of the hand holding the phone

Future applications
- The navigation device should support future applications such as image editing, advanced web browsing and browsing through long lists

Multifunctional
- The ability to operate in different directions and ways

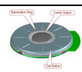
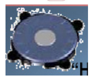
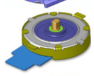
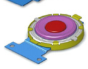
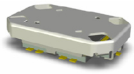
5 Component Screening

5.1 Compilation of Components

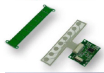
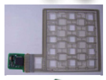
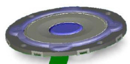
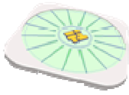
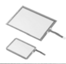
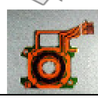
Several manufacturers have joysticks that are very similar to Panasonics Micro Stick, which is the joystick used by SEMC today. In consultation with our supervisor at SEMC the decision was made to exclude these joysticks since they would neither imply any change from today nor add any novelty value.

The remaining components found in the state of the art survey have been put together in table 5.1 to get a better overview. To further enhance the overview and to more easily compare the components a division is made into different groups based on the components mode of operation.

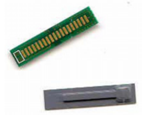
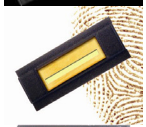
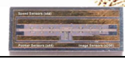
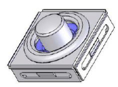
Table 5.1: Compilation of components

Type	Supplier	Name	Picture	Nr
Mechanical wheel	Avago Technologies	X-Tracker		1
	Avago Technologies	Hot Wheel		2
	SEMC	Component A	No Picture	3
	ITT Electronic Components	Analog Navigation Disc		4
	Omron	Combination Jog		5
	Panasonic	SD-Jog		6
	Tyco	Coin Key II		7
Side operated mechanical wheel	Mitsumi	Slide and Rotary Encoder Switch		8
	Panasonic	ED-Jog		9
Floating button	Alps	Analog Push Switch		10
	Alps	Slide Switch		11
	Alps	Analog Stick Type		12
	Alps	Analog Flat Type		13
	SEMC	Component B	No Picture	14
	ITT Electronic Components	Senso Nav I		15
	SMK	Wonder Pointer		16

cont. Table 5.1

Ball	ITT Electronic Components	Track Ball		17
	Panasonic	Jog Ball		18
Touch sensor	Alps	Feather Touch		19
	Alps	Touch Motion		20
	Alps	Glide Sensor		21
	Alps	TTP		22
	Atrua	VSense Touch Disc		23
	Atrua	VSense Touch Pad		24
	SEMC	Component C	No Picture	25
	IEE	FSR (Force Sensitive Resistor)		26
	ITT Electronic Components	Senso Nav II		27
	Mitsumi	MOMS (Mitsumi Optical Motion Sensor)	No Picture	28
	Omron	Touch Sensor	No Picture	29
	Panasonic	Touch Panel		30
	Panasonic	Analog Key		31
Barrel	Panasonic	FD-Jog		32
Force sensor	Atrua	VSense Analog Rocker Switch		33
	SEMC	Component D	No Picture	34
	SEMC	Component E	No Picture	35
Side switch	Alps	Lever and Push Operation Type		36
	ITT Electronic Components	Tri-direction Scan Switch		37
	ITT Electronic Components	Spring Finger Contact Switch		38
	SMK	Lever Push Switch		39

cont. Table 5.1

Fingerprint sensor	Atmel	Finger Chip		40
	Atrua	Atrua Wings		41
	AuthenTec	EntréPad		42
	Idex	Smart Finger		43
Analogue joystick	Alps	Stick Pointer		44
	Atrua	Ultra-miniature VSense Joystick		45
	Fujitsu	Ergo Track Sensor		46
	ITT Electronic Components	Ergo Nav Analog Joystick		47
	SMK	Micro Joystick Switch		48

5.2 Rate/Rank Components

The components in table 5.1 above are rated in table 5.2 according to the initial target specifications in chapter four.

A five graded marking scale from ++ to -- has been used. The existing Micro Stick is used as a reference and has the grade 0 in each criterion in the initial target specifications. The different components has been compared with the reference and graded with 0 if they are equally good as the reference, graded + or ++, depending on how much better than the reference they are or graded - or --, depending on how much worse than the reference they are.

Table 5.2: Rating and ranking of the components

Criterion / Product	Commercial property	Usability	Size	Freedom of design	Tactile feedback	Analogue behaviour	Single hand operation	Future applications	Multifunctional	Sum -	Sum 0	Sum +	Total sum	**Rank**
Micro Stick (reference)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**9**	**0**	**0**	**34**
1. X-Tracker	-	+	0	--	-	0	0	+	+	4	3	3	-1	38
2. Hot Wheel	-	+	0	+	-	0	0	+	+	2	3	4	2	30
3. Component A	-	+	+	+	-	0	0	+	+	2	2	5	3	25
4. Analog Navigation Disc	-	+	0	+	-	0	0	+	+	2	3	4	2	30
5. Combination Jog	-	+	+	+	0	0	0	+	+	1	0	5	4	24
6. SD-Jog	-	+	0	+	0	0	0	+	+	1	4	4	3	25
7. Coin Key II	-	+	-	+	0	0	0	+	+	2	3	4	2	30
8. Slide and Rotary Switch	-	-	0	--	0	0	0	-	-	6	4	0	-6	44
9. ED-Jog	-	-	0	--	0	0	0	-	-	6	4	0	-6	44
10. Analog Push Switch	+	+	--	0	0	++	0	++	+	2	3	7	5	23
11. Slide Switch	+	+	+	+	0	++	0	++	+	0	2	9	9	3
12. Analog Stick Type	+	+	-	+	0	++	0	++	+	1	2	8	7	10
13. Analog Flat Type	+	+	+	+	0	++	0	++	+	0	2	9	9	3
14. Component B	+	+	+	+	0	++	0	++	++	0	2	10	10	1
15. Senso Nav I	+	+	+	+	0	++	0	++	++	0	2	10	10	1
16. Wonder Pointer	+	+	--	--	0	++	0	++	+	4	2	7	3	25
17. Track Ball	-	-	--	--	0	+	0	+	+	6	2	3	-3	39
18. Jog Ball	-	--	-	--	-	+	0	+	+	7	1	3	-4	43
19. Feather Touch	++	0	+	++	--	++	0	++	+	2	2	10	8	6
20. Touch Motion	++	0	+	++	--	++	0	++	+	2	2	10	8	6
21. Glide Sensor	++	0	+	++	--	++	-	++	+	3	1	10	7	10
22. TTP	++	0	+	++	--	++	--	++	+	4	1	10	6	15
23. VSense Touch Disc	+	0	0	+	-	+	0	++	++	1	3	7	6	15
24. VSense Touch Pad	++	0	0	+	--	++	0	++	++	2	3	9	7	10
25. Component C	++	0	+	++	--	++	0	++	-	3	2	9	6	15
26. FSR	++	0	+	++	--	++	0	++	++	2	2	11	9	3
27. Senso Nav II	++	0	+	+	--	++	0	++	+	2	2	9	7	10
28. MOMS	++	0	--	-	--	++	0	++	+	5	2	7	2	30
29. Touch Sensor	++	0	+	++	--	++	0	++	+	2	2	10	8	6
30. Touch Panel	++	0	+	++	--	++	--	++	+	4	1	10	6	15
31. Analog Key	++	0	+	++	--	++	0	++	+	2	2	10	8	6
32. FD-Jog	--	-	--	--	0	0	0	-	-	9	3	0	-9	49
33. VSense Rocker Switch	-	0	-	0	0	+	0	-	-	4	4	1	-3	39
34. Component D	-	0	-	0	0	+	0	-	-	4	4	1	-3	39
35. Component E	++	+	0	+	0	+	0	+	+	0	3	7	7	10
36. Lever and Push Type	--	-	0	-	0	0	0	-	-	6	4	0	-6	44
37. Tri-direction Switch	--	-	0	-	0	0	0	-	-	6	4	0	-6	44
38. Spring Finger	-	0	0	0	0	0	0	-	-	3	6	0	-3	39
39. Lever Push Switch	--	-	0	-	0	0	0	-	-	6	4	0	-6	44
40. Finger Chip	++	0	+	-	--	++	0	++	++	3	2	9	6	15
41. Atrua Wings	++	0	+	-	--	++	0	++	++	3	2	9	6	15
42. EntréPad	++	0	+	-	--	++	0	++	++	3	2	9	6	15
43. Smart Finger	++	0	+	-	--	++	0	++	++	3	2	9	6	15
44. Stick Pointer	+	-	--	--	-	++	0	++	+	6	1	6	0	34
45. VSense Joystick	+	-	-	0	-	++	0	++	+	3	2	6	3	25
46. Ergo Track Sensor	+	-	--	--	-	++	0	++	+	6	1	6	0	34
47. Ergo Nav Analog Joystick	+	-	--	--	-	++	0	++	+	6	1	6	0	34
48. Micro Joystick Switch	+	-	-	0	-	++	0	++	+	3	2	6	3	25

5.3 Selected Components for Further Work

A decision was made to select six components to work further with. If these six were to be selected only based on the ranking in table 5.2 it would mean that solely components from the two groups, floating button and touch sensor, would be selected. But since different customer groups may have different needs and the component is intended to be used in entry, mid and high segment phones, and the gaps between these segments are getting larger, it may be impossible to find one component that suits all segments and customers. It was therefore decided to scatter the selection among the different groups to get the best of a variety of components.

The Component B from SEMC and the Senso Nav I from ITT Electronic Components are the two components with highest grades when considering the ranking in table 5.2. They are both from the floating button category and only one should be selected according to the scattering selection, but since the Component B is an ongoing internal project and much work already has been done the decision was made to work further with both of them.

Next on the ranking comes the FSR touch sensor from IEE. This one is the highest ranked among the touch sensors and is therefore selected. It should be mentioned that handling the touch sensor group could be a thesis itself because there are hardly any standard components. There are only standard techniques that can be modified and designed in unlimited different ways.

The Component E from SEMC in the force sensor group and the Combination Jog from Omron in the mechanical wheel group are also selected for further work as the best ranked components from their groups.

All four different fingerprint sensors have got the same ranking, and they work in the same way but uses different technologies e.g. capacitive, thermal and RF-techniques. The decision was made to select the EntréPad from AuthenTec based on the benefits of the RF technique, detecting the living tissue layer of the fingertip, and therefore being insensitive to damage of the visual fingerprint.

5.4 Reflections

Focus has been to evaluate the components against the overall requirements in the initial target specifications. This was to get a first rough evaluation that narrows the amount of components down to a more manageable level.

A risk of not detecting all the best components comes with evaluating like this. Some components may have advantages that won't show in the overall requirements and therefore will be missed in the evaluation, but it's as always a matter of considering the pros and cons. On one hand there is the fact that the best thing is of course to make complete target specifications before starting the evaluation. But on the other hand the question arise, is the large amount of time spent to do the complete evaluation at once worth it? In this project the time is crucial therefore it's better to narrow the amount of components down to have more focus on six components rather than trying to focus on all fifty-seven components.

6 Preliminary Design

This chapter gives a more detailed description of the six selected components. It explains how the components are constructed, how they work and also what their technical specifications are. The data used refers to existing or in near future available standard components offered by the manufacturers.

6.1 EntréPad, AuthenTec

Figure 6.1: EntréPad

The EntréPad, see figure 6.1, from AuthenTec is a fingerprint sensor with the ability of navigation. The technique used is that a small RF signal is generated between the sensor and the finger's living tissue layer as the finger is swept over the sensor. 1024 individual sensing elements in the slide sensor matrix form a planar antenna array that receives this signal. This creates a digital pattern that accurately reproduces the fingerprint's underlying structure. When used for fingerprint detection, images with the fingerprint pattern are matched against a database, and when used for navigation, the movement of the finger is calculated in the x- and y-plane. The sensor can also be programmed to detect a single- or double-click to get validation and selection like on a computer.

The EntréPad is a surface mounted component with a 40 ball grid array for soldering, see figure 6.2. The communication is made through either a 4-bit asynchronous parallel bus or a synchronous serial bus

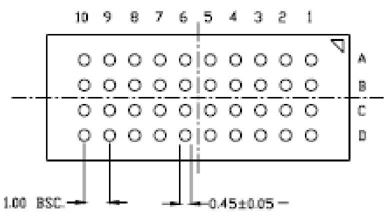


Figure 6.2: 40 ball grid array

The only change in the design of the sensor that can be made is the choice between gold, see figure 6.3, and silver, see figure 6.4.

Figure 6.3: Gold version

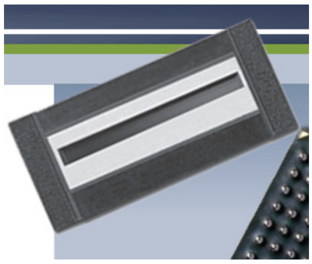


Figure 6.4: Silver version

Specifications	
Operating voltage	2.5 V – 3.0 V
Operating temperature	-20°C – +70°C
Storage temperature	-65°C – +150°C
Lifecycle	> 10 million rubs without degradation
Thickness	1.96 mm or 1.34 mm
Footprint	60 mm^2 (12x5 mm)
Sensing elements	1024 (128x8)
Resolution	500 pixels per inch
Max soldering temperature	260°C
Power consumption at 2.6 V	0.24 mA finger detect mode 4.5 mA navigation 3.3 mA idle
Supporting operating systems	Symbian, Microsoft Windows Mobile, Linux, Qualcomm REX, Custom Native Application
ESD resistance	IEC 61000-4-2 level 4 (+/- 15 kV)

6.2 Component B, SEMC

No information about Component B can be presented.

6.3 FSR (Force Sensitive Resistor), IEE

The FSR is a pressure sensitive touch sensor that measures activation, position and applied force at the same time. The structure of the sensor is two thin films with a spacer frame in between, one film with a substrate of silver tracks and one film with substrate of a printed FSR ink, see figure 6.5. A connection between the FSR ink and the silver track arise when the sensor is depressed leading to a change in signal that is measured to give the position and applied force. The connection from the sensor to the mobile phone is made by four wires, see figure 6.6.

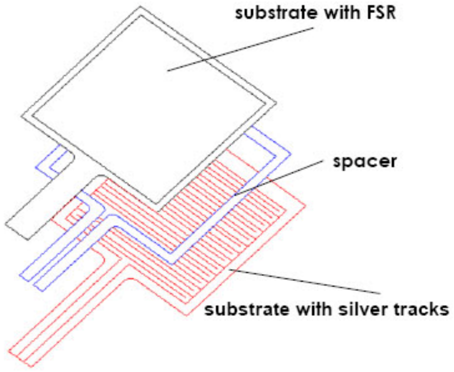


Figure 6.5: Structure of the FSR

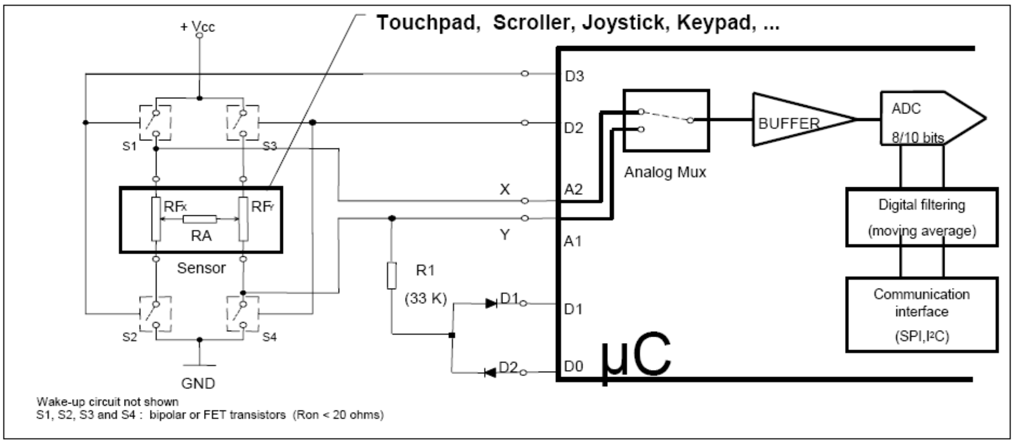


Figure 6.6: Schematics

The minimum size of the sensor is restricted to a 2 mm active sensing area with a 2 mm frame around. And the maximum size possible for a square sensor is 600x900 mm. The shape of the sensor can be customized to fit any design or function and the thickness is as low as 0.3 mm.

The sensor can be activated through the cover material by two methods: deflection or tilting of the cover. In the case there actuation is done by deflection of the cover material, the different materials are restricted in thickness for the sensor to function with typical forces used for input devices in mobile phones or similar electronics products.

Some examples on different materials, and the maximum thickness, are listed below.

- Flexible films – maximum 1 mm in thickness
- Elastomers – maximum 3 mm in thickness
- Aluminium – maximum 0.4 mm in thickness
- Stainless steel – maximum 0.3 mm in thickness

In the case there the sensor is activated by tilting there is no limitation for the cover thickness.

Specifications

Thickness	0.3 mm thick
Durability	10 million actuations
Activation force	0.3 N – 5 N (depending on cover material)
Width of active area	min 2 mm
Active area to edge of sensor	min 2 mm
Resolution	depends on electronics (8, 10 or 12 bits)
Power consumption	close to 0 in stand by

6.4 Senso Nav I, ITT Electronic Components

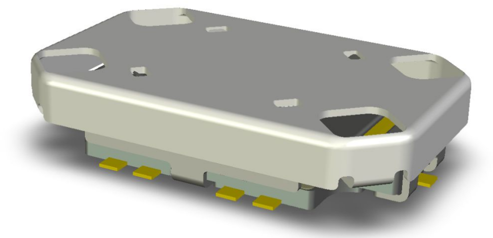


Figure 6.7: Senso Nav I

The Senso Nav I, see figure 6.7, is a new concept from ITT Electronic Components protected by several patents. The Senso Nav I have four switches in the corners of a square and one metal dome in the centre. The four corner switches are actuated with a light force, and when the force increases the metal dome is actuated.

Different functions can be achieved depending on the combination and in which order the switches are actuated by the top plate. There are nine different areas each representing a function in the sensor e.g. contact of switches A and B gives the area 1, see figure 6.8, that can be interpreted as moving upwards.

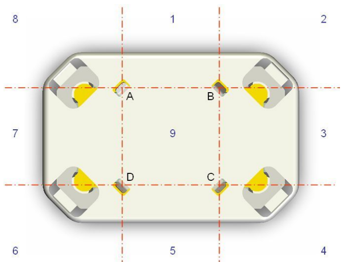


Figure 6.8: Switches and Areas

The Senso Nav I only use five standard discrete outputs, and table 6.1 shows the different combinations of these outputs to get 14 different functions.

Table 6.1: Output combinations and functions. A, B, C, D and S represents the five different switches and the X means the switch is active.

	SENSITIVE									TACTILE				
	UP	DOWN	RIGHT	LEFT	CENTER	diag UP/LE	diag UP/RI	diag DO/LE	diag DO/RI	UP	DOWN	RIGHT	LEFT	SEL
A	X			X	X	X				X			X	X
B	X		X		X		X			X		X		X
C		X	X		X				X		X	X		X
D		X		X	X			X			X		X	X
S										X	X	X	X	X

The Senso Nav I is a surface mounted component that needs to be soldered to the PCB, printed circuit board, of the mobile phone. The PCB layout needed for the soldering can be seen in figure 6.9 and how the switches correspond to that layout can be seen in figure 6.10.

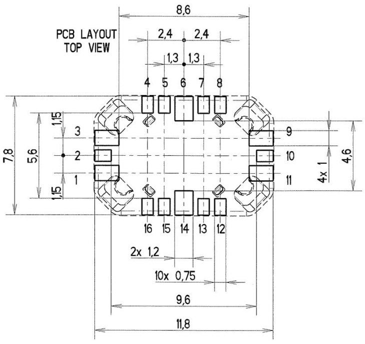


Figure 6.9: PCB Layout

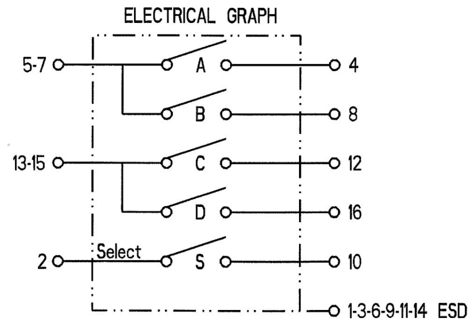


Figure 6.10: Electrical Graph

The key-top is positioned on top of the component or can be a part of the keypad silicon structure, and can be customized to fit the design of different mobile phones. ITT Electronic Components have some design rules regarding the key-top to ensure functionality. The key-top can be shaped in any way e.g. a circle, a rectangle or an oval shape, but the size of the key-top is restricted to be fitted inside a square with the size of minimum 8x8 mm and maximum 18x18 mm.

Specifications

Operating temperature	-30°C – +70°C
Storage temperature	-30°C – +85°C, 0 – 93% RH
Thickness	2.5 mm (without the key-top)
Footprint	100 mm^2 (10x10 mm) or 96 mm^2 (12x8 mm)
Click force (centre validation)	4.5 N
Click force (4-way direction)	2.5 N
Click force (jog function)	0.4 N
Stroke distance (centre validation)	0.3 mm
Stroke distance (4-way navigation)	max 1.0 mm (depending on button size)
Output resolution (for scrolling)	8 pulse/360°
Sensitive directions (for mouse)	8 directions
Environmental protection	IP 63
Durability	1 000 000 cycles in each direction
Power consumption (standby mode)	0
Max soldering temperature	260°C

6.5 Combination Jog, Omron

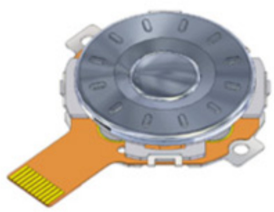


Figure 6.11: Combination Jog

Omron's Combination Jog, see figure 6.11, is constructed to be a stand alone component. This means that the component is fastened in the phone, aligned with a couple of guiding holes and electrically connected by a FPC.

The function of Combination Jog is a mechanical rotating disc for scrolling with pushbuttons underneath for centre validation and 4-way navigation. Inside the rotating disc there is a ring magnet that consists of a number of magnets. On the FPC there is two hall elements mounted to sense the rotation of the ring magnet. The hall elements are mounted so that a phase difference in their signal occurs, and by measuring which signal comes first the software can determine in which direction the disc is rotated. There is a second magnet inside the Combination Jog that interacts with the ring magnet, and this interaction gives the force for the click feel. This click feel force can easily be modified by changing the strength of the second magnet, but the resolution is determined by how many magnets the ring magnet consists of.

A dome sheet containing metal domes is placed on top of the FPC for the five push buttons and to achieve a backlight there are four LEDs, light emitting diodes, mounted on the FPC. The backlight is an optional feature and the LEDs can be removed if not needed.

How the two hall elements, the five metal domes and LEDs are connected can be seen in figure 6.12.

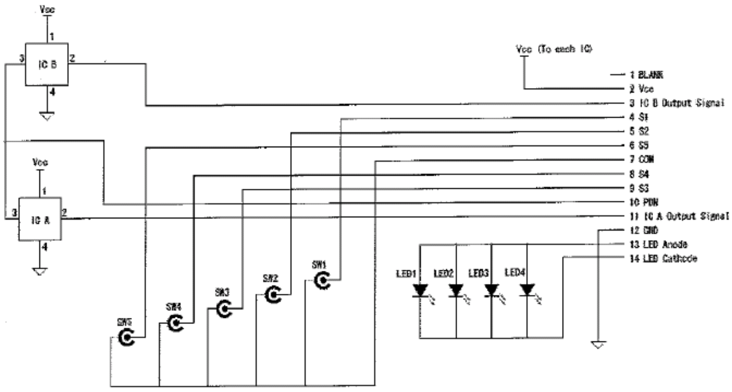


Figure 6.12: Schematics

The key-top and the centre push button, which are the two components visible for the user, can be customized to fit the design of different mobile phones.

Specifications

Operating temperature	-20°C – +60°C
Storage temperature	-40°C – +85°C
Footprint and thickness	177 mm^2 (Ø15 mm) and fairly thin
	254 mm^2 (Ø18 mm) and fairly thin
	452 mm^2 (Ø24 mm) and fairly thin
Operating voltage	2.3 V – 3.3 V
Power consumption	5 mA (max 12 mA, power down 4 µA max)
Output resolution	8 – 12 pulse/360° (depending on footprint)
Durability (rotation)	200 000 times
Durability (push)	min 300 000 times (customer customizable)
Rotation torque	1 mNm
Push force	2 N
Stroke distance	0.3 ± 0.2 mm
Contact resistance	30 Ω max

6.6 Component E, SEMC

No information about Component E can be presented.

6.7 Ease of implementation

The intention with this section is to make a initial judgment of the effort needed to implement the components in a future mass produced mobile phone. Three key areas were considered:

- **Assembly process**
  How easy is it to assemble the component in a phone? Peter Åberg, Industrialization Specialist – Mechanical Systems section, was contacted to get some inputs. He meant that if a component was well designed it was just one of all the other components and that the assembly process for a phone is adapted so that all the components can be assembled. He also said that there isn't any big difference in assembly time if the component is machine soldered or manually mounted and connected via a FPC as an example.
- **Baseband**
  What is required to electrically connect the component to the phone? Gunnar Klinghult, Senior Staff Engineer – Baseband section, was consulted in this matter.
- **Software**
  How many working weeks, 40h, would it approximately take to write drivers to the component and how many man weeks would it take to adapt existing applications? Magnus Midholt, Development Engineer – Product Software Device Drivers section, has done the estimations since our knowledge in this area is very limited.

EntréPad, AuthenTec

The EntréPad is a surface mounted component that needs to be soldered to a PCB or FPC. The signals from the EntréPad must be interpreted and processed by a micro controller. It would approximately take 20 weeks to make the driver and 40 weeks to adapt the applications. But if the EntréPad shall be used for identification and security applications measures to ensure that the sensor can't be hardwired must be made, and this will have a negative impact on the EntréPads ease of implementation.

Component B, SEMC

No information about Component B can be presented.

FSR, IEE

The FSR is connected with four wires and the sensor must rest on a planar surface. To connect the FSR to the phone four transistors, controlled by two I/Os, inputs/outputs, to alter the feeding/reading between x- and y-led, a LDO, low dropout, regulator to feed the sensor, a analogue MUX, multiplexer, to go from two signals to one, a amplifier to amplify the signal from the MUX, an I/O to control the MUX and an A/D, analogue to digital, converter to convert the signal are needed. An OR-operator, connected to the two I/Os that control the transistors, can be used to control the LDO. It would approximately take eight to ten weeks to make the driver and 60 weeks to adapt the applications.

Senso Nav I, ITT Electronic Components

The Senso Nav I need to be soldered to the PCB and needs five inputs in the keyboard matrix, just like an ordinary rocker key. The driver would take approximately four weeks and the applications 30 weeks.

Combination Jog, Omron

The Combination Jog comes with an FPC. It needs five inputs in the keyboard matrix to handle the rocker key function and two more for the hall elements. It will take two weeks to make the driver and 25 to 30 weeks to modify the applications.

Component E, SEMC

No information about Component E can be presented

7 Technical Target Specifications

SEMC has several internal requirements what a component needs to fulfil before they can be implemented in a phone. Based on these internal requirements and other relevant technical issues the technical target specifications were established. The specifications is divided into two parts, the first part with requirements that are absolute i.e. specifications that must be fulfilled, and the second part with targets i.e. requirements that aren't absolute. These specifications will be used to evaluate the six different components.

Requirements

Durability

The component shall withstand 100 000 full revolutions CW and CCW, and 400 000 push activations in each direction; without functional damage.

Operating temperature

The component shall withstand an operating temperature of -30°C – +60°C without functional damage.

Storage conditions

The component shall withstand to be stored at the temperature -40°C – +85°C, and with a relative humidity of 0 – 90%, without functional damage.

Solder temperature

The component shall withstand a solder temperature of 260°C without functional damage.

Banned substances

The component shall not contain any banned substances. (Svensson 2006)

Solar radiation

The component shall withstand solar radiation of 280 nm – 780 nm for ten days without any functional or cosmetic damage.

Targets

Power consumption

The component shall have a power consumption in standby mode that is as close to zero as possible.

Environmental protection

The component shall in usage mode withstand dust from the environment without functional damage.

Ease of implementation

The component shall be easy to implement in regards of resources needed from baseband, software and user interface programmers and the component shall be easy to integrate in the production of a mobile phone.

7.1 Rate/Rank Components

The components described in chapter six are rated in table 7.1 according to the technical target specifications. The requirements are graded yes or no depending on if the components fulfil the requirement or not. The targets are graded by a five graded marking scale from 1 to 5, where 5 is the best, based on how well they agree with the targets in the technical target specifications. The ratings from the targets are summarized and the ranking is based on that sum.

Table 7.1: Rating and ranking of the concepts.

Product / Criterion	EntréPad	Component B	FSR	Senso Nav I	Combination Jog	Component E
Requirements						
Durability	Yes	Yes	Yes	Yes	No*	Yes
Operating Temperature	No*	Yes	Yes	TBI	No*	TBI
Storage Conditions	TBI	TBI	TBI	No*	TBI	TBI
Solder Temperature	Yes	N/A	N/A	Yes	N/A	N/A
Banned or Restricted Substances	TBI	TBI	TBI	TBI	TBI	TBI
Solar Radiation	TBI	TBI	TBI	TBI	TBI	TBI
Targets						
Power Consumption	1	2	4	5	4	4
Environmental Protection	4	1	5	4	3	5
Ease of implementation	2	3	2	4	4	4
Total Sum	7	6	11	13	11	13
Rank	**5**	**6**	**3**	**1**	**3**	**1**

* The data behind these ratings are provided by the component manufacturers and are their specifications. The component manufacturers don't know SEMC internal requirements and their specifications are therefore based on their own requirements. That doesn't mean that the specifications can't be customized or adapted to SEMC internal requirements since they are close to the required values. In regards of this the decision was made to neglect the fact that they didn't meet the requirements.

7.2 Reflections

This evaluation was performed with specifications available now and it shows there the different manufacturers have weaknesses in their components. But since the components are continuously under development they probably, in most cases, can be customized or adapted in the future to better meet SEMC requirements.

8 Build Mock-ups

When the project started the intention was to build some kind of mock-ups so the components could be evaluated from the end users point of view. When the state of the art and first selection was finished an investigation was started on how these mock-ups should be edified and how the output from these should be presented. A discussion was established with people within the section of User Interface Design, at SEMC, what should be thought about if the mock-ups should be used in a usability study. The most important is that the surrounding environment of the different components is as similar as possible and that the output is presented equivalent. This because as few parameters as possible should influence the outcome of the usability test.

At this stage it was already obvious that the six components couldn't be built-in in a real phone since this has been done in an earlier project within SEMC and took several months with just one component.

The intention was to create six boxes with the outer shape similar to a phone and place each and one of the components in the boxes. Then the device should be connected to a computer via the USB port and software should be written. In an earlier thesis work at SEMC two students conducted a usability test regarding the navigation device on several existing mobile phones. (Berg-Ljunggren 2006) They used two small java programs, jMaze and jNav, to evaluate the different devices. If this software could be reused the six devices in this project could be compared with the devices they tested.

To investigate if this was possible and if any help could be offered within SEMC several persons were contacted; Gunnar Klinghult, Senior Staff Engineer – Baseband section, Magnus Midholt, Development Engineer – Product Software Device Drivers section, Torgny Heimler, Usability Specialist – Usability and Interaction Design section, Carl Tönsgård, Consultant – Usability and Interaction Design section, Stefan Olsson, Manager – Software Prototype section, Thomas Rosdahl, Systems Analyst – Industri-Matematik International. The outcome of these contacts was that there is no knowledge within SEMC in Lund how to write software and drivers in Windows environment and that it was necessary to use micro processors to take care of the signals from the devices before they were sent to the computer. These micro processors also needed to be programmed and due to lack of resources no help could be given. It was estimated that all this, excluding the build time of the boxes, would take approximately 15 weeks. This was considered as unrealistic since the time frame for the whole thesis work was 20 weeks.

Since there was not enough time for making the software other solutions were discussed. One solution was to use a matrix of LEDs as interface instead of a computer. Gunnar Klinghult was consulted again as well as Magnus Birch, Consultant – Baseband section, and the outcome was that this solution needed at least the same amount of time as the solution with a computer.

The next solution was to try to get hold of demo kits from the suppliers like those some of them had shown during their visits at SEMC. The concerned suppliers were contacted and asked if they could assist with the demo kits. The demo kits from AuthenTec, ITT and Omron were delivered without any problems. Regarding the demo kit from IEE they told that their FSR had been used in the Ophira project, a phone project within SEMC. A computer connected prototype combining an ordinary rocker key with the FSR should exist within SEMC. Several persons where contacted to find this prototype with no success. After some weeks of searching IEE was contacted and asked if they could manufacture a new prototype. To manufacture a new prototype would take several weeks. Since they were unable to deliver a new prototype within the timeframe for this thesis work they offered another simpler demo kit instead that they call Joystick. The joystick is a standard component based on the FSR. The demo kits for Component B and E already existed at SEMC.

When a demo kit was requested from Omron they asked which diameter of the component that was preferable. A decision to use the component with Ø15 mm was made because of the earlier mentioned lack of space in a phone. It should also be interesting to see how it performed in the usability test.

8.1 Demo Kits

In this part each demo kit is presented in table 8.1. The available functions for each demo kit will also be presented. Note: some demo kits offers fewer functions than the component itself.

Table 8.1: The demo kits and their functions

<table>
<tr><th colspan="2">EntréPad, AuthenTec</th></tr>
<tr><td>
</td><td>This demo kit uses software that controls the mouse pointer or gives the same signals as the arrow keys on the keyboard. The following functions are available:
• 4-way navigation
• 8-way navigation
• Centre select
• Scrolling
• Mouse</td></tr>
</table>

cont. Table 8.1

<table>
<tr><th colspan="2">Component B, SEMC</th></tr>
<tr><td>No Picture</td><td>The component uses a mouse driver to present the following functions:
• 4-way navigation
• 8-way navigation
• Centre select
• Scrolling
• Joystick
• Mouse
• Mouse + Joystick</td></tr>
<tr><th colspan="2">Joystick, IEE</th></tr>
<tr><td></td><td>This demo kit uses a software that controls the mouse pointer and this functions are available:
• Joystick
• Centre select</td></tr>
<tr><th colspan="2">Senso Nav I, ITT Electronic Components</th></tr>
<tr><td></td><td>The Senso Nav I uses its own software and the following functions are available:
• 4-way navigation
• Centre select
• Scrolling
• Scrolling + 2-way navigation
• Scrolling + 4-way navigation
• 8-way joystick</td></tr>
<tr><th colspan="2">Combination Jog, Omron</th></tr>
<tr><td></td><td>In difference with the other demo kits this device isn't connected to a computer. The output is presented with LEDs and the following functions are available:
• 4-way navigation
• Centre select
• Scrolling</td></tr>
<tr><th colspan="2">Component E, SEMC</th></tr>
<tr><td>No Picture</td><td>This component is connected to the computer and uses it's own software to present the different functions which are:
• 4-way navigation
• Centre select
• Force sensitive scrolling</td></tr>
</table>

9 Usability Study

9.1 Introduction

9.1.1 Statement of the Problem

The navigation device is one of the most crucial input devices in a mobile phone and its usability affects the experience of the entire phone.

When developing new products one must consider how the usability is experienced by the end users. The usability study is therefore an important part of the development process to get an early input from the end users. This enhances the possibility of developing a successful product.

9.1.2 Purpose

The purpose of this study was to find out how well the different navigation devices perform in menu navigation, list scrolling and analogue navigation. The purpose was also to find out how the different navigation devices were experienced by the end user and to be provided with an understanding and foundation about the usability aspects for the final selection

9.2 Study Questions

The questions for this study were:

- How well does the different navigation devices function in menu navigation mode?
- Is ease of use in list scrolling different for the different navigation devices, and if so, which navigation device is measured as the best?
- How do the end users manage the analogue behaviour in navigation?

9.3 Background

Usability refers to the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of user. (ISO DIS 9241-11 1994) During usability testing, the aim is to observe how people use a product in an as realistic situation as possible. This is to discover errors and areas of improvement for the development project to work with to improve the product and enhance the chances of developing a successful product.

9.4 Methodology

A literature study to gather information about usability studies and how they are conducted were carried out and that involved reading *A Practical Guide to Usability Testing* (Dumas-Redish 2000) and *Handbook of Usability Testing: How to Plan, Design and Conduct Effective Tests* (Rubin 1994). This usability study is based on that literature study and discussions with Andreas Espinoza and Sally White, both Hardware Usability Specialists at the Usability and Interaction Design section.

The test participants for this usability study were recruited both internally at SEMC and externally at Lund University. The decision to make recruitment like that came from lack of time and the need to find participants that were easily contacted and available with short notice during working hours. The recruitment was scattered among ages to get input from different user groups. They were all considered as inexperienced users i.e. they had never used or tested any of these components before, and were therefore selected without any regards to their mobile phone experience.

A test monitor supervised the usability test and was always present in the test room, with the test participant. The test monitors role was to welcome the participant, brief him/her about the study, hand over the different tasks and questionnaires and offer guidance and help if so needed. An observer was also present in the room, making notes of the performance, writing down comments during the tasks and measuring the time to complete the different tasks. The observer was positioned away from the test participant and test monitor and had no active part in the test.

Two pilot tests were conducted before the actual test. This was to get information and experience about what to improve in the test, all to optimize the test and get the most out of it.

The usability study was conducted as follows:
The participant arrived to the test room. He/She were briefed on the purpose of the study and asked to read and sign a Usability Test Agreement, see appendix C. Then he/she were asked to answer a background questionnaire, see appendix D. Then the first part of the test, the explorative test, started and after the explorative test was finished the participant was asked to answer a test questionnaire, see appendix E. Then the participant moved on to the assessment test where different tasks were conducted and after every task the participant were asked to answer a test questionnaire, see appendix F-H. After the assessment test a concluding discussion, see appendix I, took place to get additional information about how the participant experienced the different navigation devices.

The test participants were asked to read the Usability Test Agreement to understand the terms and conditions of their participation in the test. The background questionnaire was answered in order to have information about the test participant's background to correlate possible differences in the result against differences in background. The different test questionnaires were answered to be used for the subjective part of the result.

9.5 Test Equipment

9.5.1 Test Environment

The test took place in the user experience room at SEMC, and in the room there were two tables put together as one. At one end of the table there were two chairs, one for the test participant and one for the test monitor and at the other end of the table there was a chair for an observer. On the table there were a laptop and some writing material for the test participant, and an extra display and two stopwatches for the observer.

9.5.2 Demo kits

The study tested the six different navigation devices selected in the first evaluation, see table 9.1. The navigation devices used were demo kits borrowed from the different component manufacturers and connected to either the computer or an array of LEDs according to chapter eight. The index numbers of the different demo kits were randomly selected to avoid any favouring.

Table 9.1: The six different navigation devices

DK 1, Combination Jog (Omron) 	DK 2, Component E (SEMC) No Picture
DK 3, Senso Nav I (ITT Electronic Components) 	DK 4, Joystick (IEE) 
DK 5, Component B (SEMC) No Picture	DK 6, EntréPad (AuthenTec) 

9.6 Test Plan

9.6.1 Participants and Test chart

Usability studies conducted with 4-5 participants discovers 80% of the eventual usability problems. (Rubin 1994) This study used 12 test participants to test two demo kits each i.e. each demo kit was tested by four different test participants. Which test participant testing which two demo kits was randomly selected and is presented in table 9.2.

The twelve participants needed for this study was divided into two groups both randomly selected. The first group, test participant 1 to 6, consisting of participants recruited from employees at SEMC and the second group, test participant 7 to 12, consisting of participants recruited outside SEMC.

Table 9.2: Test Chart

	DK 1	DK 2	DK 3	DK 4	DK 5	DK 6
Test Participant 1			X			X
Test Participant 2				X		X
Test Participant 3	X			X		
Test Participant 4	X	X				
Test Participant 5		X			X	
Test Participant 6			X		X	
Test Participant 7			X	X		
Test Participant 8	X					X
Test Participant 9		X		X		
Test Participant 10	X				X	
Test Participant 11		X	X			
Test Participant 12					X	X

9.6.2 Explorative Test

The explorative test was a test there the test participant was allowed to get acquainted with the demo kit in three different steps.

- In the first step the test participant was only allowed to look at the navigation device and then asked to, from a list of functions, select which functions they believed the navigation device possesses. The test participant had 30 seconds to complete the entire step.
- In the next step the test participant were allowed to touch and feel the demo kit and they were given a chance to alter their selection of functions. The test participant had 60 seconds to complete the entire step.
- In the last step the demo kit was connected to the computer/LEDs and the software started. The test participant was asked to perform some small tasks with guidance to get familiar with how the demo kit works.

9.6.3 Assessment Test

Three different tasks was conducted to get a comparison and evaluation of the different demo kits, but not all the demo kits were able to be tested in every task. Which task that's applicable to which demo kit is presented in table 9.3.

Table 9.3: Task vs. demo kit

	DK 1	DK 2	DK 3	DK 4	DK 5	DK 6
Task 1, Menu Navigation	X	X	X	N/A	X	X
Task 2, List Scrolling	X	X	X	N/A	X	X
Task 3, Analogue Behaviour	N/A	N/A	X	X	X	X

Task 1 – Menu Navigation

In this task the test participant should move around in an imagined menu, according to a pre-determined sequence. The time to complete the task was measured and the number of errors was counted. The task was performed five times with different sequences, see table 9.4, to get an average of the performance.

The test participant was handed the different sequences in writing and asked to follow them without looking at the computer screen or indicators. The observer followed the movement on the screen or the indicators and recorded any errors.

Table 9.4: The five sequences for menu navigation

	1	2	3	4	5
Sequence	2 Down 1 Right 1 Up 1 Right 2 Down 2 Left 3 Up 2 Right 1 Down 1 Left 2 Down 1 Left	2 Right 1 Down 1 Left 2 Down 1 Right 2 Up 2 Left 1 Up 2 Down 1 Right 1 Down 1 Left	1 Down 2 Right 2 Down 2 Left 2 Up 1 Right 2 Down 1 Right 2 Up 1 Left 1 Up 1 Left	1 Right 2 Down 1 Left 2 Right 1 Up 2 Left 2 Down 1 Right 1 Up 1 Left 2 Up 2 Right	2 Down 1 Right 2 Up 1 Down 1 Left 2 Down 2 Right 1 Up 1 Left 2 Up 1 Right 2 Down

Task acceptance:

Time to complete task: 15 sec
Maximum number of errors: 1

Task 2 – List Scrolling

In this task the test participants were asked to scroll to three different positions in a list or picture. The time to complete the task was measured and the number of errors was counted, and by errors meaning number of times they were not able to stop at the specific position. The task was performed five times with different positions to get an average of the performance.

The five different sets of positions, for the demo kits able to move in a list of names, are viewed in table 9.5. For one demo kit these positions were converted into number of turns in a ring of LEDs, see table 9.6, and for another demo kit the positions were converted into pictures inside a big picture, see table 9.7.

Table 9.5: The five set of positions in lists of names

	1	**2**	**3**	**4**	**5**
Position	Name 55 Name 10 Name 42	Name 28 Name 56 Name 14	Name 12 Name 40 Name 57	Name 50 Name 41 Name 19	Name 39 Name 8 Name 27

Table 9.6: The positions converted into number of turns

	1	**2**	**3**	**4**	**5**
Position	2 turns CW 4 turns CCW 3 turns CW	2 turns CW 3 turns CW 4 turns CCW	1 turn CW 2 turns CW 2 turns CW	4 turns CW 1 turn CCW 2 turns CCW	3 turns CW 2 turns CCW 1 turn CW

Table 9.7: The positions converted into pictures

	1	**2**	**3**	**4**	**5**
Position	Down to Motorcycle 	Down to House 	Down to Glasses 	Down to Baseball 	Down to Room 
	Up to Technology 	Down to Motorcycle 	Down to Room 	Down to Room 	Up to Wired Mag 
	Down to Fish 	Up to Fridge 	Down to Motorcycle 	Up to Mexico Map 	Down to House 

Task acceptance:
Time to complete task: 20 sec
Maximum number of errors: 2

Task 3 – Analogue Behaviour

A map with a path marked with a red line and three circles numbered 1, 2 and 3 were used for this task, see figure 9.1.

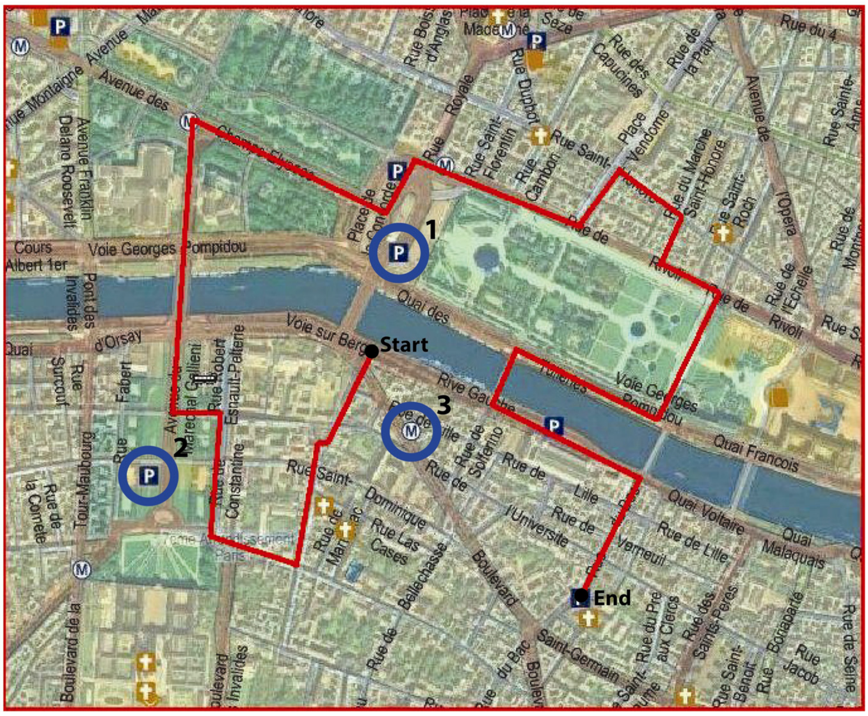


Figure 9.1: Map with path and markings

In the first part the test participant were asked to follow the path marked with a red line on the map, the time to complete the path and the time beside the red line was measured. The task was performed five times, see table 9.8, with the starting point alternating between start and end, to get an average of the performance.

In the second part the test participant was asked to, in a pre-determined sequence, go to the three different circles. The time to complete the task was measured. The task was performed five times, see table 9.8, in different sequences, to get an average of the performance.

Table 9.8: The five sequences for analogue behaviour

	1	2	3	4	5
Sequence	Start – End Circle 1 Circle 2 Circle 3	End – Start Circle 2 Circle 1 Circle 3	Start – End Circle 2 Circle 3 Circle 1	End – Start Circle 3 Circle 2 Circle 1	Start – End Circle 3 Circle 1 Circle 2

Task acceptance:

Time to complete following the red line: 50 sec
Error percentage following the red line: 10%
Time to complete moving between three circles: 10 sec

9.7 Results

In this part the outcome of the questionnaires and the measured data will be evaluated. This will be done in two steps; first general observations will be presented and after that each device will be discussed. A compilation of the gathered data from the questionnaires and the performances are available in appendix J.

To better interpret the rankings in this section a reminder with the number of demo kits tested in each task is listed below:

- Menu navigation – five demo kits
- List scrolling – five demo kits
- Analogue behaviour – four demo kits

9.7.1 General Observations

During the usability test some general observations was made. In the explorative test several test participants took it for granted that the navigation device offered centre push and 4-way navigation i.e. up, down, right and left. The analogue devices can’t compete with the digital devices when it comes to navigation in a menu with fixed positions i.e. like the menus used in SEMC phones today. A common experience for most of the analogue devices is the lack of feedback and the test participants request that, preferably tactile. Some of the test participants thought that it wasn’t intuitive to move their finger in a circle when scrolling up and down in a list. None of the devices that offer analogue behaviour is ready to be used in tasks like following the red line on the map, they are not accurate enough. A participant’s way of handling a device sometimes changed during the test. At the end of the test they performed more efficient regarding finger movement. In the beginning they have a tendency to push along the outer edge of the device instead of letting their finger rest in the middle of it. On some of the navigation devices there were no function to the centre select button, but if there were they would have performed much worse since the test participants often depressed the centre select unintentionally.

The differences in test results were compared with the differences in background of the test participants and no obvious correlations could be found.

9.7.2 DK1 – Combination Jog, Omron

All the participants thought that it was pretty obvious that this device offered a scroll function. There weren’t any complaints about the size of the component being too small during the test. Three out of four participants could see themselves using the device in a mobile phone.

Menu navigation

Some of the test participants thought that it was hard to know where the four cardinal points are on the device. One of the participants had problems to orientate the thumb without looking at the device. One of the explanations to this could be that the scroll wheel sometimes rotated during the navigation.

The results from the questionnaires show that this device had fairly high points on all questions. It had the highest score on the question regarding how easy it was to complete the task. The average point puts the device in third place in this task.

The measurements made during the test shows that this device is the most efficient one both in terms of error rate and time. Three of the participants didn't make any errors at all.

List scrolling

As mentioned above some of the test participants didn't think that it was intuitive to move their finger in a circle when scrolling up and down in a list. During the test the observation was made that the device sometimes gave a reading in the CCW direction even though the wheel wasn't moved one step. According to Omron the component that was used in the test was handmade and this fault won't exist in a mass produced component.

This device got very good scores on the questionnaires. It was ranked to be the best regarding several questions; how easy it was to complete the task, if it was easy to stop at the right position, if they efficiently could solve the task with the device, if they got the expected response and if they felt confident using it. This device also got the highest average value.

The test participants also performed very well with this device. There is no other device that is close to compete with it, neither with the error rate nor with the time needed to complete the task.

One thing that could have influenced both the outcome of the questionnaires and the measured data in a favourable way for the device is how the output from it was presented. The output was presented with twelve LEDs mounted in a circle. Instead of scrolling to different posts in a list the participants were asked to rotate so many whole laps, along the circle, that approximately accorded to the number of posts that were passed with the other devices.

9.7.3 DK2 – Component E, SEMC

During the explorative test three out of four participants thought that this device reminded of a rocker key while looking at it. Since it offers the same basic functions as a common rocker key this is a good thing. The end users will know how to use it directly based on earlier knowledge. It's was not obvious to the users that it was force sensitive. All the participants could see themselves using the device in a mobile phone.

Menu navigation

Three of the participants thought that this device was very easy and precise to use. The fourth user was worried about pressing the centre select button during the task and had problem to orientate the thumb without looking at the device.

The Component E got the highest average on the questionnaires. It had the highest score on the questions regarding how efficiently the participants felt they could solve the task and how confident they felt using the device.

The results from the measured data show that the Component E had the second fastest average time. It had the third error rate but it should be mentioned that three of the participants didn't make any errors. The participant that did make the errors often clicked twice in a direction when he was asked to click ones. The error wasn't specific for this device since he had the same problem with the other device he tested.

List scrolling

The results from this task are very hard to compare with the results from the other devices because of the software. The participants were asked to scroll through a document with images and text and they got the different images they should go to on a paper and in which direction they were placed in relation to the previous image. This makes it hard because there is neither any indication how far down or up in the list the image is placed nor any help from fixed positions as in a list. The participants also had problems to see the images while scrolling and often went past the image before they recognized it. This affects both the results from the questionnaires and the measured data. The questionnaires are affected since it might feel ineffective to use the device because of the reasons mentioned above. The measured data are affected since it's impossible to have the same pace as when exactly knowing where to go and it's easy to miss the image.

Some of the participants thought that it took some time to get used to the force sensitiveness and some thought that it was too sensitive.

After all, the average value from the questionnaire is the second best and this is the device that causes least strain.

The measured data shows the big disadvantages with the software. The Component E has the longest time to complete the task of all devices. A surprise is that it has the second best error rate tested, in spite of the fact that the participants had problems to see the images.

9.7.4 DK 3 – Senso Nav I, ITT Electronic Components

The test participants had difficulty understanding that this component offered functions just by tilting the button without collapsing the metal dome. Even if they were told how the device worked they unintentionally collapsed it pretty often. If the device would be implemented in a phone and someone would test a switched off phone or a non functional display model, like those that are available in stores, it's a risk that it feels wobbly and gives a poor quality impression. Only one out of four participants would like to use the device in a real phone.

Menu navigation

The participants thought that it was good that the device offer tactile feedback in the menu navigation.

The device got the second best average value on the questionnaires regarding this task and was the device that the participants felt that they needed to look least at during the task.

The measured data shows a third place regarding the time to complete the task and fourth place regarding the error rate. Three participants made errors and one of them is the participant that sometimes clicked twice instead of once.

List scrolling
Just like the Combination Jog this device offers a circular thumb movement to move up and down in a list. This wasn't appreciated by some of the participants, as mentioned in part 9.7.1, since they thought it wasn't intuitive. With this device all participants had problem with that the device didn't give output signal some part of the lap and that they unintentionally collapsed the metal dome. The cause of this is probably that the contact surface of the thumb changes when it's moved in a circular path. They also had big problems with the exact navigation when they were close to the right position. The edge ridge on the key-top wasn't appreciated since the participants thought that it was to sharp. Maybe it's better to use a two way navigation like the one used today by just pressing up and down. If so the key-top could be designed totally differentially.

The questionnaires show that this is the device that causes most strain and it reaches the fourth place regarding the average value.

This device had the fourth best average time to complete the task and the third error rate.

Analogue behaviour
The participants also in this task had big problems with accidentally collapsing the metal dome. The device is only semi analogue and offers movement in eight directions. So when the red line on the map wasn't aligned with these eight directions the participants had big problems to follow the line. But the eight way navigation was exactly enough to solve the task where they were asked to move between the circles. This device had a big disadvantage compared to the other devices while moving between the three circles since the participants only could se a small bit of the map.

The device got the lowest value on three questions; how easy it was to follow the red line, how effective it was to follow the red line and how easy it was to go to the positions of the three circles. The average value was enough to reach the third place.

The measured data shows that the Senso Nav I got the worst result, in all the measured data, among the tested devices.

9.7.5 DK 4 – Joystick, IEE

The shape of the button was appreciated by several participants because it was obvious that the finger should rest in the concavity. But when they started to use the device they moved the thumb along the edges instead. Three out of four participants would like to use the device in a real phone.

Analogue behaviour
A wider range of speed depending on the movement of the thumb was demanded and one participant thought that the movement didn't stop immediately when the button was released.

The Joystick got the lowest value on four questions; how efficient it was to go to the positions of the three circles, if they got the expected response, how much they needed to look at the device and how confident they felt using it. It also got the lowest average point on the questionnaires.

The Joystick ended up in third place in regards of all the measured data.

9.7.6 DK 5 – Component B, SEMC

The participants had big problems with accidentally pressing the centre select button during all tasks. This was because they had to press hard to get the needed friction to pull the button to the outer edge, and sometimes the button also got stuck in one position. During all tasks the participants made big finger movements and didn't experience the spring force as tactile feedback. It should also be mentioned that only one of the participants guessed right on how the scroll function worked. Two out of four participants want to use the device in a mobile phone.

Menu navigation
The participants thought it was hard to know how far they needed to move the button to get a reading and they missed some kind of feedback. One of the participants thought it felt needless to move the button if there wasn't any feedback. Some of the participants released the button after each step and some of them pushed on the outer edge of the button.

The Component B scored the lowest average point on the questionnaires and got the lowest value on the questions regarding how easy it was to complete the task and how efficient it was to solve the task.

This device needed the longest average time to solve the task and had the second best error rate.

List scrolling
When the button is moved from the initial position to the outer circular path the indicator often makes a big jump. The participants had problems to know how far out from the centre the button had to be while scrolling. If the button wasn't moved as far

out as possible it gave read errors with big jumps on the indicator as a consequence. When the participants were told that they had to move the button along the outer edge they complained about the big force that they needed to apply to keep the button along the path.

The Component B scored the lowest average point also in this task and got the lowest value on the following questions; how easy it was to complete the task, how easy it was to stop at the right position, how efficiently it was to solve the task, if they got the response they expected and if they felt confident using the device. The device got the best score on the question regarding how much they needed to look at the device.

The measured data shows that the Component B needs most time to solve this task and also has the highest error rate and all participants made errors.

Analogue behaviour
During this task the participants had problems to find the exact right direction every time it changed. They also though that the speed of the indicator changed in different directions and that it was hard to vary the speed of it.

On the questionnaires the Component B got the second best average point and was judged to be the device they needed to look at least.

The measured data shows a second place regarding the time needed to complete the red line and the time needed to go between the three circles. The Component B got the lowest time off the red line and error percent.

9.7.7 DK 6 – EntréPad, AuthenTec

The biggest disadvantage with this device is the lack of feedback. Several of the participants only used their fingertip instead of the whole pad of the finger to manoeuvre the device. The participants made big thumb movements during the tests. Three out of four participants would like to use the EntréPad in a mobile phone.

Menu navigation
Of course the lack of feedback was the biggest issue during this task and as mentioned above the thumb was moved a lot.

This device got the fourth best average point on the questionnaires. It got the best point on how easy it was to complete the task and the lowest points on the questions regarding how confident the participants felt using it and how much they needed to look at it.

The measured data shows that this device gave the biggest error rate and got the fourth average time to complete the task.

List Scrolling
The participants thought that the speed while scrolling was much to fast. The device offers variable speed but since it was so fast they didn't get the right feeling of it. One big advantage against the other devices was that it could walk one post at the time when they were close to the right position.

The EntréPad got the third best average score on the questionnaires and was the device that the participants felt that they needed to look most at.

The device scored the third best average time to complete the task and the fourth error rate.

Analogue behaviour
As the indicator only moved while the thumb was in movement much and big thumb movements were needed.

On the questionnaires the EntréPad got the highest average score and the best score on several questions; how easy it was to follow the red line, how efficient it was to follow the red line, how easy it was to go to the three circles, if the participants got the expected response and if they felt confident using the device.

The measured data shows first place regarding both the time needed to complete the red line and the three circles. It had the second lowest time off the red line and second lowest error percentage.

9.7.8 Summary of the Results

The result of the usability study is summarized in two parts:

- In the first part the total score on the answered questions are compared with the maximum score. The result is presented in table 9.9 as a percentage of the maximum score.

Table 9.9: Summary of answered questions

	DK 1 Combination Jog (Omron)	DK 2 Component E (SEMC)	DK3 Senso Nav I (ITT Electronic Components)	DK 4 Joystick (IEE)	DK 5 Component B (SEMC)	DK 6 EntréPad (AuthenTec)
Question score (% of max)	83.5	78.5	59.3	40.0	51.7	61.3

- In the second part the performance in the tasks is compared with the task acceptance, see table 9.10. The time is presented as the time used divided with the acceptance limit and the errors is presented as the number of errors divided with the acceptance limit.

Table 9.10: Summary of the performance

	DK 1 Combination Jog (Omron)	DK 2 Component E (SEMC)	DK3 Senso Nav I (ITT Electronic Components)	DK 4 Joystick (IEE)	DK 5 Component B (SEMC)	DK 6 EntréPad (AuthenTec)
Time (time used / acceptance)	58.9	110.0	115.0	102.2	80.7	80.6
Errors (errors / acceptance)	12.8	80.0	131.0	167.0	107.0	127.3

9.8 Conclusions

When performing a usability study it's easier to compare the results if there are as few parameters as possible varying between the tested products. Problems arise when trying to compare products that neither offer the same functions nor look the same. That problem was tried to be avoided in this usability study by comparing the products to task acceptance criteria instead of comparing them to each other. But none the less, the difference in the demo kits is still a factor that may have influenced the results. Different software is the reason for the bad result in the list scrolling with the Component E from SEMC. It was more difficult to scroll in a picture without knowing the relation between the positions, as one do in a numbered list.

One more thing that had an impact on the result of the usability study was the visual design of the navigation device i.e. the appearance and feeling of the button. Some of the navigation devices had a button design that allowed the test participants to understand how the device was supposed to be used, but on some devices the button design didn't give any indication at all how to be used. When using the navigation devices the button design sometimes implied discomfort for the user e.g. the strain experienced when using the Senso Nav I was a result of bad button design. All of the navigation devices could have better performance if their buttons and appearance were better designed.

The summary of the result show that Combination Jog from Omron was experienced as the best and performed the best in the tasks. In second place is the Component E from SEMC, despite its bad performance in list scrolling. It's obvious that the analogue devices can't compete with the digital when it comes to digital behaviour like moving in a matrix based menu as the one used in mobile phones today. One reason for this can be that people are best at what they are used to i.e. the digital navigation. That doesn't mean that they can't be better with the analogue devices after some usage. One benefit of the analogue devices is that they are capable of performing tasks the digital devices can't. The third place is shared between the Component B from SEMC and EntréPad from AuthenTec. They performed rather equally in the tasks and had both problems with list scrolling; Component B because large strength was needed to make the rotating movement and the EntréPad because it was too sensitive and went too fast. The Senso Nav I from ITT Electronic Components performed much worse than expected and ended up in fifth place. The biggest problem with the Senso Nav I was finding the balance between the force needed to actuate the corners switches without depressing the metal dome. The worst performance in the usability study was achieved by the Joystick from IEE. This can be explained by the fact that the joystick was only able to be tested in the analogue behaviour, which was the hardest and most demanding task, and not to its full extent of functions.

The navigation devices used in this study are under development and there are still improvements to be made i.e. the technical and software problems that affected the usability study are issues that most likely can be solved by further development of the navigation devices. The result from this usability study shows how well the different navigation devices perform in there current state and it gives an indication in which areas the navigation devices needs to be improved.

This usability study had to work with demo kits from the different suppliers, all with different appearance and interfaces. For the future it would be good to have a common platform where the navigation devices easily could be connected and used with standard software. Then the navigation devices could be better compared in an environment equal for all and similar to a mobile phone.

10 Final Evaluation

The components have been evaluated, rated and ranked throughout this work according to the initial target specifications, technical target specifications and the usability study. In this section the different rankings are put together to form a final evaluation.

10.1 Ranking of Components

If a product shall have success in the market it must have good usability and live up to the customers expectations regarding technical aspects. Since both usability and technical aspects are important have no weight of the different rankings been made.

The components are ranked in table 10.1 according to the summary of their ranking in the three earlier evaluations. They are ranked by the lowest total sum since the ranking scale goes from 1 to 6 where 1 is the best.

Table 10.1: Ranking of components

	EntréPad (AuthenTec)	Component B (SEMC)	FSR (IEE)	Senso Nav I (ITT Electronic Components)	Combination Jog (Omron)	Component E (SEMC)
Initial Target Specifications Rank	5	1	3	1	6	4
Technical Target Specifications Rank	5	6	3	1	3	1
Usability Study Rank	3	3	6	5	1	2
Total Sum	13	10	12	7	10	7
Rank	6	3	5	1	3	1

10.2 Final Selection and Recommended Components

The evaluations and rankings throughout this work have resulted in a final ranking, see table 10.1. This ranking shows that the Senso Nav I and the Component E are the best ranked components. Therefore the recommendation for SEMC is to work further with:

- **Senso Nav I from ITT Electronic Components**
- **Component E from SEMC**

The reason for recommending both navigation devices is that the Component E could work as an easy replacement for the current navigation devices in entry and mid segment phones where the analogue behaviour is not crucial. It could also, to some extent, work for high segment phones. The Senso Nav I is more suitable for high segment phones because it’s in these phones the analogue applications first will be implemented. It can also be used in entry and mid segment phones when they have the need for an analogue navigation device. The Component E is mature enough to be implemented in a mobile phone in a near future but the Senso Nav I need some attention regarding the usability before it’s ready for implementation.

11 Conclusions

The outcome of this master thesis is the selection of two navigation devices that can be recommended to SEMC as suitable to work further with and in an extension replace the navigation devices used today.

The two recommended components are:

- **Senso Nav I from ITT Electronic Components**
- **Component E from SEMC**

Both these components offer the same functions as the navigation devices used today and in addition they also offer new features suitable for future applications. The decision to recommend these two is based on the three different evaluations performed throughout this thesis work where the components have been evaluated against certain criteria and requirements.

The evaluations are based on the current technical state of the components. The technical area of navigation devices is constantly changing and the components in this work are no exception. They are continuously being developed and improved to meet the demands and requirements from different manufacturers. This means that the recommended components can be further developed to be even better, but also that the other components will be further developed and might in the future be better than they are today and can perhaps be an alternative to the two recommended. The internal requirements, that SEMC has established, are not commonly known by the component manufacturers and their specifications are therefore based on their own or other customer's requirements. This means that the specifications didn't always meet the requirements because the components were not tested according to SEMC requirements. That doesn't necessarily mean that the components couldn't meet the SEMC requirements if they were tested against them.

A component with a good technical construction and technical specifications that meets the requirements doesn't necessarily have good usability. The components evaluated and tested in this work had not been optimized from both a technical and usability aspects. Some of the components scored well in the usability study but not so good in the technical evaluation, and some components the other way around. The final evaluation and selection would have been easy if one of the factors, technical or usability, could have been neglected. It's essential to understand that the two aspects are equally important when developing a new product.

One important result from the usability study is that the analogue navigation devices can't compete with the digital ones when it comes to navigating in a matrix based menu like the one used in SEMC phones today. But the question arises; will the menu system in a mobile phone look the same in the future if an analogue navigation device is used? The answer is probably no, because the analogue navigation device opens up new dimensions and possibilities. There is no reason to restrict the movement in a menu to just up, down, right or left when a navigation devices is being used that can move freely in the x- and y-plane. The need for a full 360º analogue behaviour can be discussed. This thesis work has tested both components with full 360º analogue behaviour and components with 8-way navigation. The usability study shows that none of the tested components are accurate enough to follow a pre-determined path between two points, but worked well when moving in an optional path between different points. This indicates that it's enough with 8-way navigation for the demands of future applications.

11.1 Recommendations of Further Work

All throughout this project there have been problems/improvements that haven't been attended due to lack of time or resources. It's recommended that these problems/improvements are investigated and if possible taken care of.

The problems/improvements follow below:

- One big problem with the Senso Nav I was that the difference in force needed to actuate the different switches was not distinct enough which resulted in actuation of more switches than intended and that resulted in bad usability. Another problem regarding the actuation force of the Senso Nav I is that the button felt loose and wobbly due to the low force needed for actuation of the corner switches. It must be investigated if the different forces needed for actuation could be modified and most important, at what levels the forces should be for this component to be experienced as good from the usability aspect.
- The Senso Nav I didn't fulfil all the requirements in the technical target specifications and some of the requirements were not specified. It's recommended to test it against the internal SEMC requirements to determine if this is a problem or not.
- The supplier for the metal dome sheet must be changed in order to implement the Component E from SEMC. It must be investigated what possible problems that may imply and what the effect on the assembly process of the key-pad is.
- Some of the requirements were not specified for the Component E. It's recommended to test it against the internal SEMC requirements.
- It must be analyzed how the implementation of the two different navigation devices affects the mechanical construction of the phone, and to establish some guidelines with recommendation what to think of when implementing them.

- The area of the touch sensors is very wide and there are hardly any standard components. This makes it difficult to select a touch sensor without knowing how the actual sensor should look and what functions it should have in a phone, since most of the touch sensors are able to be modified in unlimited number of ways. The recommendation is therefore to first determine how the sensor should look and what functions it should have, and then contact a suitable supplier that can customize a solution for the specific request.
- If different components that neither looks the same nor have the exact same functions shall be compared and evaluated it's important to be able to implement them in an environment that is the same for both. If these components shall be used in a mobile phone, and perhaps compared with already existing solutions, it's important that the environment resemble a real mobile phone. The recommendation is therefore to have a platform there the different components can be easily integrated and tested with the same software in the same environment. This platform could be a mobile phone, a test plate in a laboratory or a simple mock-up of a real phone.

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Component manufacturers

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Hamasaki Kazunori
Keller Mads
Kohata Mitsumi
Kubota Suguru ‘Shane’
Linsmaier Marc
Martin Dirk
Miller Donald
Myochin Katsumi
Nishijima Akio
Olsson Ulf
Pirttiniemi Timo
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Appendix A: Time Plan

As a part of managing the thesis work a time plan, see figure A1, was established showing when in time the different steps in the work process will occur. The time plan also shows some milestones when certain steps should be reached and when to hold a brief presentation of the outcome so far.

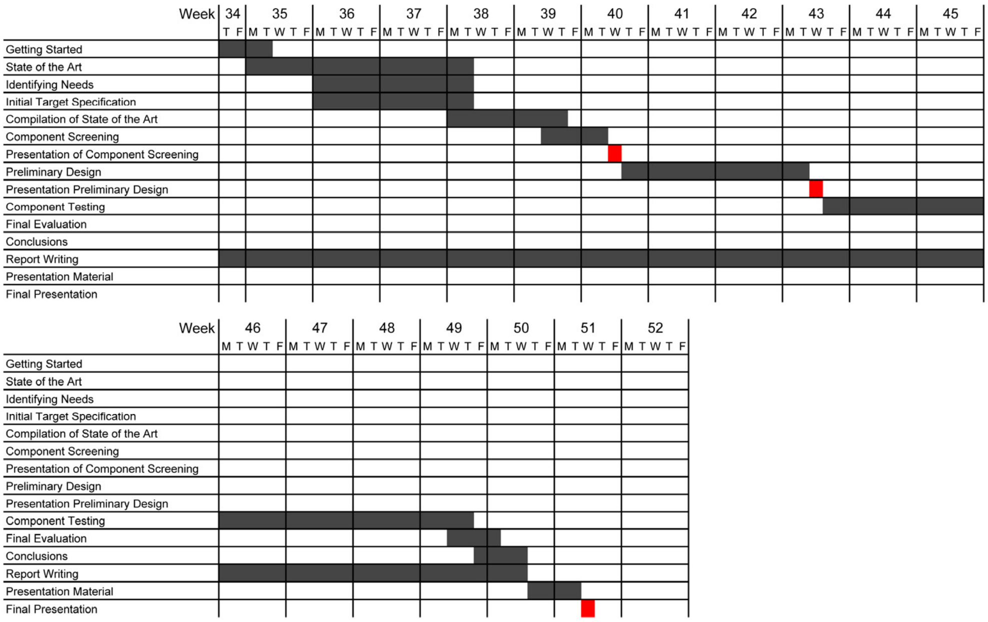


Figure A1: Time plan showing estimated time

In the end of the thesis work a revision of the time plan took place, see figure A2, to compare the actual time spent in each step against the time planned.

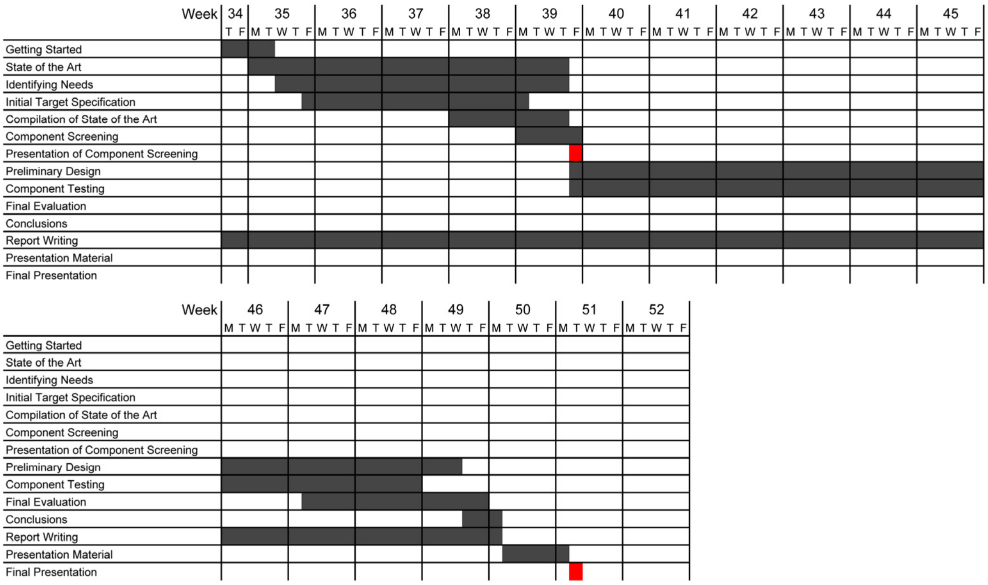
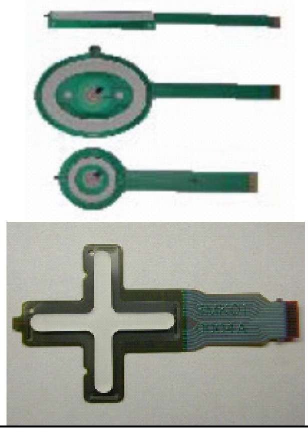
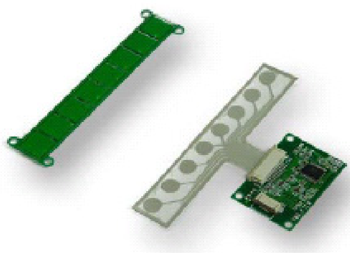


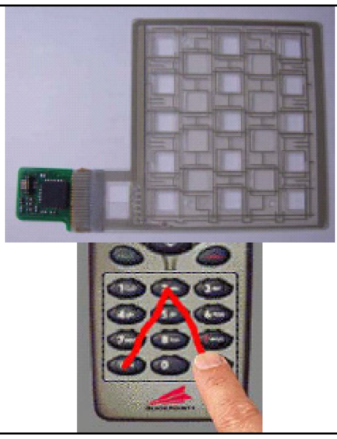
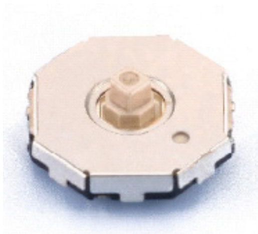
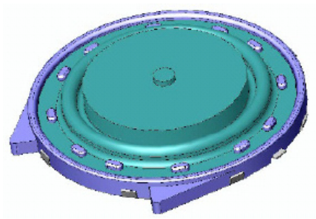
Figure A2: Time plan showing actual time spent

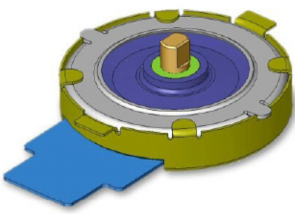
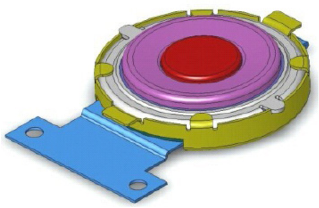
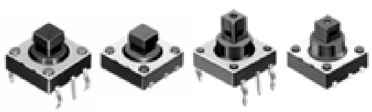
Why is it necessary to go back and review the outcome against the planned timetable? Because it's not easy in advance to estimate the time for different steps in a project. But looking back on planned and actual time spent in a project gives the participants an experience to use in future projects.

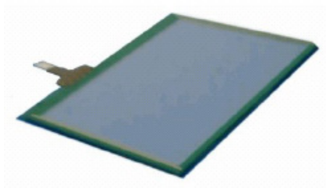
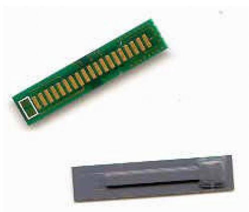
Appendix B: Components

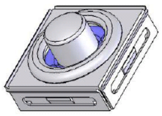
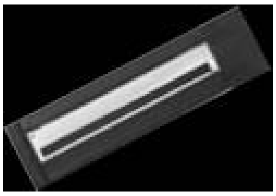
In this appendix the information from the state of the art regarding manufacturers, what components they offer and a brief description of the components are compiled.

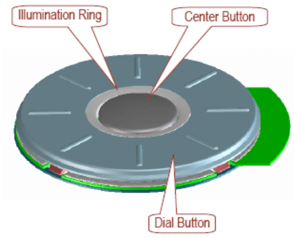
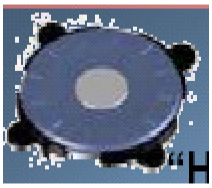
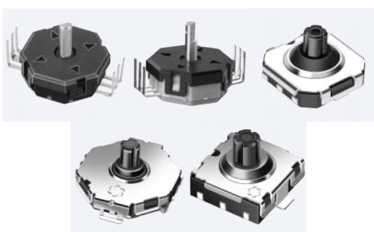
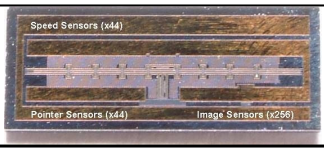
Alps	
	**Feather Touch** The function of the Feather Touch is a switch array which has a lightweight operation force. The sensor has a thickness of 0.8 mm and the shape can be customized to fit the design of different mobile phones.
	**Stick Pointer** This joystick offers an analogue behaviour. Its functions can be compared with a point stick on a laptop. The footprint is 40x22.5 mm and the height is 5.6 mm. The knob itself is Ø7 mm. The design of the component can't be customized.
	**Touch Motion Sensor** The Touch Motion Sensor is a capacitive touch sensor with up to eight sensors in a row. The sensors can be used in combination for scrolling or individual as switches. The footprint of the Touch Motion Sensor can be customized to fit different design needs and the thickness is 0.5 mm.

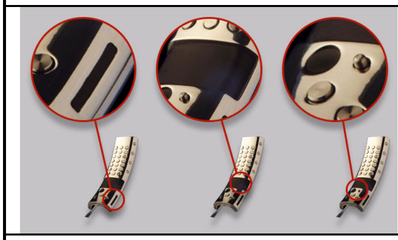
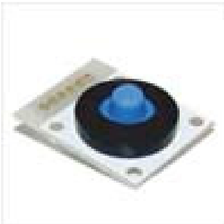
cont. Alps	
	**Glide Sensor** The Glide Sensor is a capacitive touch sensor that shares the same area on a mobile phone as the keypad. The sensor is used for navigation, scrolling and writing characters with, on top of the keypad. The design of the Glide Sensor can be customized to fit different keypad constructions.
	**8-Direction Switch** A joystick that allows navigation in eight directions. It’s also equipped with a centre push switch. The diameter of the component alters between 11.7 mm and 12.3 mm. The height is 4.45 mm with the actuator and the house itself is 2.3 mm high. The key-top is fitted over the knob and can be fully customized.
	**Analog Push Switch** The function of the Analog Push Switch is a 360° switch with centre validation. And it can be used for cursor operations.
	**Slide Switch** The function of the Slide Switch is a disc able to move 360° and with a centre validation. The position of the disc is detected by eight switches and the rubber suspension makes the disc self centring. There’s a little bit of tactile feedback on the movement due to the rubber suspension. The key-top is fitted over the Slide Switch and can be fully customized. The diameter of the Slide Switch is 15.3 mm and the thickness is 2.3 mm, without the key-top.

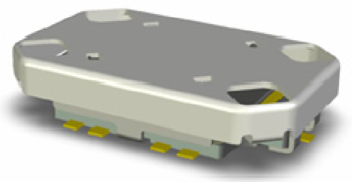
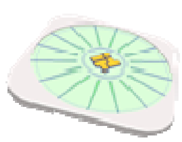
cont. Alps	
	**Analog Input Device – Stick type** The function of the Analog Input Device-Stick type is a stick able to move 360° and with a centre validation. The position of the stick is detected by four strain gauges and the rubber suspension makes the stick self centring. There's a little bit of tactile feedback on the movement due to the rubber suspension. The key-top is fitted over the Analog Input Device-Stick type and can be fully customized. The diameter of the Analog Input Device-Stick type is 17.4 mm and the thickness is 3.8 mm, without the key-top.
	**Analog Input Device – Flat type** The function of the Analog Input Device-Flat type is a disc able to move 360° and with a centre validation. The position of the disc is detected by four strain gauges and the rubber suspension makes the stick self centring. There's a little bit of tactile feedback on the movement due to the rubber suspension. The diameter of the Analog Input Device-Flat type is 11.8 mm and the thickness is 1.9 mm, without the key-top.
	**4-directional Switch with Centre Push** Alps offer several different 4-way joysticks with centre push. The footprint alters between 10x10 mm and 6.5x5.4 mm and the height between 8.6 mm and 4 mm. The height of the house alters between 3.15 mm and 1.55 mm. The key-top is fitted over the knob and can be fully customized.
	**Lever and Push Operation Type Switch** The component is available in various designs. This switch offers a 2-way navigation and centre push to select items. The size of the component alters with the various designs but they are within the range of 11.3-11.8x11.8x2.3-3 mm. The design of the component can't be customized.

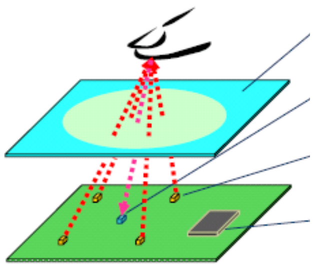
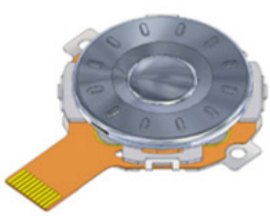
cont. Alps	
	**TTP** The TTP is a touch film to be placed on top of a LCD-Screen to achieve a touch screen. The film is constructed of film/plastic which is a development that combines the advantages of film/glass and film/film without their disadvantages. This means that the TTP is transparent, shock resistant, light weight and has an anti-glare view.
Atmel	
	**Finger Chip** The functions of the Finger Chip are detection of fingerprint and navigation. The technique used is a thermal based sensor that detects the thermal difference between the ridges and valleys of the finger. The only customization to be made is change of colour. The footprint of the sensor is 23x5 mm and the thickness is 1.8 mm.
Atrua	
	**VSense Analog Rocker Switch** The Rocker Switch product line consists of pressure sensitive switches that are typically mounted on the side of a handset for analogue, variable speed scrolling control. The size of the standard product is 16x5x1.25 mm thick, but that can be varied to fit the requirements of the handset. Rocker switches can incorporate metal domes for tactile feel and have customizable actuators for industrial design flexibility.
	**VSense Touch Disc** The Touch Disc product line consists of circular or rectangular devices with an analogue pressure sensitive area for navigation and a centre select switch. The analogue area allows for both scrolling navigation and pressure-based 360° motion control. Typical size is Ø12x1.5 mm thick and larger. Touch Discs can incorporate metal domes for tactile feel and have customizable actuators for industrial design flexibility.

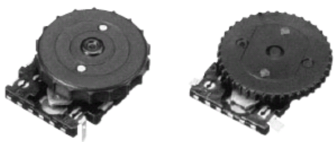
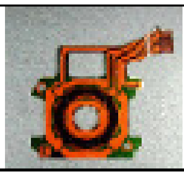
cont. Atrua	
	**Ultra-miniature VSense Joystick** The joystick product line offers very small form factor joysticks capable of deflection based, analogue input for variable speed motion and cursor control. The minimum footprint is 8x8 mm and the height is 4.62 mm. The joysticks leverage metal domes for centre select functionality and the actuator can be customized for industrial design flexibility.
	**VSense Touch Pads** The Touch pad product line offers very thin, small form factor devices with analogue sensing areas allowing for finger swipe input (much like laptop touch pads). The minimum foot print is 12x12 mm and the thickness 1mm but can be made larger. The industrial design can be very flexible using backlighting with customizable upper wear layers.
	**Atrua Wings** Atrua Wings sensors are very small form factor fingerprint sensors with the capability of analogue navigation and user authentication. These CMOS silicon sensors are capacitive based and capable of detecting the difference in capacitance between the ridges and valleys of the user's finger.
AuthenTec	
	**EntréPad** The function of the EntréPad is detection of fingerprint and navigation. The technique used is a semiconductor based sensor that uses a small RF signal to detect the ridges and valleys of the finger beneath the skin surface. The footprint of the sensor is 12x5 mm and the thickness is 1.34 or 1.96 mm.

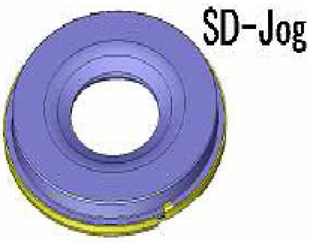
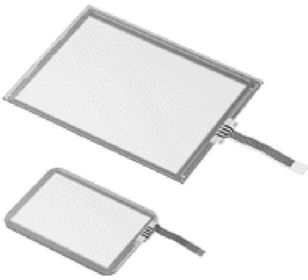
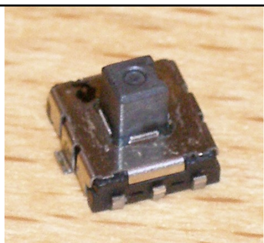
Avago Technologies	
	**X-Tracker** The function of X-Tracker is a mechanical rotating disc for scrolling with pushbutton underneath for centre validation and 4-way navigation. The rotation of the disc is detected by an optical system and since that is a non-contact system there is no tactile feedback on the rotation. The upper part of the rotation disc can be customized to fit the design of different mobile phones. The diameter of the X-Tracker is 20 mm and the thickness is 2 mm.
	**Hot Wheel** The function of Hot Wheel is a mechanical rotating disc for scrolling with pushbutton underneath for centre validation and 4-way navigation. The rotation of the disc is detected by an IC sensing change in capacitance in different fields. The diameter of the Hot Wheel is 19 mm and the thickness is 1.5 mm.
Fujitsu	
	**Ergo Track Sensor** This joystick offers an analogue behaviour. Its functions can be compared with a point stick on a laptop. The footprint is 22.3x14.8 mm and the height is 11 mm. The knob itself is Ø20 mm. The design of the component can't be customized.
Hosiden	
	**Multi-Direction Switch** Hosiden offers several different 4-way joysticks with centre push. The footprint alters between 6.2x6.2 mm and 15x15 mm and the height between 5 mm and 13.5 mm. The height of the house alters between 1.7 mm and 6.5 mm. The key-top is fitted over the knob and can be fully customized.
Idex	
	**Smart Finger** The function of the Smart Finger is detection of fingerprint and navigation.

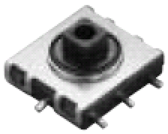
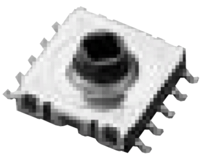
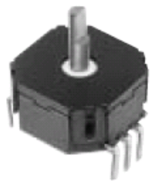
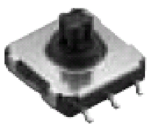
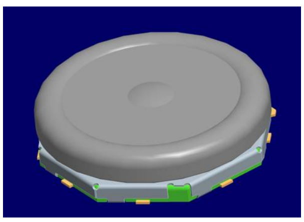
IEE	
	**FSR (Force Sensitive Resistor)** The FSR is a pressure sensitive touch sensor that measures position and activation at the same time. The shape of the sensor can be customized to fit any design or function and the thickness is as low as 0.3 mm.
ITT Electronic Components	
	**Ergo Nav Analog Navigation disc** The function of Ergo Nav Analog Navigation Disc is a sensitive rotating disc for scrolling with 4-way navigation and centre validation. The diameter of the Ergo Nav Analog Navigation Disc is 20 mm and the thickness is 2 mm.
	**Ergo Nav Analog Joystick** This joystick offers an analogue behaviour. Its functions can be compared with a point stick on a laptop with additional centre validation. The footprint is 30.5x24 mm and the height is 8.23 mm. The house itself is Ø16.3 mm. The freedom of design is limited
	**Navigation Tact Switch** This joystick offers 4-way navigation and centre push. The footprint is 8x8 mm and the height is 5 mm. The house is 2.2 mm high. The key-top is fitted over the knob and can be fully customized.
	**Tri-direction Scan Switch** This switch offers a 2-way navigation and centre push to select items. The size of the component is 10.6x13.6x1.65 mm. The design of the component can be customized.
	**Spring Finger Contact Switch** This switch offers a 2-way navigation. The size of the component is 18.4x6.1x0.9 mm. The key-top can be fully customized.

cont. ITT Electronic Components	
	**Track Ball** The Track Ball can be compared with a scroll wheel on a mouse. The biggest difference is that the Track Ball offers scrolling in all directions and not just in one dimension like the scroll wheel. Roller elements are used to determine the movement of the ball. The ball is pressed down to make a selection. While the ball is rotated the user gets tactile feedback in terms of small clicks, thanks to the rollers. The ball is Ø8 mm. The footprint is 12x12 mm and the height is 9.1 mm. The house is 7.3 mm high. The design of the component can't be customized.
	**Senso Nav I** The Senso Nav I offer 4-way navigation and centre push, plus additional sensitive rotating disc or point stick function. The functions are achieved by tilting a plate and actuating the different switches. There are four switches in the corners of a square underneath the plate that detects the position and a metal dome that gives a tactile feedback. However it's not an analogue device and is seen as five metal domes of a matrix from a hardware point of view. The key-top is positioned on top of the plate or can be a part of the keypad silicon structure, and can be fully customized, but with the limitation that is has to be fitted in a square with the size from 8x8 mm to 18x18 mm. The footprint of the Senso Nav I is either 10x10mm or 12x8mm and the thickness is 2.5 mm without the key-top.
	**Senso Nav II** The Senso Nav II is a combination of a resistive touch sensor that provides position of the finger and a metal dome underneath in the centre that provides a good tactile feedback anywhere the user press. The decoration and shape of the Senso Nav II can be fully customized. Footprint can be customized to any dimensions from around 12 mm to 30 mm and the thickness is 2.5 mm.

Mitsumi	
	**Multi-Functional Tactile Switch** This is a 4-way joystick with the footprint 6.4x6.4 mm and a height of 5 mm. The house is 1.8 mm high. The key-top is fitted over the knob and can be fully customized.
	**Slide and Rotary Encoder Switch** The Slide and Rotary Encoder Switch is a side mounted mechanical rotating wheel for scrolling up/down and validation by pressing the wheel. The rotation of the wheel is detected by actuation of switches and this gives the Slide and Rotary Encoder Switch a tactile feedback on the rotation. The diameter of the wheel is 14.5 mm and the thickness is 4 mm.
	**MOMS (Mitsumi Optical Motion Switch)** The MOMS is an optical sensing system that detects movement in all three dimensions. The footprint of the sensor increases when the thickness is reduced. A thickness of 6 mm gives a footprint of 11x11 mm, but when the thickness is reduced to 3 mm the footprint increases to 30x30 mm (since the MOMS is still under development the size is only a reference). The touch area of the sensor is recommended to be a round convex shape.
Omron	
	**Combination Jog** The function of Combination Jog is a mechanical rotating disc for scrolling with pushbuttons underneath for centre validation and 4-way navigation. Inside the rotating disc there is a magnet that's detected by a hall IC. The hall IC senses the movement of the magnet which gives the scrolling. The magnet inside the rotating disc gives the rotation a click feel and a resolution of 8-12 steps/360°. The upper part of the rotation disc and the force of the click feel can be customized to fit the design of different mobile phones. The diameter of the Combination Jog can be varied from 15 mm to 24 mm, and the thickness is fairly thin.

cont. Omron	
No Picture	**Touch Sensor** The Omron Touch Sensor is a capacitive sensor with high sensitivity and reliability. The shape and size can be customized to any application.
Panasonic	
	**Jog Ball** The Jog Ball can be compared with a scroll wheel on a mouse. The biggest difference is that the Jog Ball offers scrolling in all directions and not just in one dimension like the scroll wheel. Hall elements are used to determine the movement of the ball. The ball is pressed down to make a selection. The ball is Ø5.5 mm. The footprint is 10.7x9.3 mm and the height is 6 mm. The house is 3.7 mm high. The colour of the ball can be customized.
	**ED-jog** The ED-Jog is a side mounted mechanical rotating wheel for scrolling up/down and validation by pressing the wheel. The rotation of the wheel is detected by actuation of switches and this gives the ED-Jog a tactile feedback on the rotation. The diameter of the wheel is 15 mm and the thickness is 5.4 mm.
	**FD-Jog** The FD-Jog is a rotating cylinder for scrolling up/down and validation by pressing the cylinder. The rotation of the cylinder is detected by actuation of switches and this gives the FD-Jog a tactile feedback on the rotation. The footprint of the FD-Jog is 18.3x10 mm and the height is 7 mm.
	**Analog Key** The Analog Key is a resistive touch sensor. The shape and size can be customized to any application

cont. Panasonic	
	**SD-Jog** The SD-Jog is only a mechanical rotating disc with a magnet inside. To be functional as a navigation device it must be combined with a PCB, five metal domes, a centre button and two hall IC's. The hall IC's senses the movement of the magnet which gives the scrolling, and the metal domes are the switches for the 4-way navigation and centre validation. The magnet inside the rotating disc gives the rotation a click feel of 8 steps/360°. The upper part of the rotation disc can be customized to fit the design of different mobile phones. The diameter of the SD-Jog is 16 mm and the thickness is 2.5 mm.
	**Touch Panel** The Panasonic Touch Panel is a film/plastic type to be placed on top of a LCD-Screen to achieve a touch screen. The Touch Panel comes in three different thicknesses, 1.1, 1.4 or 1.9 mm, and the size restricted to maximum 4 inch.
	**Micro Stick** The Micro Stick is the joystick that is used in SEMC phones today. It's a 4-way switch with centre push. The footprint is 6.5x6.1 mm and the height is 5 mm. The house is 2 mm high. The key-top is fitted over the knob and can be fully customized.
SMK	
	**Lever Push Switch** The component is available in various designs. This switch offers a 2-way navigation and centre push to select items. The size of the component alters with the various designs but they are within the range of 10.5-12.1x8.5-10x2.53-3.3 mm. The design of the component can't be customized.

cont. SMK	
	**Wonder Pointer** The Wonder Pointer is a resistive pressure sensitive multi functional switch. The footprint of the Wonder Pointer is 31x29 mm and its thickness is 6.5 mm.
	**Micro Joystick Switch** This joystick offers an analogue behaviour with centre push. Its functions can be compared with a point stick on a laptop. The footprint is 8x9.1 mm and the height is 4.5 mm. The house is 2.05 mm high. The key-top is fitted over the knob and can be fully customized.
	**Multi-Functional Switch** This joystick offers 4-way navigation and centre push. The footprint is 10x10 mm and the height is 5 mm. The house is 2.3 mm high. The key-top is fitted over the knob and can be fully customized.
	**Multi-Way Switch** This joystick offers 4-way navigation and centre push. The footprint is 12x12 mm and the height is 14 mm. The house is 6 mm high. The key-top is fitted over the knob and can be fully customized.
	**Small Multi-Way Switch** This joystick offers 4-way navigation and centre push. The footprint is 6.5x6.5 mm and the height is 4.5 mm. The house is 1.6 mm high. The key-top is fitted over the knob and can be fully customized.
Tyco	
	**Coin key II** The function of Coin Key II is a mechanical rotating disc for scrolling with pushbutton underneath for centre validation and 4-way navigation. The rotation of the disc is detected by actuation of the eight switches along the rotation path. This gives the Coin Key II a resolution of 8 pulse/360° and a tactile feedback on the rotation. The upper part of the rotation disc can be customized to fit the design of different mobile phones. The diameter of the Coin Key is 16.7 mm and the thickness is 3.7 mm.

Appendix C: Usability Test Agreement

This is an Agreement between me, the Signee of this Agreement and Sony Ericsson Mobile Communications AB, Nya Vattentornet, 221 88 Lund ("Sony Ericsson").

The scope of this Agreement is to regulate the terms and conditions for my participation in Usability Tests arranged by Sony Ericsson. This Agreement forms the only exhaustive Agreement between the Parties and any amendments must be made in writing and duly signed by both Parties.

I hereby certify that I am not an employee of, or in any other way hold a position similar to that of an employee of a company competing with Sony Ericsson. I have accepted to participate as a test pilot and may come in contact with confidential information relating to Sony Ericsson and/or other companies in the Ericsson-group.

I am aware of that I may not under any circumstances reveal or in any other way hand over any kind of information regarding Sony Ericsson's products or business to an unauthorized person without the prior written consent from an authorized person from Sony Ericsson. With unauthorized person means any person within or outside Sony Ericsson who are not directly engaged in the test.

After completed test I shall return any kind of equipment and documentation to Sony Ericsson, which has been provided by Sony Ericsson or otherwise in connection with the test.

I hereby undertake to act in accordance with these provisions and am aware that any kind of violation of the secrecy undertaking with regards to confidential information or company secret information may result in legal action.

Nothing in this Agreement or any other circumstances in connection with the performance under scope of this Agreement shall be interpreted as giving me a position similar to an employee of Sony Ericsson. I also understand that my participation in the tests performed are entirely voluntary and without remuneration. I may therefore at any time choose to cancel my participation.

I further approve that Sony Ericsson documents the test, for example by means of video and audio recordings. I understand that such recordings only may and will be used for company internal purposes, for instance in educational material, courses and presentations. I also understand that details about me will be anonymized in rapports, presentations and other material. I understand that any further external use must be authorized by me in writing before such use may take place. The personal information given will be stored in a company internal database and will be used only to contact me in the future.

I also give Sony Ericsson the full and exclusive right to use, and title to ownership, to any possible ideas and other suggestions that I may contribute to in connection with the test, and also undertake to fully cooperate with Sony Ericsson to fill out necessary documentation which can be necessary to facilitate the acquiring or maintenance of rights by Sony Ericsson.

Sony Ericsson will keep the original of this document and as a test pilot I have received a copy.

Lund _________________

In witness hereof by authorized person:

____
Signed Test Pilot

____
On behalf of Sony Ericsson

____
Clarification of signature

____
Clarification of signature

____
Personal Code Number

____
Guardian of Test Pilot (N.B. Mandatory if Test Pilot is under 18 years of age)

Appendix D: Background Questionnaire

Name: ______________________________ Male ☐ Female ☐

Year of Birth: _____ ☐ Right handed ☐ Left handed

Thumb width: ______________ (mm)

Occupation: __________________________ Company: ______________

Do you have a technical education?
☐ Yes ☐ No

Which mobile phone are you using today?

____

For how long have you had your current mobile phone?

____

How often do you use your mobile phone?

☐ Every day ☐ 2-3 times a week ☐ 2-3 times a month ☐ Rarely

Which functions do you use in your mobile phone?

☐ Phone calls ☐ SMS ☐ MMS ☐ Phone book ☐ Calendar
☐ Camera ☐ Music player ☐ Web Browsing ☐ Bluetooth
☐ Other: ____

How would you describe your skills in using your mobile phone?

☐ Excellent ☐ Good ☐ Ok ☐ Bad

Appendix E: Explorative Test

Name: ______________________________ Date: ______________

Demo kit nr: _____

1) Looking

Functions

☐ Navigation Up/Down	☐ Navigation Left/Right
☐ Centre Select	☐ Force Sensitive
☐ Scrolling	☐ Analogue Behaviour (like a computer mouse)

2) Touch and Feel

Functions

☐ Navigation Up/Down	☐ Navigation Left/Right
☐ Centre Select	☐ Force Sensitive
☐ Scrolling	☐ Analogue Behaviour (like a computer mouse)

3) Comments:

____

____

____

Appendix F: Assessment Test, Task 1 – Menu Navigation

Name: ______________________________ Date: ______________

Demo kit nr: _____

1A) How easy was it to complete the task?

Easy ———————————————— Difficult

1B) Were you able to efficiently solve the task?

Not Efficiently ———————————————— Very Efficiently

1C) Was it necessary to look at the navigation device to know what you were doing?

Never ———————————————— Always

1D) Did you feel confident using this navigation device?

Little Confidence ———————————————— Large Confidence

Comments:

____

____

____

____

Appendix G: Assessment Test, Task 2 – List Scrolling

Name: ______________________________ Date: ______________

Demo kit nr: _____

2A) How easy was it to complete the task?

Easy ———————————————————— Difficult

2B) Was it easy to stop at the right positions?

Easy ———————————————————— Difficult

2C) Were you able to efficiently solve the task?

Not Efficiently ———————————————————— Very Efficiently

2D) Did you get the response you expected?

Never ———————————————————— Always

2E) Was it necessary to look at the navigation device to know what you were doing?

Never ———————————————————— Always

2F) Did you feel confident using this navigation device?

Little Confidence ———————————————————— Large Confidence

2G) Did you feel any strain when performing the task?

No Strain ———————————————————— Large Strain

Comments:

____

____

____

Appendix H: Assessment Test, Task 3 – Analogue Behaviour

Name: ______________________________ Date: ______________

Demo kit nr: _____

3A) How easy was it to follow the red line?

Easy ________________________________ Difficult

3B) Were you able to efficiently follow the red line?

Not Efficiently ________________________________ Very Efficiently

3C) How easy was it to go to the position of the three different circles?

Easy ________________________________ Difficult

3D) Were you able to efficiently go to the position of the three different circles?

Not Efficiently ________________________________ Very Efficiently

3E) Did you get the response you expected?

Never ________________________________ Always

3F) Was it necessary to look at the navigation device to know what you were doing?

Never ________________________________ Always

3G) Did you feel confident using this navigation device?

Little Confidence ________________________________ Large Confidence

Comments:

____

____

____

Appendix I: Concluding Discussion

Name: ______________________________ Date: ______________

Demo kit nr: _____

4A) Is this a navigation device you can see yourself using in a mobile phone?

☐ Yes ☐ No

Mention an excellent quality about this navigation device.

____

____

____

Mention a poor quality about this navigation device.

____

____

____

Is there anything that you would like to change about this navigation device?

____

____

____

Comments:

____

____

____

____

Appendix J: Data from the usability test

The data from the background questionnaires with the different tasks and the opinions from the usability test are presented in table J1 to table J10.

Table J1: Summary of the data from the answered background questionnaires. The background questionnaires can be found in appendix D.

Test participant	Gender	Age	Left/Right handed	Thumb width (mm)	Technical education	Usage rate	Skills
1	Female	32	Right	19	Yes	Every day	Bad
2	Male	35	Right	24	Yes	Every day	Good
3	Female	27	Right	19	Yes	Every day	Excellent
4	Female	42	Right	20	No	Every day	Ok
5	Male	54	Right	20	Yes	Every day	Good
6	Male	37	Right	22	Yes	Every day	Ok
7	Female	24	Right	19	Yes	Every day	Good
8	Female	24	Right	20	Yes	Every day	Good
9	Female	55	Right	20	No	Every day	Ok
10	Male	24	Left	20	Yes	Every day	Good
11	Male	26	Right	23	Yes	Every day	Ok
12	Female	25	Left	18	Yes	Every day	Excellent

Table J2: Number of participants that though the function was available just by looking at the device. A green figure means that the function is available and a red that is unavailable.

Function	DK 1	DK 2	DK 3	DK 4	DK 5	DK 6
Navigation up/down	4	4	3	4	4	3
Navigation left/right	4	4	3	4	4	4
Centre push button	4	4	3	4	4	4
Force sensitive	1	2	0	3	1	1
Scroll function	3	4	3	3	4	3
Analogue behaviour	2	1	1	1	3	1

Table J3: Number of participants that though the function was available after they touched and felt the device. A green figure means that the function is available and a red that is unavailable.

Function	DK 1	DK 2	DK 3	DK 4	DK 5	DK 6
Navigation up/down	4	4	4	4	4	3
Navigation left/right	4	4	4	3	4	4
Centre push button	4	4	4	4	4	3
Force sensitive	1	1	1	2	1	2
Scroll function	4	3	3	3	4	4
Analogue behaviour	2	2	1	1	4	1

Table J4: The average scores for each question asked after the menu navigation test. An overall average is also presented. A scale between 0 and 10 is used where 10 is the best. The questions can be founding in appendix F.

Question	DK 1	DK 2	DK 3	DK 4	DK 5	DK 6
1A	9,1	8,7	8,3	n/a	7,5	9,1
1B	8,1	8,8	8,5	n/a	4,8	6,9
1C	8,5	8,9	9,3	n/a	8,8	8,0
1D	7,9	8,7	8,3	n/a	5,0	3,3
Average	**8,4**	**8,8**	**8,6**	**n/a**	**6,5**	**6,8**

Table J5: The average values for each test participant of the measured data from the menu navigation test.

	Demo kit 1			Demo kit 2			Demo kit 3		
Test	Errors	Time to complete	Pass /Fail	Errors	Time to complete	Pass /Fail	Errors	Time to complete	Pass /Fail
1	0,0	8,7	Pass	0,0	10,1	Pass	0,0	12,7	Pass
2	0,0	13,7	Pass	0,0	11,1	Pass	0,2	11,4	Pass
3	0,4	8,0	Pass	0,0	9,2	Pass	0,4	9,9	Pass
4	0,0	10,8	Pass	1,0	14,5	Pass	2,2	13,6	Fail
Av.	**0,1**	**10,3**	**Pass**	**0,3**	**11,3**	**Pass**	**0,7**	**11,9**	**Pass**

	Demo kit 5			Demo kit 6		
Test	Errors	Time to complete	Pass /Fail	Errors	Time to complete	Pass /Fail
1	0,2	13,5	Pass	1,2	14,4	Fail
2	0,2	10,9	Pass	0,6	10,7	Pass
3	0,2	11,5	Pass	1,0	12,0	Pass
4	0,0	13,2	Pass	0,2	11,3	Pass
Av.	**0,2**	**12,3**	**Pass**	**0,8**	**12,1**	**Pass**

Table J6: The average scores for each question asked after the list scrolling test. An overall average is also presented. A scale between 0 and 10 is used where 10 is the best. The questions can be found in appendix G.

Question	DK 1	DK 2	DK 3	DK 4	DK 5	DK 6
2A	9,3	7,2	6,3	n/a	3,6	6,2
2B	7,0	3,9	3,6	n/a	1,2	4,6
2C	8,6	6,7	4,6	n/a	2,9	5,4
2D	8,1	6,5	4,8	n/a	3,5	5,3
2E	9,5	9,3	9,5	n/a	9,7	8,8
2F	8,1	6,7	5,0	n/a	1,4	4,1
2G	7,2	7,8	3,0	n/a	5,5	6,9
Average	**8,3**	**6,9**	**5,2**	**n/a**	**4,0**	**5,9**

Table J7: The average values for each test participant of the measured data from the list scrolling test.

	Demo kit 1			Demo kit 2			Demo kit 3		
Test	**Errors**	**Time to complete**	**Pass /Fail**	**Errors**	**Time to complete**	**Pass /Fail**	**Errors**	**Time to complete**	**Pass /Fail**
1	0,6	8,6	Pass	3,0	24,9	Fail	4,0	23,2	Fail
2	0,4	9,2	Pass	2,4	28,7	Fail	2,4	16,8	Fail
3	0,2	10,8	Pass	2,4	30,5	Fail	1,8	18,8	Pass
4	0,0	10,5	Pass	2,6	31,8	Fail	2,4	35,1	Fail
Av.	**0,3**	**9,8**	**Pass**	**2,6**	**29,0**	**Fail**	**2,7**	**23,5**	**Fail**

	Demo kit 5			Demo kit 6		
Test	**Errors**	**Time to complete**	**Pass /Fail**	**Errors**	**Time to complete**	**Pass /Fail**
1	2,0	12,8	Pass	2,2	20,9	Fail
2	6,4	16,8	Fail	4,0	13,2	Fail
3	4,0	12,5	Fail	4,2	19,6	Fail
4	5,0	12,4	Fail	2,4	10,8	Fail
Av.	**4,4**	**13,6**	**Fail**	**3,2**	**16,1**	**Fail**

Table J8: The average scores for each question asked after the analogue behaviour test. An overall average is also presented. A scale between 0 and 10 is used where 10 is the best. The questions can be found appendix H.

Question	**DK 1**	**DK 2**	**DK 3**	**DK 4**	**DK 5**	**DK 6**
3A	n/a	n/a	1,1	1,7	3,5	4,6
3B	n/a	n/a	1,0	1,4	3,8	5,4
3C	n/a	n/a	5,8	5,9	6,6	8,3
3D	n/a	n/a	5,6	4,3	5,2	6,4
3E	n/a	n/a	3,8	2,4	4,0	6,5
3F	n/a	n/a	9,5	9,2	9,6	9,3
3G	n/a	n/a	1,2	0,8	2,4	6,2
Average	**n/a**	**n/a**	**4,0**	**3,7**	**5,0**	**6,7**

Table J9: The average values for each test participant of the measured data from the analogue behaviour test.

	Demo kit 3					Demo kit 4				
Test	Time Red line	Time off red line	% Error	Time Circle	Pass/ Fail	Time Red line	Time off red line	% Error	Time Circle	Pass/ Fail
1	66,9	30,4	45,4	18,2	Fail	38,8	7,7	19,8	6,6	Fail
2	45,2	n/a	n/a	12,5	Fail	56,7	4,3	7,6	11,9	Fail
3	61,3	5,5	9,0	15,0	Fail	52,0	9,9	18,9	8,0	Fail
4	46,5	9,6	20,7	15,7	Fail	71,1	14,5	20,4	11,6	Fail
Av.	**55,0**	**11,4**	**18,8**	**15,3**	**Fail**	**54,7**	**9,1**	**16,7**	**9,5**	**Fail**

	Demo kit 5					Demo kit 6				
Test	Time Red line	Time off red line	% Error	Time Circle	Pass/ Fail	Time Red line	Time off red line	% Error	Time Circle	Pass/ Fail
1	59,7	4,3	7,3	9,8	Fail	53,8	11,3	21,0	9,6	Fail
2	40,7	n/a	n/a	7,4	Pass	34,9	2,9	8,2	4,5	Pass
3	32,8	1,8	5,6	6,6	Pass	48,7	10,1	20,7	7,4	Fail
4	54,2	6,2	11,4	7,9	Fail	44,8	3,0	6,7	6,5	Pass
Av.	**46,8**	**4,1**	**8,1**	**7,9**	**Pass**	**45,6**	**6,8**	**14,2**	**7,0**	**Fail**

Table J10: Number of participants that answered that they could see themselves using the device in a mobile phone. The question can be found in appendix I.

Question	DK 1	DK 2	DK 3	DK 4	DK 5	DK 6
4A	3	4	1	3	2	3