

UNIVERSITY OF TWENTE.



Industrial Design Engineering

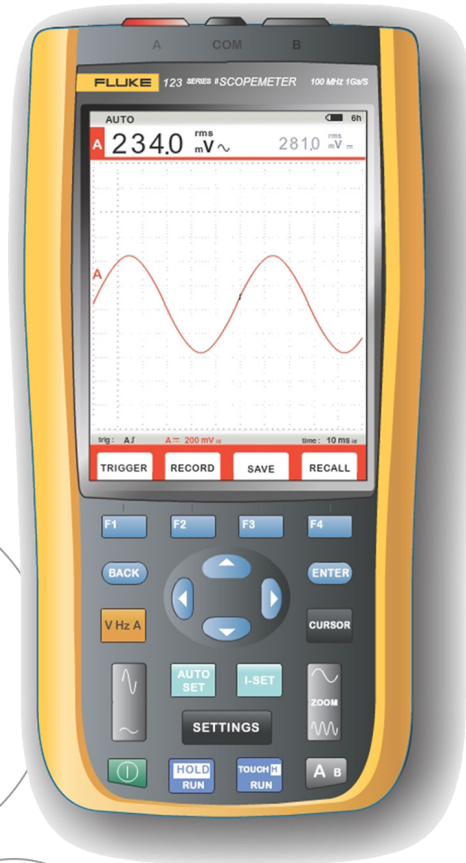
# USER INTERFACE DESIGN

of the next generation Fluke ScopeMeter 120 Series

Rosanne Andriessen

January 1<sup>st</sup>, 2013

2 years confidentially



ERROR  
TOLERANT

EFFICIENT

EFFECTIVE

ENGAGING

MARKETABLE

EASY  
TO  
LEARN

# TITLE PAGE

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User interface design of the next generation Fluke ScopeMeter 120 Series

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# PREFACE

This report contains the results of a research performed in order to design the user interface of the next generation of the Fluke ScopeMeter 120 series. The research is performed within the final assignment of the bachelor program Industrial Design Engineering of the University of Twente and executed at Benchmark Electronics in Almelo, the Netherlands. The research has ground in common with specific disciplines like user interface design, user-centered design, and interaction design.

Performing this assignment has made a valuable contribution to my knowledge on industrial design engineering, as well as to my knowledge about the business world, and to insight into my personal strengths and weaknesses. Besides, writing this report made a great contribution on my skills in English writing. Several people have helped me, whom I want to thank.

I want to thank Maarten Essers for guiding me through the process, helping me with those things I had difficulties with and giving me the feedback I needed. I want to thank Christian Suurmeijer for his guidance at Benchmark, his commitment, and feedback on my work. Furthermore I want to thank Peter Deverson for his time and effort helping me and his patience in explaining me everything about Fluke and the ScopeMeter series. In addition I want to thank Maarten van Alphen and Bertus Kottier for their time and enthusiasm. Lastly I want to thank the other people at Benchmark and those who were willing to help me perform a usability test.

I hope you will enjoy reading my report.

Rosanne Andriessen  
Enschede, December 2012

# ABSTRACT

An analysis on Fluke's view regarding the development of the next generation of the ScopeMeter 120 series is conducted, as well as an analysis on the user, usage, product functions, and user interface of the ScopeMeter 123. This is done in order to determine the focus required in redesigning the user interface and the requirements that should be used during the concept generation. After the concept generation, a usability test is performed in order to evaluate several design aspects within the chosen concepts.

The ScopeMeter 123 can be described as a basic handheld oscilloscope which is mainly used for industrial troubleshooting. The user can be described as an electrical technician within the field of 'maintenance and repair' and with an intermediate or higher technical educational background. Because the user has to deal with time pressure, as well as a pressure to achieve, the ScopeMeter must be efficient, effective and error tolerant.

In most of the cases, a multimeter is sufficient to find the cause of a problem. Most users have little experience with using the ScopeMeter, as the ScopeMeter is only used once in a while. Therefore the ScopeMeter must be easy to learn.

It is analyzed that the current product is not experienced as easy to use by users with less or no experience using the product. From an analysis of the user interface it has become clear that the current interface was made efficient by giving access to a function or menu within as few steps as possible without taking the real time it takes to reach the function or menu into account. This approach has resulted in an inconveniently arranged screen with a lot of information visible at the same time.

The current proportions are conceived as baseline in redesigning the user interface of the ScopeMeter 123. This is done to remain a clear identification with 120 series as well as a clear communication of the products capacities and price. As the user interface of the ScopeMeter is a decisive factor in selling the product, a marketability requirement is taken into account in redesigning the user interface of the ScopeMeter.

Figure 1 represents the balance of usability and marketability requirements within a frame of baseline requirements, which is used in decision making during the concept generation. Figure 2 shows the chosen concept, i.e. redesign, and the updated concept based on the original concept.

A qualitative usability test is performed in order to find the advantages and disadvantages of the generated concept and its design aspects. A comparison is made with the task performance regarding an update of the current concept. The test results of 11 participants are analyzed and gave insight into the strengths and weaknesses of both concepts, as well as insight into the strengths and weaknesses of the performed test.

It has become clear that clustering menus under one button should be considered as the test results indicate that this makes it easier to reach one of the menus compared to placing menus under separated buttons. Also, it has been found that if one button is really eye-catching, other equally important buttons may not be noticed. Furthermore, a comparison is made between the new concept, using a signal selection button, and the old concept where buttons for signal A and signal B are separated. The test results show that the concept with separated buttons resulted in fewer difficulties. However, as using a signal selection button saves a lot of space which can be used for other buttons, it is recommended to use a signal selection button if this button is placed in a more eye-catching way compared to the generated concept (figure 2).

Another result showed that the display interface of the redesign was preferred compared to the updated display interface based on the original design. Lastly, the newly designed menu navigation was rarely used. However, further research on the possibilities of navigation with the function keys is recommended.

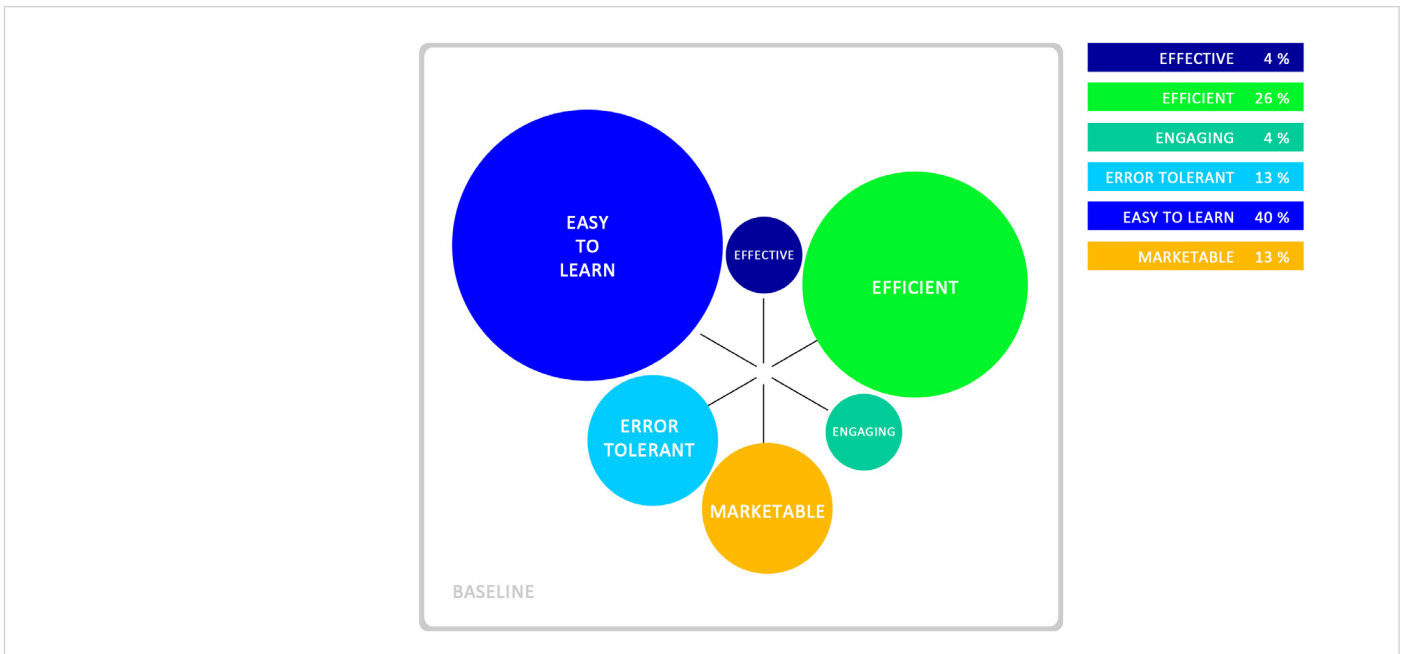


Figure 1: balance of requirements within a frame of baseline requirements



Figure 2: concept based on original concept (left) and generated concept, i.e. redesign (right)

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# INTRODUCTION

This report contains a concept generation and evaluation regarding the user interface of the next generation of the Fluke ScopeMeter 120 series.

## Fluke Corporation

*Fluke Corporation is the world leader in the manufacture, distribution and service of electronic test tools and software <sup>[17]</sup>. The Fluke brand has a reputation for portability, ruggedness, safety, ease of use and rigid standards of quality <sup>[17]</sup>. Figure 3 gives an impression of Fluke in words.*

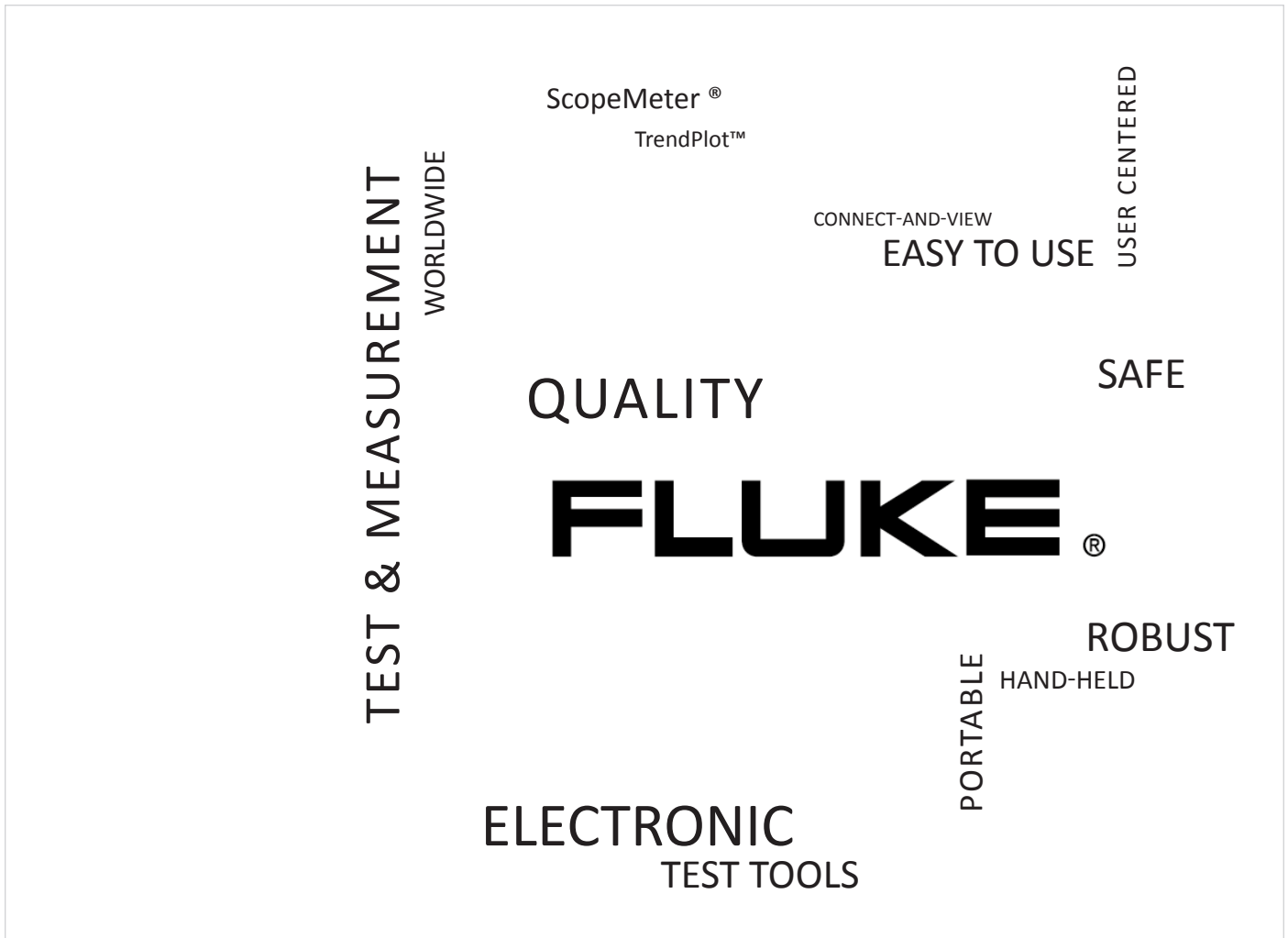


Figure 3: Fluke Corporation in words

# ScopeMeter 120 Series

The products from the ScopeMeter 120 series can be described as basic handheld oscilloscopes [07]. Although they can be best described as oscilloscopes, they in fact are a combination of a digital multimeter (DMM) and a digital storage oscilloscope (DSO). With those two functions, Fluke mentions the “paperless” recorder function [32] as ‘one of the three’ functions that are combined in the ScopeMeter 120 series. Because the products from this 120 series are a combination of an oscilloscope and a multimeter, Fluke mentions that *the ScopeMeter 120 Series is the only tool you’ll need*. Appendix A can be consulted for information about the differences between an oscilloscope and a multimeter.

According to Fluke (2012) the *compact ScopeMeter 120 Series is the rugged solution for industrial troubleshooting and installation applications* [20] and designed for *industrial maintenance technicians* [18] or *service technicians* [32]. The ScopeMeter 120 series meets *today’s need of simultaneously measuring and checking waveforms*, which is realized by implementing the *Connect-and-View™ automatic triggering functionality*; an important selling point of the product line. This *Connect-and-View* functionality *recognizes signal patterns, and automatically sets up correct triggering. It provides a stable, reliable and repeatable display of virtually any signal (...) without you touching a button* [18]. Next to this, the ScopeMeter 120 series is designed to *endure extreme temperatures, moisture, dust, corrosives, and rough handling* [32]. In figure 4 the ScopeMeter 120 series is visualized in words.

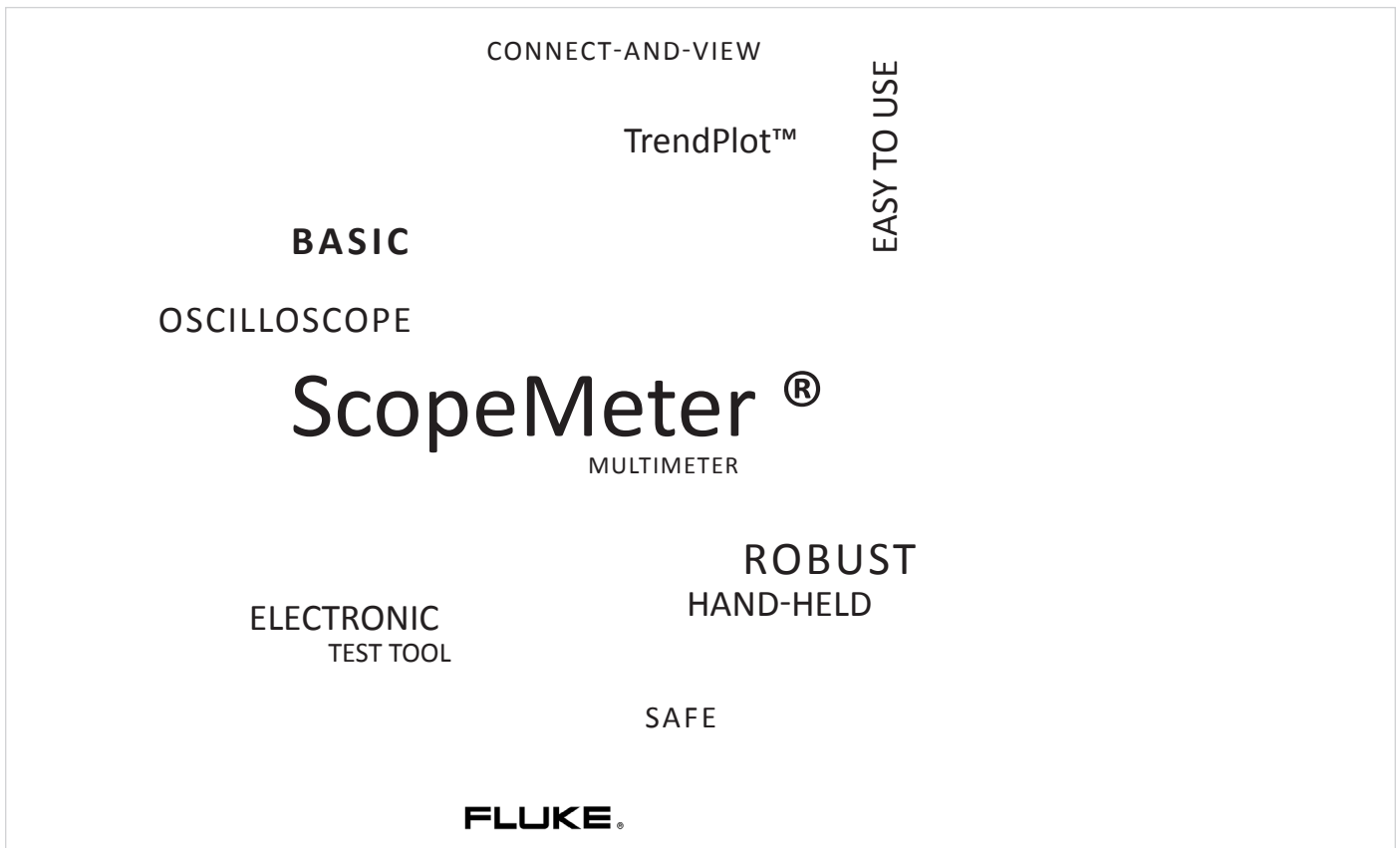


Figure 4: Fluke ScopeMeter 120 series in words

The ScopeMeter 120 series exists of three types: the ScopeMeter 123, 124 and 125 (figure 5). The ScopeMeter 123 can be seen as the basis for the 124 and 125; all the functions that are realized in the 123 are realized in the 124 and 125, plus more.



Figure 5: Fluke ScopeMeter 123 (left), 124 (middle) and 125 (right)

To give insight in the basic functionality of the Fluke ScopeMeter 120 series, a Function Analysis System Technique (FAST) diagram is created. This figure with explanation can be found appendix B.

In order to determine the focus required in redesigning the user interface and the requirements that should be used during the concept generation, an analysis of Fluke's view on redesigning the ScopeMeter 120 series preceded the design phase, as well as an analysis of the user, usage, functions, and user interface of the ScopeMeter 123. The design phase consists of an ideation from which several concepts are generated. After the concept generation, one of the generated concepts is chosen. A usability test is performed in order to review the chosen concept. Figure 6 on the next page, graphically represents the coherence of the conducted researched, concept generation, and the performed usability test.

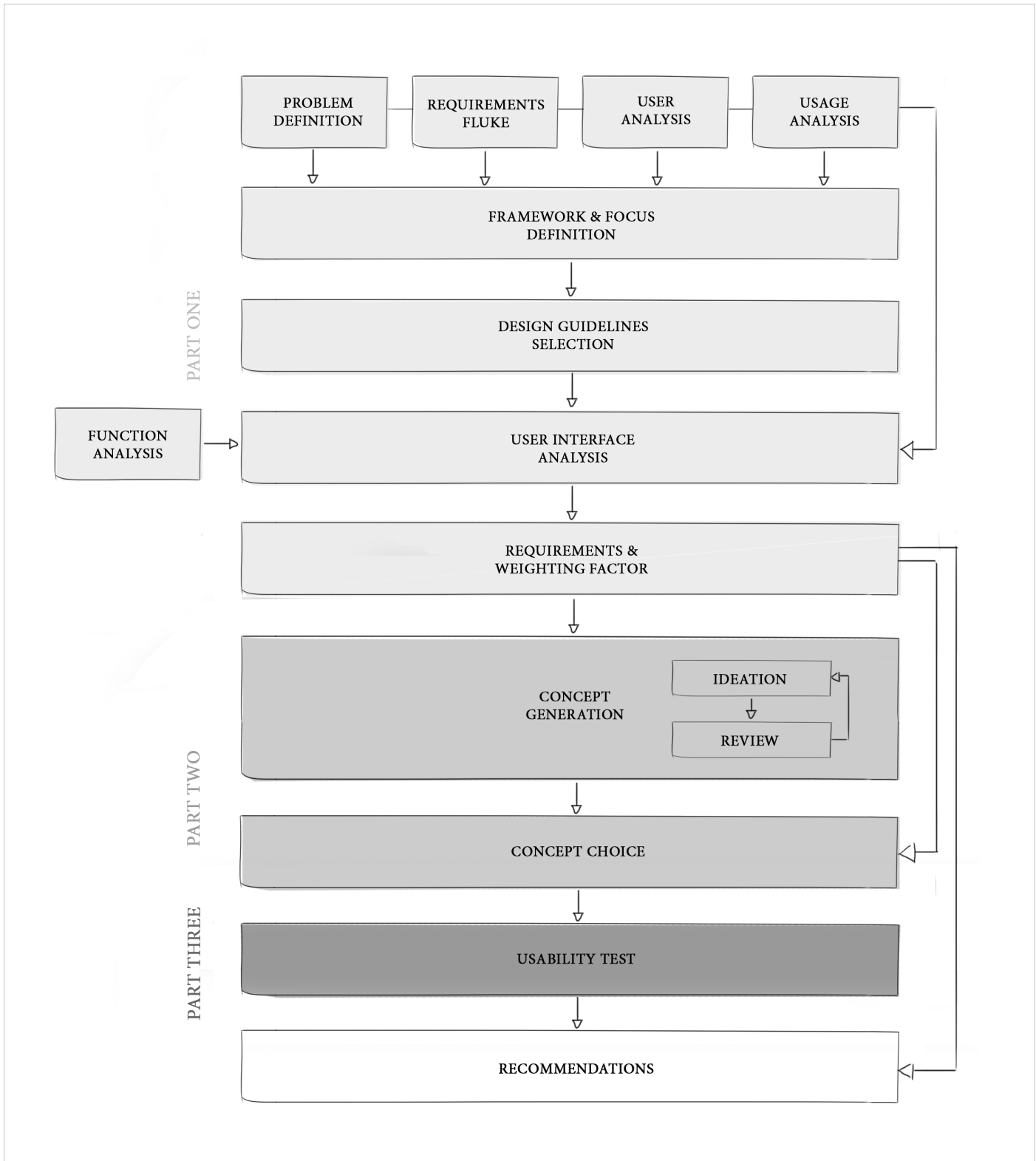


Figure 6: graphical representation of the process

# 1 PART ONE | from analysis to requirements

Part one consists of an analysis in order to determine the focus required in redesigning the user interface and the requirements that should be used during the concept generation. In addition to research on the ideas of Fluke regarding the next generation of the ScopeMeter 120 series, an analysis of the user, usage, and user interface of the ScopeMeter 123 are used to get insight into the strengths and weaknesses of the current product. A product analysis is conducted to gain insight in the products capacities. A classification on importance of the functions, menus and measurement options is used in the evaluation of the user interface. Furthermore, design guidelines are used to evaluate the user interface observations. The mentioned analyses are subsumed under the following headings:

- 1.1 Fluke's view on redesigning the ScopeMeter 120 series**
  - Technical improvements
  - Main goal and communication through the outer design
- 1.2 User analysis**
  - User profile
  - Personas
- 1.3 Usage analysis**
  - Use scenarios
- 1.4 Framework and focus**
  - Framework for usability
- 1.5 Design guidelines**
  - Efficiency
  - Learnability
  - Legibility
  - Use of color
- 1.6 Product analysis**
  - Function analysis
  - User interface analysis
  - Multimeter analysis
- 1.7 Conclusion**
  - Requirements with weighting factor

## Resources

The product, usage and user analyses, as well as the research on the ideas of Fluke, are mainly based on several interviews with Peter Deverson, senior product planner for the Fluke ScopeMeter product range, and Bertus Kottier, senior engineer at Brusche Elektrotechnik and user of the ScopeMeter 123. In addition, some literature and internet sources are consulted to verify the information. The literature *User Interface Design and Evaluation* <sup>[02]</sup>, *An Introduction to Human Factors Engineering* <sup>[03]</sup>, and internet sources from the *Nielsen Norman Group* <sup>[24] [25] [26]</sup> are consulted in order to gain information about design guidelines, principles and heuristics.

## 1.1 Fluke's view on redesigning the ScopeMeter 120 series

From several interviews with Peter Deverson, the most important ideas by Fluke regarding the development of the user interface of the next generation of the ScopeMeter 120 series are reported. First the ideas on technical improvements are clarified. Secondly the by Fluke conceived main goal is mentioned, as well as aspects that should be taken into account regarding the marketability. To what extent these ideas should and will be taken into account in redesigning the user interface of the ScopeMeter 123 within this assignment, depends on the outcomes of the user and usage analysis.

### Technical improvements

One of the reasons for the development of a next generation of the ScopeMeter 120 series is the fact that the current display will no longer be produced. Therefore, a new display should be applied. In addition, improvement of the battery life is desired as well as the application of a new function called *Intella Set*.

#### New display

Because the current display of the ScopeMeter 120 series will no longer be produced, a new display needs to be applied in the new generation of the 120 series. Next to the fact that the current display will no longer be produced, the display performance is one of the critical points mentioned by the users of the current product <sup>[35]</sup>. Users expect a modern display <sup>[35]</sup> that meets today's expectations of a display; colored and with a high resolution.

#### Battery life improvement

If you ask any user for complains about the current product, 75% will definitely complain about the battery <sup>[35]</sup>. It is by far the most critical point of the current ScopeMeter <sup>[35]</sup>.

The current battery, a rechargeable Ni-MH BP 120MH battery, can perform seven hours without charging. This should be enough for about one day of use without charging. In practice, it turns out that in most of the cases the battery is not fully charged when the device needs to be used, which leads to the critical case that the ScopeMeter is out of power during the measurements.

Although the battery can be charged during usage, this is not desired. In most of the usage environments, production plants, only three-phase electric power is available with a power supply of 400 or 600 volt, which makes charging difficult. In addition, only 50% of the users take the product in its original suitcase. That means that 50% of the users take the product in their own toolbox and are likely to forget their battery charger <sup>[34]</sup>.

Next to the fact that the ScopeMeter is not charged after usage most of the time, the product uses energy while powered off. Especially when the product is infrequently used, this leads to critical use cases. Another problem of the current battery is the need for battery refreshment once in a while. A rechargeable Ni-MH BP 120MH battery needs to be fully uncharged once in a while to keep its optimal capacity. In practice this is rarely done, resulting in a performance of less than seven hours. All together it may be clear that a battery life improvement for the next generation is highly desired.

#### New functions

In addition to improvement of the display and battery life, the current product functionalities of the ScopeMeter 120 series are scrutinized, in order to adjust the functionality to today's user needs and in order to improve the products capacities.

#### *Battery refreshment & print functionality*

With the application of a new battery, the function to 'refresh the battery' will no longer be

necessary and therefore can be removed <sup>[35]</sup>. Also the functionality to directly print measurement results can be left out. These days everyone has a computer and wants to save the results on the computer and not print them directly <sup>[34]</sup>. This makes the print functionality unnecessary.

#### *Intella Set function*

In order to improve the products capacities, Fluke has developed a new function, called 'Intella Set' or 'I-Set' <sup>[33]</sup>. With this 'I-Set' function not only the amplitude, time base, trigger level, trigger slope, and trigger hold off are automatically set, but also the 'measurement input' will be set. This means that the device will, given the received signal, determine which result is probably wanted to be displayed in the numeric read-out area, like voltage, frequency, resistance etc. According to Peter Deverson, a lot of research is done and sufficient information is gathered to realize this functionality <sup>[33][36]</sup>. This 'I-Set' function will not replace the automatic triggering functionality <sup>[36]</sup>.

### **Main goal and communication through the outer design**

First, the by Fluke conceived main goal in redesigning the ScopeMeter 120 series is explained. In addition, aspects that should be taken into account regarding the marketability are mentioned.

#### **Direct accessibility**

The product must be easy to use and the users must do their job fast <sup>[33]</sup>, because there is a great time pressure during the usage. Therefore, according to Peter Deverson, the main goal in redesigning the ScopeMeter 120 series is to design a product that fulfills a task by the push of a single button <sup>[33]</sup>.

#### **Product appearance**

The size of the ScopeMeter is an important aspect regarding communication about its capacities and its price <sup>[35]</sup>. The products from the 120 series must look basic compared to the oscilloscopes from the 190-serie, because the 190 series oscilloscopes are more advanced and are considerable higher priced (€ 4,000.-) than the 120 series oscilloscopes (€ 2,000.-). Therefore the current product has the dimensions of a Fluke multimeter and not of an advanced oscilloscope (figure 7 on the next page). The ScopeMeter 120-serie products, on the other hand, must look more advanced than a considerable lower priced (€ 300.-) and less advanced multimeter. In the current products this is mainly realized by the application of a larger display and by the appearance of buttons instead of a knob. In figure 7 the Fluke multimeter 179, ScopeMeter 123 and ScopeMeter 190-202 are presented.



Figure 7: Fluke multimeter 179 (left), ScopeMeter 123 (middle) and ScopeMeter 190-202 (right)

**Design evolution**

According to Peter Deverson, it is very important that the customer recognizes the new generation as a new version of the old. To clarify this statement, Peter Deverson compared the by Fluke desired development to the design evolution of the Porsche 911. Looking at the evolution over the years, it can be noticed that the design has changed, but that the modern version can still be recognized as the Porsche 911 of 50 years ago. This is what Fluke wants in the development of the ScopeMeter 120 series. People must recognize it as the ‘old’ trustable ScopeMeter it has been for the last 15 years. It has to be classic and modern in the same time. Fluke wants a design evolution, not a revolution [35].

**Selling strategy**

The ScopeMeter will be sold and bought on the internet or via magazines. The customer cannot hold and try the product, but decides whether to buy the device or not, mainly by what he can see on the picture. Although he can read the product specifications, the picture will be the most important means of communication in the buying process. That is why it is desired to communicate as many product functions as possible through the outer design, or, more specific, the keypad.

## Conclusion

Fluke has communicated three important adaptations on the design of the current product that should be made:

1. The application of a new display
2. Improvement of the battery life
3. Application of a new function called *Intella Set*

Application of a new colored high resolution display will be interpreted as a baseline within redesigning the user interface of the ScopeMeter 123. The concepts should, of course, fit the displays capacities to comply with the users expectations.

Because the current battery capacity is by far the most critical point of the current ScopeMeter, battery life improvement is highly desired. Although the battery life can and will be improved by the application of a new battery, this does not ensure the battery problem to be solved, as part of the problem is caused by specific usage and not only by technical shortcoming.

In order to improve the current product capacities, a new function called *Intella Set* will be applicated. Furthermore, the battery refreshment and direct print functionality will be removed. These adaptations should be taken into account in redesigning the user interface of the ScopeMeter 123 and will be interpret as a baseline.

According to Fluke, the ScopeMeter has to fulfill a task by the push of a single button, to maintain quick usage. Therefore, this is conceived by Fluke as the main goal in redesigning the ScopeMeter 120 series. Whether this indeed should be the main goal depends on the outcomes of the user and usage analysis and therefore will be decided later on.

In redesigning the ScopeMeter, it is desired by Fluke to keep the current product proportions, to clearly communicate the products capacities and price and to maintain identification with the 120 series. From a marketing point of view it is important that the outer design clearly communicates the products strengths and capacities, as the product will only be sold and bought on the internet or via magazines.

## 1.2 User analysis

Research into the user profile is done, in order to gain insight into the user of the ScopeMeter 120 series. This section consists of a general user profile, followed by two personas to give a better insight in the target group of the ScopeMeter 123.

### User profile

The user of the Fluke ScopeMeter 123 can be generally described as a ‘blue collar worker’<sup>[04]</sup><sup>[33]</sup>; an *industrial and manual worker*<sup>[04]</sup>. As expected regarding the name, which refers to the typical blue overall, the blue collar worker wears durable clothing that can withstand the dirty environments they are exposed to<sup>[04]</sup>. Blue collar jobs are mainly male dominated. Most of the users are trained as electrical engineer and had their education at intermediate technical school (Dutch: Middelbare Technische School (MTS) or today’s Middelbaar Beroepsonderwijs (MBO))<sup>[37]</sup> or technical college (Dutch: Hogere Technische School (HTS) or today’s Hoger Beroepsonderwijs (HBO))<sup>[20]</sup>.

The user can be characterized as practical and solution oriented<sup>[37]</sup>. They have a special interest in technology and, according to Bertus Kottier, senior engineer at Brusche Elektrotechniek and user of the ScopeMeter 123, they like to create a well working installation or system, and with that want to deliver quality<sup>[37]</sup>. Next to this, diversity is what makes the user like their work as a troubleshooting engineer; the problems are solved on different locations and every problem has its own solution<sup>[37]</sup>. Regarding the use of new products, the user of the ScopeMeter 123 typically explores by trial and error and reads the manual only if necessary<sup>[33]</sup><sup>[37]</sup>.

The working field of the user of the ScopeMeter 123 can be described as that of ‘maintenance and repair’<sup>[11]</sup>. Because the product is mostly used in troubleshooting cases, the engineers using the 123 can be characterized by their experience<sup>[37]</sup>. Within Brusche Elektrotechniek, the users have round 20 years of work experience and according to Bertus Kottier at least 5 years of experience is desired, because sufficient knowledge is required. This does not mean the user has much experience with using the product; the ScopeMeter is rarely used daily. According to a market research by Fluke, about 40% of the users use the product once a week, and up to 30% once a month<sup>[11]</sup>. Moreover, the real average frequency of use is expected to be lower than stated in the research. For example, within Brusche Elektrotechniek, the ScopeMeter 123 is only used about four times a year<sup>[37]</sup>. The main reason for this was found during the interview with Peter Deverson. He explained the research was based on users with higher capabilities than the average user; ‘*the respondents of the market research are registered users and only the top half of the users do register*’<sup>[35]</sup>. Especially these users tend to use the ScopeMeter more often<sup>[35]</sup>.

### Personas

To give a better insight in the users of the ScopeMeter 123, two assumed users are described below in what is called a *persona*. The first persona represents a user of the main target group, a so called primary user. This persona therefore is called the *primary persona*. The second persona represents a more advanced user and therefore is called the *secondary persona*.

#### Primary Persona | Jason

Jason is 28 years old and lives in Houston, Texas, the United States. He finished intermediate technical school in 2004 after which he started as electrician. He has been working for 8 years for his current employer and he enjoys his job very much. Jason is very practical and solution oriented. Cable-wiring, measuring, testing and checking electrical installations are all part of his daily activities. In addition, he now and then solves electrical troubles. For measuring, testing and checking electrical installations, Jason uses his own multimeter, which is also good enough in most troubleshooting cases. Jason has used the ScopeMeter once, when the disturbance could not be found with the multimeter. He knows exactly how to interpret the values on his multimeter, but he is not trained in analyzing a waveform. Therefore Jason uses

pictures to which he compares the waveform on the ScopeMeter.

In his leisure time, Jason likes to play computer games, karting with some friends and going out. With that, Jason enjoys the use of new technologies. He has a smart phone with touch screen. Jason is an enthusiastic and energetic person and can be very fanatic. He does not like reading and find it difficult to concentrate for a long time. Nevertheless, because of his enthusiasm he can do his job very good. He is driven to deliver quality and working with his hands helps him to keep his concentration.

### **Secondary Persona | Gert**

Gert is 47 years old. Together with Ria he lives in Almelo, the Netherlands. After finishing technical college, he started working as electrical engineer. Gert has been working at Brusche Elektrotechniek for more than 20 years. Creating a well working installation is one of the things he likes about his work. Next to this, the diversity in problems and environments is what makes his work as a troubleshooting engineer interesting. With his multimeter, he can solve most of the problems but sometimes he needs a ScopeMeter to find the fault. Although Gert only uses the ScopeMeter about four times a year, he knows how to analyze the waveforms very well. Over the years, he learned how to find a glitch with the manual triggering functionality in the single shot mode. Gert is very experienced and remains calm and collected during his work, analyzing and using his common sense while many people breathe down his neck and want him to immediately repair the machine.

Gert has always had an interest for technology. Tinker with his car is still one of his main leisure activities. Furthermore, Gert has a little business in second hand electronics, which he sells on the internet. He made the website his own.

## **Conclusion**

The user interface needs to be understood by users with an intermediate educational background like Jason. With that, the interface needs to be understood by users all over the world. Furthermore, the user profile shows the importance of an interface that is easy to use in spite of the low frequency of use. Therefore the user interface must have a short learning curve, i.e. must be easy to learn, as each time the product is used can be interpreted as a first usage.

The secondary persona shows that users have to deal with a pressure to achieve, which makes it important that the user interface is error tolerant and effective, as the user cannot permit to make important mistakes. With that, the secondary persona shows the desire for advanced functions next to the most frequently used basic functionalities. Those functions therefore should not be left out.

Both personas show the experience of the user with multimeters, which they use almost every day and especially the primary persona makes clear that users do not read the manual, which makes it important that the user interface is understood without reading the manual.

The primary persona shows that the user has experience using a touch screen. It can be assumed that the user is familiar with the conventions applied on smart phones.

## 1.3 Usage analysis

Research on the usage of the product is necessary to gain insight into the strengths and weaknesses of the current product, regarding the usability. Especially the scenarios will give insight into critical use cases.

The ScopeMeter 123 is mainly used for industrial troubleshooting<sup>[20]</sup>. Therefore, the user often works on different places. On behalf of the safety, most users wear gloves during their job. Generally, the user has to deal with time pressure, as well as with a pressure to achieve. As mentioned before, most users do not have much experience with using the product; the ScopeMeter is rarely used daily. Conversely, the user does have much experience with using a multimeter. Most users share the ScopeMeter with colleagues, as the product is quite expensive. In 80 to 90 percent of the use cases, only one signal is analyzed<sup>[40]</sup>.

### Use scenarios

Three use scenarios are composed, in order to gain insight into the specific usage of the ScopeMeter and possible critical use cases.

#### Scenario no. 1 | Pressure to achieve

A production machine of a company has failed with the result that the whole production has been shut down. Every minute the production is off results in reasonably loss, so the fault must be found quickly. Because the technical service of the company tried to find the cause first, the production is already down for a while. When they could not find the disturbance, they called Imtech.

When Ruben arrives at the company, he is immediately taken to the machine. The company suspects that the disturbance is in a certain part of the machine. In spite of that, Ruben analyzes the whole situation before he starts measuring. Many people are around trying to help Ruben and hoping the cause of the defect will be found as soon as possible. Ruben knows not to take the advices and concerns too serious and that he must first think for himself using his common sense, which is quite difficult when everybody breaths in your neck and want you to immediately find the problem. When he starts checking some signals with his multimeter, he feels that the restlessness increases. To give the bystanders the idea that he is performing some difficult measurements he exchanges his multimeter for the ScopeMeter. This gives him a little more space to do his measurements the way he wants to. After 10 minutes, Ruben finds the cause of the problem. He uses the ScopeMeter to clarify the problem to the people of the technical service and the manager, who joined in the meantime. Although it is not easy to explain, a clear glitch can be recognized in the waveform, which is also for these less skilled people plausible to be the cause.

#### Scenario no. 2 | Empty battery

Rob quickly checks the battery power of the ScopeMeter 123 before he goes to the client. The battery symbol is quarter filled. That must be enough for at least one hour. With that, Rob does not have enough time to charge the battery and no other ScopeMeter is available. He has no other choice than taking this ScopeMeter.

After analyzing the situation and performing some measurements with his multimeter, Rob turns on the ScopeMeter. With his multimeter everything seems alright, so Rob is hoping that analyzing a waveform will give him more information. After 10 minutes, the ScopeMeter shuts down. Rob turns on the ScopeMeter again and looks at the battery symbol, which shows that the battery is empty. After a few seconds, the ScopeMeter turns off again. Rob is frustrated because he just found a glitch. Although Rob took an adapter with him, there is a big change the ScopeMeter cannot be charged because the mains voltage is too high near the production facilities.

### Scenario no. 3 | Compare and ask

Erwin has just got the task to solve a problem in an engine at a company. Paul expects that a ScopeMeter is needed to find the fault. Erwin has only once used the ScopeMeter before, which is almost a year ago. Generally a multimeter is sufficient to solve the problems. Erwin has his own multimeter and knows how to use it. He turns the knob to the desired parameter, connects the probes and reads out the measurement. He knows what to expect when the machine would work well and he knows where to find the fault when a deviating value appears.

Before Erwin goes to the company, Paul gives a short explanation on the problem and how to use the ScopeMeter for solving the problem. The only thing Erwin remembers from the last time he used the ScopeMeter was that was not easy because it was the first times he used it. Erwin is relieved that Paul tells him what he can expect and that he gives him a manual with example pictures of how the waveform on several points should look like. Sometimes Paul goes along when one of his people uses the ScopeMeter for the first or second time. This time he has something else to do and cannot come along. Therefore Erwin can call Peter, who has more experience, if he needs some support.

Erwin indeed needs the ScopeMeter to find the cause of the problem. Although he is glad with the manual, he rather not wants to use it, because it does not look very skilled.

## Conclusion

The first scenario clearly shows the high pressure to achieve that users have to deal with. This makes it important that the user interface is error tolerant, as mentioned in the previous section. With this, the pressure to achieve makes it important that users can achieve their goals complete and accurate. No specific problems are noticed so far regarding the effectiveness of the ScopeMeter 123. Next to a pressure to achieve, there is quite a lot of time pressure during the usage, which makes it important that the user interface provides a quick usage. Also here no specific problems, due to the efficiency of the product, came across. Furthermore it became clear that the advanced appearance of the ScopeMeter 123 is experienced as valuable. This strengthens the desire mentioned by Fluke, to design a product that looks more advanced than a multimeter. Finally the first scenario showed the benefits of an interface that supports the user to explain the found cause to other people.

The second scenario showed why the application of a new battery does not ensure the battery problem will be solved. The described critical scenario may not occur if the ScopeMeter was charged after last usage or if the device could be charged near the productions facilities. Furthermore, the scenario clarifies that the battery power symbol does not clearly enough communicates the time left for using the product without charging.

The third scenario shows the importance of an interface that is easy to use in spite of the low frequency of use. Therefore the user interface must be easy to learn. Moreover, the scenario shows that the current product is experienced as difficult to use by users with less experience using the product. Finally, the scenario clarifies that an interface that provides access to example waveforms is desired in some use cases.

## 1.4 Framework and focus

Over the years, many design principles, guidelines and heuristics are formulated in order to optimize the design process. Especially in the field of user interface design, a lot of these rules of thumb can be found. Although most of them can be useful, a selection on importance should be made in order to provide a balanced usage regarding redesigning the ScopeMeter. To make this selection, a framework for usability proposed by Quesenbery (2003) is applied on the product. This framework gives insight into the priority that should be given to each *dimension of user experience* regarding redesigning the ScopeMeter 120 series.

### Framework for usability

Quesenbery (2003) has proposed a framework for usability comprised of five dimensions of user experience<sup>[02]</sup>. Each dimension describes an aspect of the user experience: *effective*, *efficient*, *engaging*, *error tolerant*, and *easy to learn*<sup>[02]</sup>. The dimensions can be described as follows<sup>[02]</sup>:

#### *Effective*

The completeness and accuracy with which users achieve their goals.

#### *Efficient*

The speed (and accuracy) with which users can complete their tasks.

#### *Engaging*

The degree to which the tone and style of the interface makes the product pleasant or satisfying to use.

#### *Error tolerant*

How well the design prevents errors or helps with recovery from those that do occur.

#### *Easy to learn*

How well the product supports both initial orientation and deepening understanding of its capabilities.

### **Balance between the five dimensions**

The balance between these five dimensions can be graphically represented by giving each dimension a, to its priority sized, circle. If all dimensions are equally important, each circle has the same size, corresponding with 20% out of 100%. If one of the dimensions is rated more important, another dimension becomes less important, to keep a total of 100%. Although some dimensions can be more important than others, it is still important to consider them all together, because they are interdependent. *Where one dimension takes on a greater significance (...) it can be easy to lose sight of the other four dimensions which may impact negatively on your final design*<sup>[02]</sup>.

The balance between the five dimensions of user experience regarding the redesign of the ScopeMeter 123 within this assignment is represented in figure 8 on the next page. The priority that is given to each dimension is based on insight and information gathered throughout the analysis phase. The figure represents the balance of priority that should be given to each dimension *within this assignment*; it does *not* represent the priority of each dimension regarding the entire design process.

#### *Explanation on the priority*

The analysis so far, has shown the importance of all five user experience dimensions. The critical scenario 'empty battery', as well the desire of Fluke to improve the battery life, show the importance to design an interface that prevents errors to occur or helps with recovery from

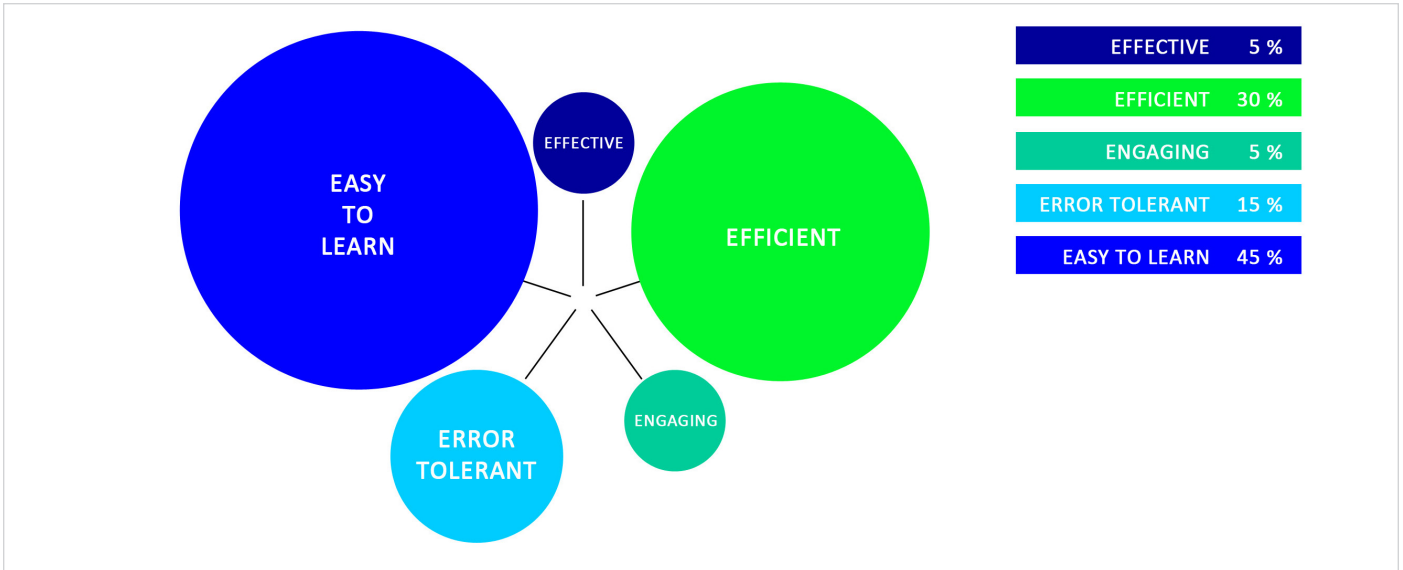


Figure 8: five dimensions of user experience regarding the redesign of the ScopeMeter 123

those that do occur, i.e. an interface that is *error tolerant*. Also the importance of the product to be efficient became clear from both the scenarios and the by Fluke conceived main goal in redesigning the ScopeMeter 120 series. Fluke mentioned that the main goal is to design a product that fulfills a task by the push of a single button, and the first scenario showed the time pressure that goes with troubleshooting. From this same scenario, the importance of the completeness and accuracy with which users achieve their goals became clear, as well the importance of an advanced appearance of the product, which can be related to the dimension referred to as 'engaging'. The user and usage analysis showed the importance of the dimensions 'easy to learn', as the interface must be easy to use in spite of the little or no experience with using the product.

No problems regarding the efficiency, effectiveness and the engagement of the product are found, contrary to problems regarding the learnability of the product, which became clear after research on the user and use scenarios. Therefore the learnability of the user interface should be an important aspect in redesigning the ScopeMeter 123.

Although no problems were mentioned regarding the efficiency of the user interface, Fluke has mentioned the improvement of the efficiency to be the main goal in redesigning the ScopeMeter. Moreover, from the usage analysis the efficiency turned out to be an important aspect, as the user experiences a high time pressure. Besides this, designing for learnability may come at the expense of the efficiency if this dimension is under prioritized<sup>[28]</sup>. Therefore also this dimension should get a relative high priority in redesigning the user interface of the ScopeMeter 123.

Although effectiveness is an important aspect of the ScopeMeter in general, improvement of this dimension should rather be obtained in redesigning technical aspects of the product and less in redesigning the user interface of the device. Next to this, the dimension is less important, as the current product delivers high quality and accuracy.

Although the critical scenario of empty battery turned out to be an important point, this problem mainly should be solved by technical improvements, like the application of a new battery, adjustments to the adapter and introduction of a chargeable holder in which the product can be placed after usage. The problem should be taken into account within redesigning the user interface of the ScopeMeter, because communication of the remaining power time turned out to be one of the problems, but this does not need a very high priority, as it is only a small part of the whole user interface.

## 1.5 Design guidelines

A selection of design principles, guidelines and heuristics is made based on the balance between the five dimensions of usability mentioned in the previous section. The guidelines are subsumed under the headings ‘efficiency’, ‘learnability’, ‘legibility’ and ‘use of color’.

### Efficiency

Because of the high time pressure users have to deal with within the field of troubleshooting, efficiency is an important *user experience dimension* (figure 8). In *User Interface Design and Evaluation*<sup>[02]</sup>, four psychological principles regarding user interface design are formulated<sup>[02]</sup>:

1. Users see what they expect to see.
2. Users have difficulty focusing on more than one activity at a time.
3. It is easier to perceive a structured layout.
4. It is easier to recognize something than to recall it.

These principles are highly related to efficiency, because ignoring these principles may lower the efficiency with which the user can perform its tasks.

The third principle, *it is easier to perceive a structured layout*, can be formulated in more detail, using *Gestalt laws of perceptual organization and grouping*<sup>[02]</sup>:

1. The law of proximity; elements that are close together appear as groups rather than as random elements.
2. The law of similarity; elements of the same shape or color appear to belong together.
3. The law of closure; where possible, we see an incomplete element as complete – we fill in the gap.
4. The law of continuity; we see this figure as two lines of dots crossing each other, rather than as a random set of dots.
5. The law of symmetry; we tend to perceive regions bounded by symmetrical borders as coherent figures.

Another guideline that should be taken into account during the design process is referred to as *the 111 solution*<sup>[28]</sup>. In short, this guideline says that the user’s productivity should be taken into account rather than the productivity of the product or system. In terms of efficiency, the guideline can be explained as the importance of looking at the efficiency in practice, rather than the efficiency in theory.

To explain this principle, the *Nielsen Norman Group (NN/g)*<sup>[28]</sup> formulated the question which task takes less time; heating water in a microwave for one minute and ten seconds or heating it for one minute and eleven seconds? The answer clarifies the guideline referred to as *the 111 solution*:

*From the standpoint of the microwave, one minute and ten seconds is the obviously correct answer. From the standpoint of the user of the microwave, one minute and eleven seconds is faster. Why? Because in the first case, the user must press the one key twice, then visually locate the zero key, move the finger into place over it, and press it once. In the second case, the user just presses the same key—the one key—three times. It typically takes more than one second to acquire the zero key. Hence, the water is heated faster when it is “cooked” longer.*

### Learnability

Because the ScopeMeter is used only a few times a year, every time the ScopeMeter is used can be interpreted as a first usage. Therefore, the interface must be easy to learn. Ideally, products would have no learning curve. In practice, all products, no matter how simple, will display a learning curve<sup>[28]</sup>.

### **Obtain a clear and correct mental models**

An easy-to-learn user interface can be described as an interface of which the users obtain a clear and correct understanding of the structure and possibilities in a short time. In order to provide a correct understanding of the structure, the way gone through the interface and the place in the system should be clearly communicated. In order to make the structure easy understandable, metaphors from the real world can be used to provide a correct mental model of the applied structure and navigation.

### **Principle of consistency**

Another guideline regarding learnability is called the principle of consistency<sup>[03]</sup>. Users will more easily understand a mental model which they are already familiar with. *Old habits die hard. Because there is no way to avoid this, good design should try to accept it and design displays in a manner that is consistent with other displays that the user may be perceiving concurrently (...) or may have perceived in the recent past<sup>[03]</sup>*. Next to consistency with other interfaces, it is important to provide consistency within the user interface. *If users know what to expect, it will be easier for them to build a conceptual map of what should happen next. If the UI meets these expectations, the user becomes comfortable, and the more comfortable a user is with the interface, the shorter the learning curve of the application<sup>[27]</sup>*.

### **Always allow a way out**

Users learn through trial and error. To encourage users to explore the interface it is important to always allow a way out<sup>[28]</sup>.

### **Limit the trade-offs**

The guidelines due to learnability do also focus on the trade-offs in designing for learnability. Leading users through the interface in one way can be a solution to make an interface easy to learn. However, this may come at the expense of the usability for the more experienced user. Nevertheless, the *Nielsen Norman Group* mentions that usability and learnability are *not mutually exclusive<sup>[28]</sup>*. They formulated the guideline to not trap users into a single path through a service, but to offer them a line of least resistance<sup>[28]</sup>. *This lets the new user and the user who just wants to get the job done in the quickest way possible and “no-brainer” way through, while still enabling those who want to explore and play what-if a means to wander farther afield<sup>[28]</sup>*.

## **Legibility**

Legibility is an important aspect regarding the usability of an interface. Therefore the most important guidelines due to legibility are selected.

### **Follow real-world conventions**

The first guideline due to legibility says that real-world conventions should be followed, *making information appear in a natural and logical order<sup>[26]</sup>*. This guideline can be applied by arranging the graphical interface from left to right and from top to bottom, as *most users read from left to right and from top to bottom<sup>[02]</sup>*.

### **Font sizes**

One obvious but still important guideline is to use font sizes that are large enough<sup>[28]</sup>. *This becomes even more important for numbers. Human languages are highly redundant, enabling people to “heal” garbled messages. Numbers, however, unless they follow a very strict protocol, have no redundancy, so people need the ability to examine and comprehend every single character<sup>[28]</sup>*.

### **Relative visibility**

The third guideline can be shortly described as minimizing the number of visible items. *Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility<sup>[28]</sup>*.

## Use of color

Color will be an important new aspect in the graphical user interface of the next generation of the ScopeMeter 120 series. Investigating the possibilities using color, several guidelines regarding the use of color are elaborated.

Color can be used to draw attention, to show status, to make information on the display clearer or to make the display more attractive<sup>[02]</sup>. If applied the right way, color can have a great advantage on the perception of information on the screen. In *User Interface Design and Evaluation*<sup>[02]</sup>, four general guidelines regarding the use of color are formulated:

1. It is better to limit the number of colors if they are used to organize the screen; *too many colors can be confusing and unpleasant to look at*<sup>[02]</sup>.
2. *Designing in black and white can help to focus attention on the layout of the user interface*<sup>[02]</sup>.
3. Avoid the use of the colors that are difficult to discriminate by people with color blindness.
4. Avoid using colors in isolation.

### Color blindness

About eight<sup>[02]</sup> to ten<sup>[28]</sup> percent of the human males have some form of color blindness<sup>[02]</sup><sup>[28]</sup>. With these people, the colors red, orange, and green are often confused, as are purple, blue, and magenta, and white, gray and cyan<sup>[02]</sup>. To convey the information to those with a form of color blindness, clear, secondary cues should be used next to the colors. These secondary cues can consist of anything from the subtlety of gray scale differentiation to having a different graphic or different text label associated with each color presented<sup>[28]</sup>.

## Conclusion

In order to design a user interface is in line with the analysis done so far, a framework of usability, consisting of five user experience dimensions is made. These dimensions of user experience can be translated to the following requirements:

- The user interface is effective (5 %)
- The user interface is efficient (30 %)
- The user interface is engaging (5 %)
- The user interface is error tolerant (15 %)
- The user interface is easy to learn (45 %)

In order to design an interface that is efficient, the four psychological principles should be taken into account. In addition to these principles, the guideline referred to as *the 111 solution* can be helpful in designing an interface that actually is efficient in practice and not only in theory.

The advantages of an efficient user interface will not be noticed if the interface has a long learning curve, as the ScopeMeter is mainly used infrequently. In order to design an easy-to-learn user interface, metaphors can be used to provide a correct mental model of the applied structure and navigation. Furthermore, the interface needs to be consistent on its own as well as consistent with interfaces the user is familiar with. To encourage users to explore the interface, it is important to always allow a way out. Finally the trade-offs of an easy-to-learn interface should be limited.

As the ScopeMeter provides visual analysis of signals, the interface should be legible. Following real-world conventions will improve the legibility of the information, as well as usage of font sizes that are large enough. With this, the number of visible items should be minimized and the used colors should be discriminable by those with color blindness.

## 1.6 Product Analysis

Within this assignment the ScopeMeter 123 will be used as starting point for the design of the new generation of the Fluke ScopeMeter 120 series. A function analysis will first give insight in the specific functionalities of the ScopeMeter 123. This is followed by an analysis of the user interface of the current product, which will give insight in the strengths and weaknesses of the current user interface. A ranking in importance of the specific functionalities will be used in the analysis of the arrangement of the keypad and the menu options in the measurements menu.

### Function analysis

To get insight in the specific functionalities of the ScopeMeter 123, the product functions displayed in the FAST diagram (appendix B) are specified and an overview is given of the parameters that can be measured and displayed (appendix D). Finally, a ranking in importance is made (appendix C).

#### Product functions

A detailed overview of the product functions can be found in appendix C. This overview represents the general product functions as represented in the FAST diagram, the realization of the functions in the ScopeMeter 123 and the name or symbol used in the ScopeMeter corresponding with the specified product functions.

#### *Importance*

The product functions can be divided into primary, secondary and tertiary functions. The functions are ordered by their frequency of use. Primary functions are most frequently used and therefore can be called most important, and the tertiary functions are less frequently used and therefore least important. This does not mean that tertiary functions can be left out by definition. The classification gives insight in whether the functions are in the right place in the current product and in the way the functions should be placed in the next generation of the 120 series. In general, the tertiary functions can be placed deeper in the menus because they are less frequently used.

Several meetings with Peter Deverson have given insight into the importance of several product functions of the ScopeMeter. In addition to this information from Peter Deverson, a selection of the product functions of the ScopeMeter was classified by Bertus Kottier, senior engineer at Brusche Elektrotechniek and user of the ScopeMeter 123. Kottier was asked to classify the product functions as frequently used (Dutch: veel gebruikt), used now and then (Dutch: af en toe gebruikt) or rarely or never used (Dutch: amper tot nooit gebruikt). The classification he made can be found in appendix M.

Although the ScopeMeter has the functionality to display two different signals at the same time, this function is only used in 80-90 percent of the cases<sup>[40]</sup>. Most of the time only one signal is analyzed. The product functions that are specific related to signal B are therefore classified as secondary functions.

Other secondary classified functions are functions that are less frequently used because they are more advanced functions, used by more experienced users; those people who are used to more advanced oscilloscopes. Those functions are classified as secondary and not as tertiary, because the tertiary functions are even less frequently used. Most of the tertiary functions are used only once or twice, like language, time or date adjustment.

Table II in appendix C presents the classification of the product function as primary, secondary or tertiary in detail.

### Conclusion

A distinguish can be made between the different product functions according to their frequency of use. The classification made in primary, secondary and tertiary product functions should be taken into account by redesigning the ScopeMeter 120 series. The reachability and the visibility of the functions and menus should be in line with the importance, i.e. frequency of use, of the functions and menus.

### Measurement options

In table III in appendix D, an overview is given of the parameters that can be measured using the Fluke ScopeMeter 123.

### Importance

Some of the measurement options are more frequently used than others and therefore can be seen as 'more important' than others. Three people are asked about the frequency of use of the measurement options.

According to Peter Deverson, the options to measure voltage in alternating current ( $V_{AC}$ ), voltage in direct current ( $V_{DC}$ ), the frequency and the peak voltage values (peak min, peak max or peak-to-peak) are most frequently used<sup>[34]</sup>. The option to measure voltage in decibels is rarely used and with that less important<sup>[34]</sup>. Deverson was asked to mention the most frequently used measurement options and the less frequently used measurement options, without presenting all measurement options.

According to Maarten van Alphen, the continuity test, diode test en resistance measurements are most frequently used and with that most important in the field of troubleshooting. The voltage measurements ( $V_{AC}$ ,  $V_{DC}$ ,  $V_{AC+DC}$ , peak min, peak max, and peak-to-peak) together with frequency measurements are also frequently used and take the second place. Less frequently used are the ampere and temperature measurements, rarely used are the Crest Factor, capacity, pulse duration and event duration measurements and even more rarely used is the phase measurement option. Van Alphen was asked to tell something about the frequency of use of all measurement options by presenting all these options. The option to measure decibel was forgotten to mention in this list.

According to Bertus Kottier, the option to measure voltage in direct current ( $V_{DC}$ ) is frequently used. The options to measure  $V_{AC}$ ,  $V_{AC+DC}$ , peak max, peak min and resistance are used now and then. Rarely or never used are the options to measure voltage in decibel, measure ampere, peak-to-peak, Crest Factor, diode test, capacity, continuity, frequency, pulse duration, event duration, phase and temperature. Kottier was asked to classify the measurement options as frequently used (Dutch: veel gebruikt), used now and then (Dutch: af en toe gebruikt) or rarely or never used (Dutch: amper tot nooit gebruikt).

Because of the different conditions during the classifications, the ratings cannot simply be counted and ordered by importance. Moreover, a specific division on importance for each single measurement option is not necessary, because as similar interpret measurement options, like  $V_{AC}$ ,  $V_{DC}$  and  $V_{AC+DC}$ , should be placed near to each other because the user will expect the  $V_{AC}$  measurement to be close to the  $V_{DC}$  and  $V_{AC+DC}$  measurement options.

The classification of the measurement options by their frequency of use is presented in table 1 on the next page. The green colored measurement options are most frequently used, followed by the orange colored measurement options and the red colored measurement options, which are least frequently used.

### most frequently used

voltage	$V_{DC}$
	$V_{AC}$
	$V_{AC+DC}$
peak	peak min
	peak max
	peak-to-peak

### moderate frequently used

resistance	
frequency	
continuity	
diode test	

### least frequently used

capacity	
ampere	$A_{AC}$
	$A_{DC}$
	$A_{AC+DC}$
temperature	°C
	°F
Crest Factor	
pulse duration	positive
	negative
event duration	positive
	negative
phase	
decibel	

Table 1: classification of measurement options by frequency of use

### Conclusion

A distinguish can be made between the different measurement options according to their frequency of use. The classification should be taken into account by redesigning the ScopeMeter 120 series. The accessibility, and visibility of the measurement menu options should be in line with the importance, i.e. frequency of use, of these options.

### Conclusion

A distinguish into the different product functions as well as a discrimination between the different measurement options can be made according to their frequency of use. The classifications made in this part should be taken into account by redesigning the ScopeMeter 120 series. The accessibility as well as the visibility of both the functions and menus as the menu options should be in line with the importance, i.e. frequency of use, as mentioned in this section.

## User interface analysis

An analysis of the user interface of the ScopeMeter 123 will give insight in the strengths and weaknesses of the current user interface. First the screen area and arrangement are analyzed, followed by an analysis of the keypad and the menu structure and navigation. The analyses consist of observations, which are evaluated in the conclusion of each part. The design principles are used for the evaluation of the observations.

### Screen area and arrangement

The screen area of the ScopeMeter 123 is presented in figure 9.

According to Fluke <sup>[30]</sup>, the screen is divided into three areas:

- the reading area;
- the waveform area;
- the menu area.

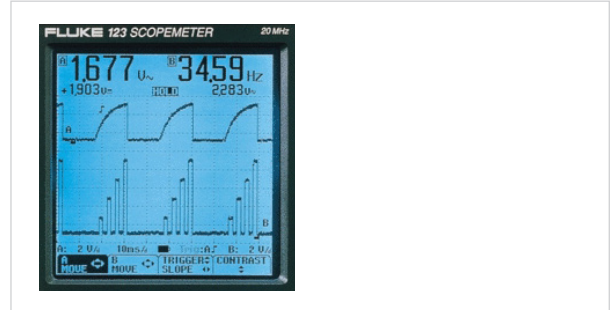


Figure 9: screen area



Figure 10: reading area (left), waveform area (middle) and menu area (right)

### Reading area

The 'reading area' displays the numeric readings, which are placed at the top of the display (figure 10). Within this area, the numeric readings of signal A are placed left and the readings of signal B, if attendant, are placed at the right. The numeric measurement results are labeled with A or B. This label is placed in the left corner of each part. Two different numeric measurement results of one signal are displayed most of the time. The largest numeric measurement result is the current measured parameter and the smallest measurement result is the previous measured parameter. The previous measured parameter is placed below the current measured parameter. Next to this measurement information, information is given about the status of the device. Between the two reading areas of signal A and B, information is given whether the waveform is set automatically, half automatically or manually. If the waveform is set automatically, the word AUTO will be displayed. If the waveform is set half automatically, nothing will be displayed and if the waveform is fully manually set, the word MANUAL will be displayed.

### Waveform area

The waveform of the received signals is displayed in the 'waveform area', which is arranged below the reading area (figure 10). The waveform area covers most of the screen area when the menus are closed. The ranges per div, power indicator and trigger information are displayed on the bottom line of the waveform area. The power indicator is placed in the middle on this bottom line. The label of the waveform of signal A is placed at the left end of the waveform. The label of the waveform of signal B is placed at the right end of the waveform. If the - left or right - end comes up, in case of a height in the signal, the label moves along with this end.

### Menu area

The menu items, which can be controlled by the function keys (F1, F2, F3 and F4) below them, are displayed in the 'menu area' which is placed at the bottom of the screen (figure 10). The menu area enlarges if a menu is opened. In this state it covers most of the screen area. The reading and waveform area are compressed along the length by opening a menu (figure 11) and the labels of the waveforms disappear.



Figure 11: compressed waveform area when a menu is open

## Conclusions

From an analysis of the screen several conclusions can be drawn:

### Reading area

- A lot of information is placed in the relative small reading area, especially when measurement results of two signals are displayed (figure 9). With that, little white space is used and boundaries are unclear which makes this area inconveniently arranged.
- Information about the status of the device (automatic, half automatic, manual or hold) is placed near to measurement information in the reading area while this is a different kind of information (figure 12). This makes the arrangement of information in the reading area even more inconveniently arranged.
- The meaning of the smaller numeric readout, which contains the measurement results of the previous measured parameter, is unclear. This was initially stated by personal observation but did also turn out during the usability test.
- The numeric readout of signal A is placed left from the readout of signal B, which reflects the reading direction from left to right of most users and therefore results in a logical arrangement of information. With that, the measurement information of signal A is placed near to the input of the probe corresponding with signal A and the measurement information of signal B is placed near to the input of the probe corresponding with signal B, which is consonant with the law of proximity<sup>[02]</sup>.
- There is a difference in size between the current and the previous numeric readout of a signal, which is consonant with the design principle that says that '*similarity causes confusion: use discriminable elements*'<sup>[03]</sup>.

### Waveform area

- The place of the power indicator in the middle of the bottom line of the waveform area does not follow the conventions which the users are familiar with. The power indicator is placed in the upper right corner of the display in most of today's devices. In addition, this kind of information differs from the information about waveform settings like the ranges per div and trigger information. The power indicator should be placed in the upper right corner of the screen.
- The waveform of signal B is placed below the waveform of signal A, which reflects the reading direction from top to bottom of most users and therefore results in a logical arrangement of information.

### Menu area

- The menu area is placed close to the function keys (F1, F2, F3 and F4) which are needed to control the menu. This is in line with the law of proximity<sup>[02]</sup> and will have a positive influence of the communication of the relation between the menu items of the menu area and the corresponding function key.

### General

- Next to a logical order (in reading direction) of the numeric readout areas and waveforms of signal A and B, they are labeled with A or B. This is consonant with the design principle called *redundancy gain*<sup>[03]</sup>, which says that *a message is more likely to be interpreted correctly when the same message is expressed more than once*<sup>[03]</sup>. This principle can be applied even better when color is used also to discriminate.
- The numeric readout area and waveform area are compressed by opening a menu, with the result that this information stays visible. This is in line with the design principle that says that *it is easier to recognize something than to recall it*<sup>[02]</sup>, which says that information must be visible so that people do not need to remember them.

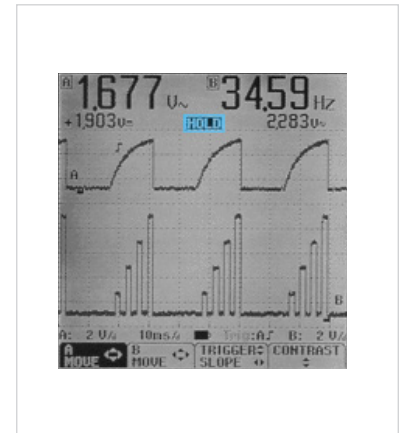


Figure 12: information about the status of the ScopeMeter in the reading area

## Keypad

The keypad of the ScopeMeter 120 series has 20 soft keys with which the device can be controlled. They are all situated in the area below the display. All keys have a textual or graphical indication and a color. The keypad is represented in figure 13 on the next page. The most important aspects are explained in this section. A detailed analysis of the keypad can be found in appendix E.

### *Keypad area A and B*

Two areas can be distinguished at the left and right side of the area with the arrow keys. The left area is related to signal A and the right area is related to signal B. This is indicated by an inscribed line around each area and an inscribed letter; A or B.

### *Function & arrow keys*

The four blue keys just below the display do not have one specific function. They are related to the menu items in the menu area on the display. The keys are called 'function keys' and are used in order to navigate through the menus, although they can only control the menu item on the screen right above the key. Arrow keys are used for navigation through menu options and to move a signal, trigger or cursor. As both the function keys and arrow keys are used for navigation, they have the same color.

### *Menu keys*

The two yellow keys correspond with the measurement menus related to signal A and signal B. The 'scope menu' button opens the 'scope inputs' menu and gives access to the 'scope options' menu, the 'probes' menu and the 'trigger' menu. The 'save | print' button gives access to save measurements or settings, recall measurements or settings, delete saved measurements or settings, and print measurements, settings or the current screen. All opened menus can be closed by pressing the corresponding button a second time.

### *Amplitude & time base button*

The two vertical oriented light gray buttons are used to adjust the amplitude of signal A and signal B. The horizontal oriented light gray button can be used to adjust the time base the signals. The texts on both sides of each key refer to the actual effect on the screen.

### *Hold & auto button*

The purple colored button enables the user to toggle between the hold and run function. Pressing the button once results in holding the measurements. Pressing the button again results in stop holding the measurements or in start running the measurements again.

The turquoise colored button labeled with 'auto' enables the user to toggle between the auto and manual modus. Pressing the button once results in automatic triggering and with that stabilizing the waveform. Pressing the button again results in turning off the automatic triggering function.

### *Arrangement on importance*

The function analysis can be used to analyze whether the arrangement of the buttons on the keypad is in line with the importance of the functions and menus corresponding with those buttons. In order to provide insight into this arrangement, figure 14 is made. Figure 14 can be found on the next page. In this figure, the buttons are marked green, orange or red, based on the results from the function analysis. Green corresponds with a primary function, orange with a secondary function and red with a tertiary function.



Figure 13: keypad of the ScopeMeter 123.



Figure 14: keypad marked according to importance of the corresponding function or menu

## Conclusions

From the conducted analysis of the keypad several conclusions can be drawn:

### General

- Many different colors are used, which can be confusing and unpleasant to look at<sup>[02]</sup>.
- The bright colored buttons attract the attention because the background of the keypad is dark gray, which is good because the bright colored buttons represent primary functions.
- There is an inconsistent use of the horizontal stroke between two words on a button. A stroke is placed between the words hold and run as well between the words save and print. The first one communicates a toggle function between hold and run, where the second one communicates two different functions that can be reached by pressing the button. This thereby results in an inconsistent communication of a button with toggle function.
- There is a consistent use of closing an opened menu by pressing a button a second time.

### Amplitude button

- Although 'mV' (millivolt) is less than 'V' (volt), the deflection of the waveform increases by pressing 'mV' and decreases by pressing 'V', which is technically correct, but not intuitive. The focus must lie on the effect on the screen and not on the technical correct effect. This must be taken into account by redesigning these (amplitude) keys.

### Time base button

- Although 's' (seconds) is more than 'ns' (nanoseconds), the length of the waveform decreases by pressing 's' and increases by pressing 'ns', which is technical correct, but not intuitive. The focus must lie on the effect on the screen and not on the technical correct effect. This must be taken into account by redesigning the time base key.

### Arrangement on importance

- The measurements button on the right, corresponding with the 'input B measurements menu', is brightly colored and situated near the screen, which does not reflect its importance; this menu is classified as a secondary function.
- The amplitude button on the right, corresponding with the 'amplitude B adjustment function', is situated near the screen, which does not reflect its importance; this function is classified as a secondary function.
- The trigger and cursor function are placed under function keys, which does not reflect their importance; these functions are classified as primary important.

### Menu structure and navigation

The higher order function of the ScopeMeter is to analyze a measured signal. In order to realize this, two basic tasks can be discriminated: (1) functions can be activated and (2) settings can be adjusted. The menu structure is initially designed to make these kinds of tasks possible.

#### General menu structure

The general menu structure of the ScopeMeter can be described as a tab menu structure (figure 15). Two different menu types can be distinguished in this tab menu structure.

The first consist of four always visible menu items at the bottom of the screen in the 'menu area'. These items can be selected by using the four function keys; F1, F2, F3 and F4. Although this menu type looks like a menubar<sup>[20]</sup>, there is one significant difference; the menu items change by selecting a function or opening a submenu. Regarding this analysis, this first menu type will be described as main menu (figure 16).

The second menu type can be described as a file tab that appears by opening a certain menu. This can be the 'measurement options' menu, the 'scope inputs' or 'scope options' menu, the 'user options' menu etc. The menu items in a submenu can be selected by the four arrow keys. Regarding this analysis, the second menu type will be described as submenu (figure 17).

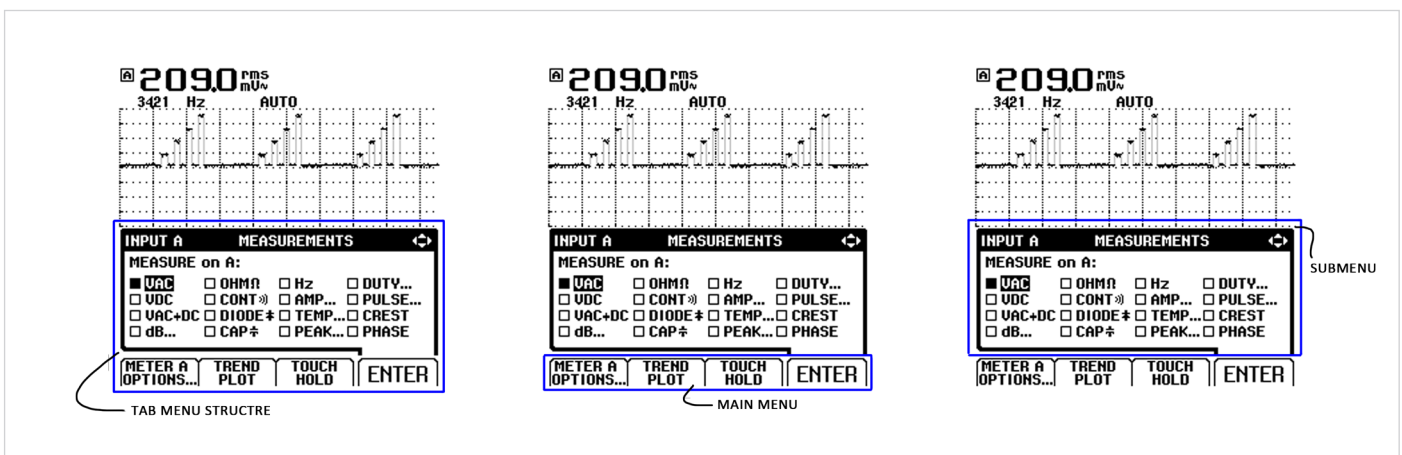


Figure 15: tab menu structure

Figure 16: main menu

Figure 17: submenu

### Main menu

The main menu (figure 16) is always visible. Menu items in this main menu are used to activate a function, to open or close a submenu, to toggle between several options, to accept a selected option, or to accept or reject a given action (figure 18). The menu items differ depending on the submenu that is opened or function that is active.

The menu items that activate a function differ from items that open a submenu by the dots that are placed when a submenu will follow. The only distinguish between menu items that accept or reject a action is the word that is used; YES or NO.

The ENTER key is always placed in the most right menu item, above the F4 key. The BACK... key is always placed in the menu item that opened the concerning submenu. This means that the place of BACK... differs for each opened submenu.

### Submenu

A submenu appears by opening a certain menu. This submenu or popup menu has fixed dimensions, irrespective the amount of options. A submenu is visually connected with ENTER in the most right menu item on the main menu to communicate that the selection(s) can be confirmed by pressing ENTER (figure 18).

There is always an option selected in the menus where an options needs to be selected. The current active option is the first selection by opening the submenu that contains that option (figure 19). One or more options can be selected by using the arrow keys,

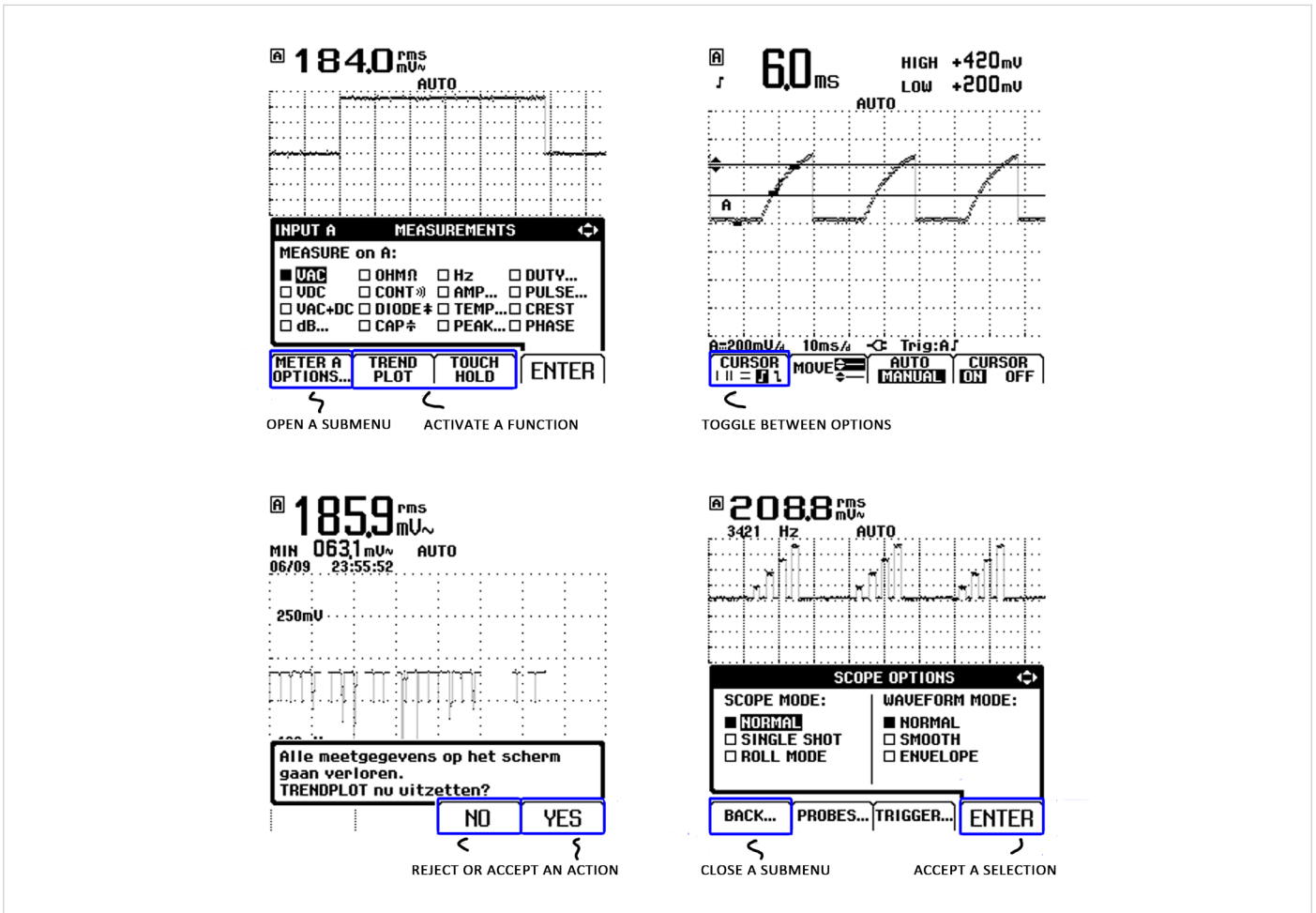


Figure 18: different functions of a menu item in the main menu

depending on the submenu that is opened (figure 20). When more options must be selected, the different column or columns where one option must be selected are separated by a vertical line.

The up and down arrow must be used to navigate through a column in a submenu. If the upper option is selected, the bottom option can be selected by using the down arrow. It is not possible to select the bottom option by going up after selecting the upper option.

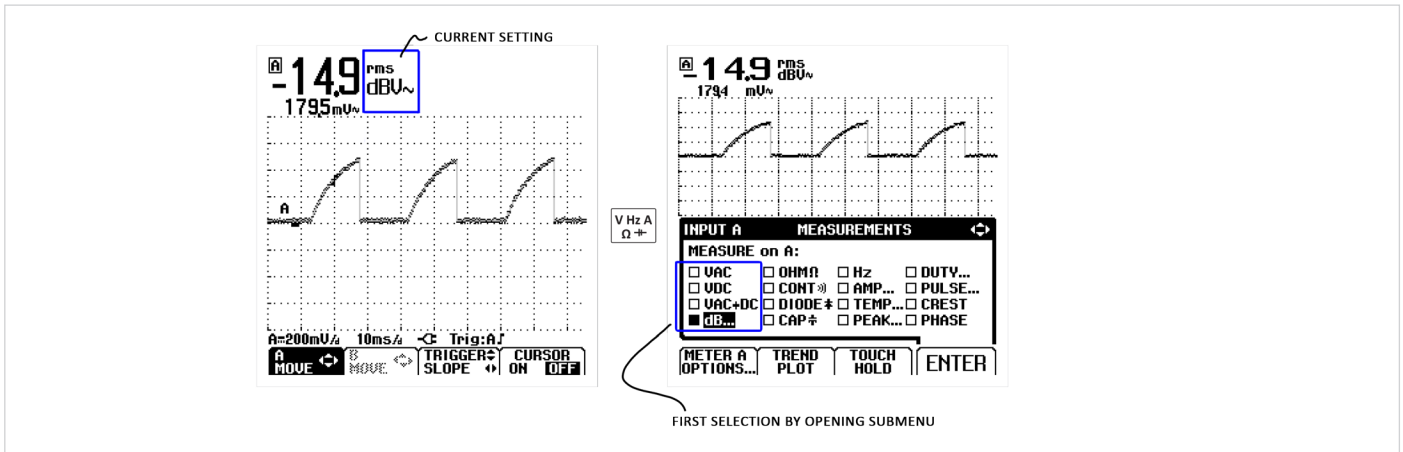


Figure 19: selected option corresponding with the current setting by opening a menu

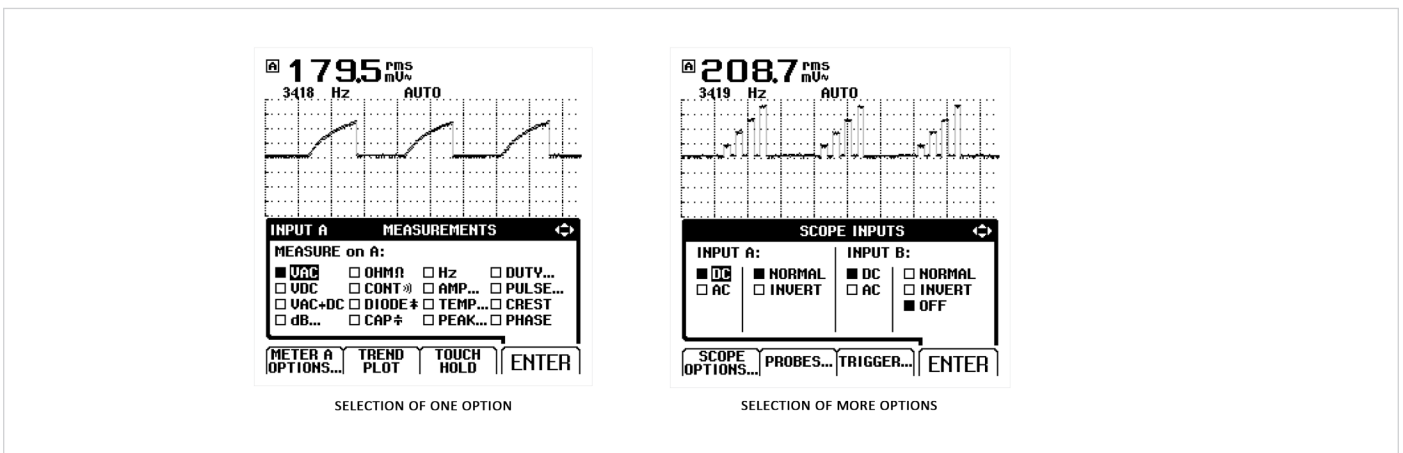


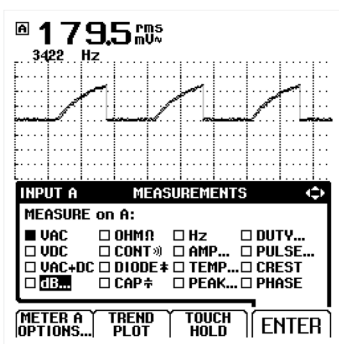
Figure 20: selection of one option versus selection of more options

### Popup menu

Some options in a submenu need more specification. Therefore a popup menu appears after selection of such an option (figure 21). The attendance of a popup menu, i.e. another submenu, is communicated by three dots behind an option. In the manual of the ScopeMeter this is explained as follows: *The dots ... behind (...) indicate that a submenu will follow on this section.*<sup>[30]</sup>

A popup menu appears on top of the opened submenu. This submenu stays visible at the top and left side of the popup menu, which results in a layering effect of the two menus (figure 22). Subsequently, the lower menu becomes gray instead of black, which communicates

The menu items of the 'main menu', which can be controlled by the function keys right below them, are empty when a popup menu is opened. Only the F4 key, 'Enter', is used to confirm a selection (figure 21 and 22). There is no explicit way of getting out of a popup menu (figure 24).



F4

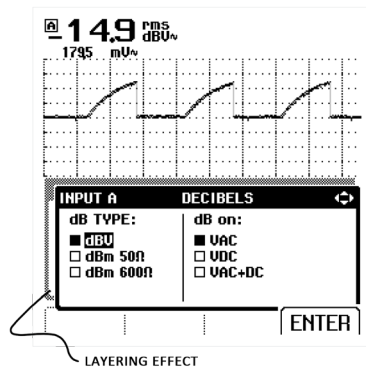
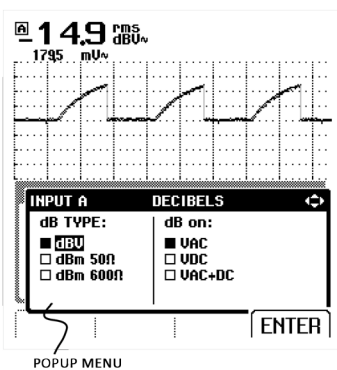


Figure 21: appearance of a popup menu

Figure 22: layering effect

In the case that one option needs to be selected, the submenu or popup menu closes after confirmation of the selection (by pressing 'enter' after selection with arrow keys). In the case that more options need to be selected, the submenu or popup menu closes after confirmation of the 'last' selection. With 'Last' selection, the selected option in the most right column or columns is meant. In case of selection in a popup menu, this means that also the corresponding submenu closes after confirmation of the selection. In other words: all currently opened submenus and popup menus are closed after confirmation of the (last) selection in a submenu or popup menu.

Unselected options are represented in black on white, which means black letters on a white background. Selected options are represented in white on black, which means white letters on a black background (figure 21).

All options in a menu have a checkbox, which is empty if the option is inactive. The checkbox becomes filled by confirmation of selection of the corresponding option (figure 21). There is direct feedback after confirmation of a selection by changing the numeric readout and/or the waveform representation, when a popup menu is opened after confirmation of a selection in a submenu or when other settings can be changed after confirmation of a selection (figure 23).

There is no explicit way of getting out of a submenu if that submenu is not opened by selection of one of the menu items in the 'main menu' when a submenu is opened (figure 24). If a submenu appears after selection of the menu in another submenu, there is an explicit way of getting out of the submenu (figure 24).

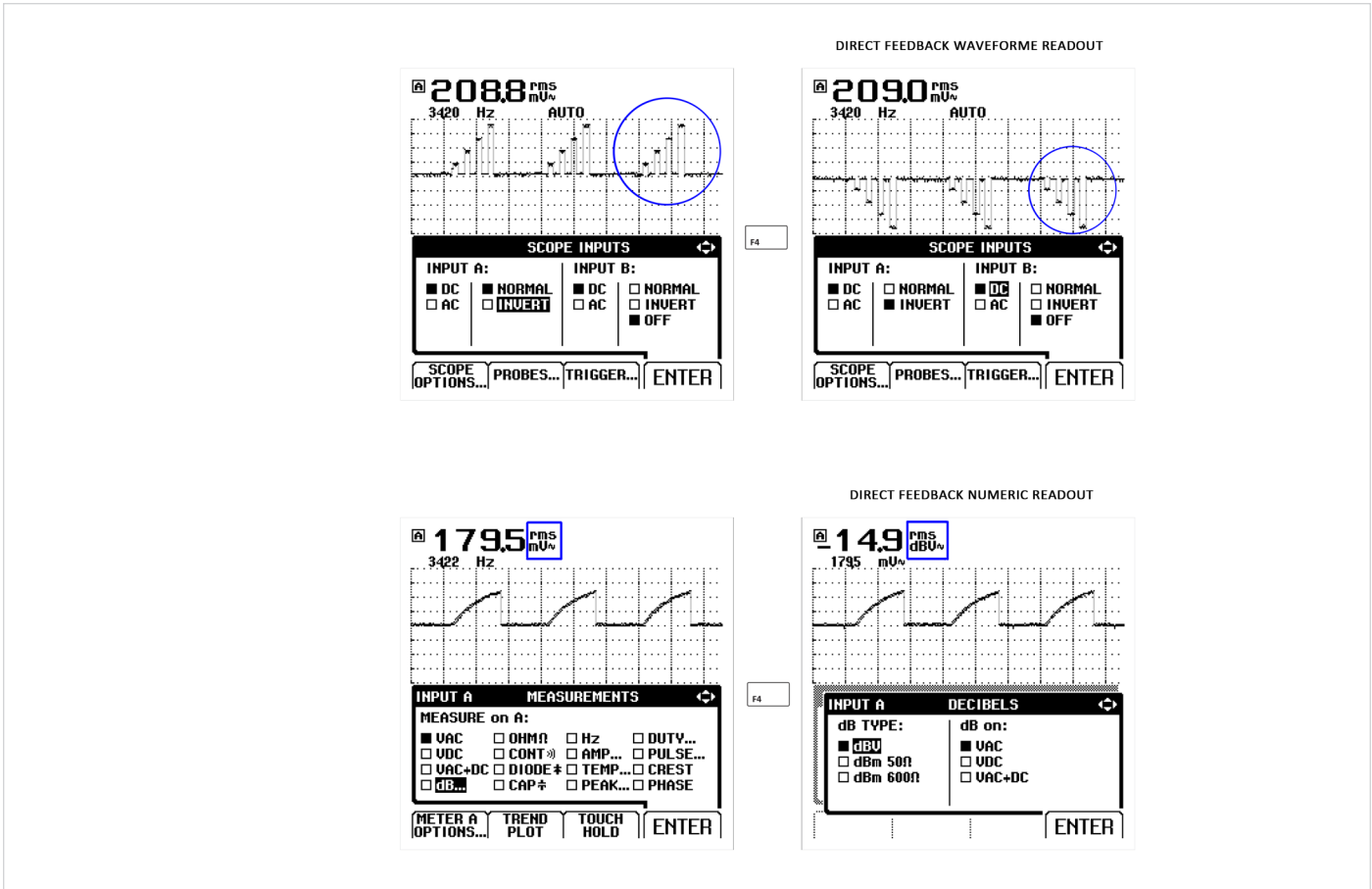


Figure 23: direct feedback after confirmation

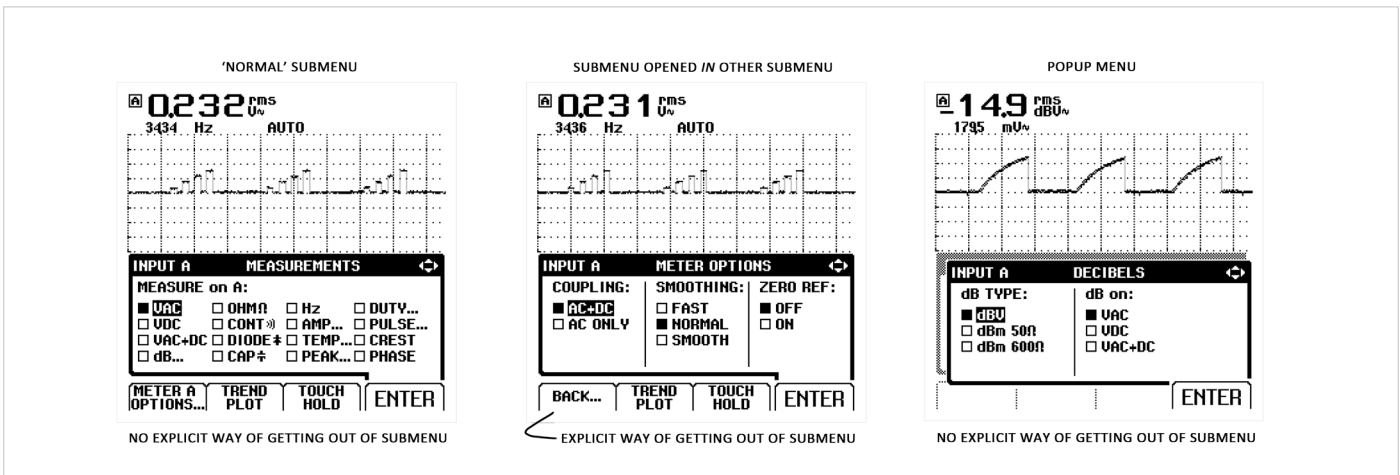


Figure 24: explicit versus no explicit way out of a submenu

*Specific observations*

The menu items in the cursor menu (the menu items of the main menu after activation of the cursor function) contain several options (figure 25). The desired option can be selected, i.e. activated, by toggling between the options with the function keys (F1, F2, F3 and F4). When a horizontal cursor is selected, the up and down arrow keys can be used to move the selected cursor up and down (figure 25 left). When a vertical cursor is selected, the left and right arrow keys can be used to move the selected cursor to the left and to the right (figure 25 right). In the cases with two cursors, the other arrow keys, which cannot be used to move the cursors, can be used to toggle between the two cursors. The concerning menu item does not need to be selected with the function key. More specific, the user can toggle between the horizontal cursors, which are arranged under each other, with the left and right arrow key. With the F1 key the cursor type can be selected. Although the cursor type options are arranged next to each other, it is impossible to use the left and right arrow key to select another cursor type.

Several labels on the menu items of the main menu contain instructions about their control (figure 26). For example, move A or move B can be done by using the four arrow keys, the triggering can be accomplished by using the up and down arrow and changing the slope (when triggering) can be accomplished by using the left and right arrow. Although these instructions are visible all the time, they can be used only if the corresponding function, i.e. action, is activated.

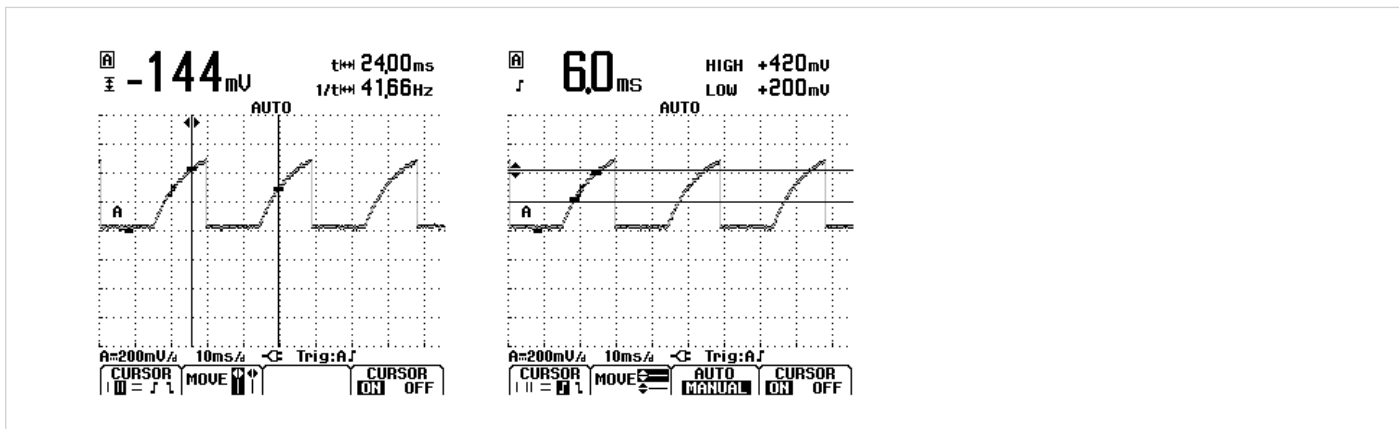


Figure 25: screen with cursor menu after activation of cursor function

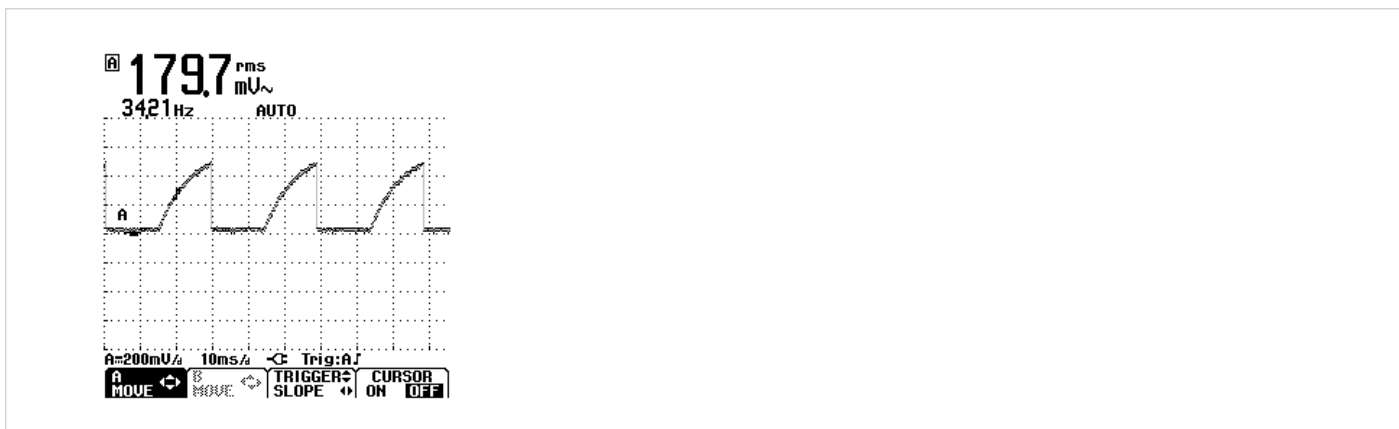
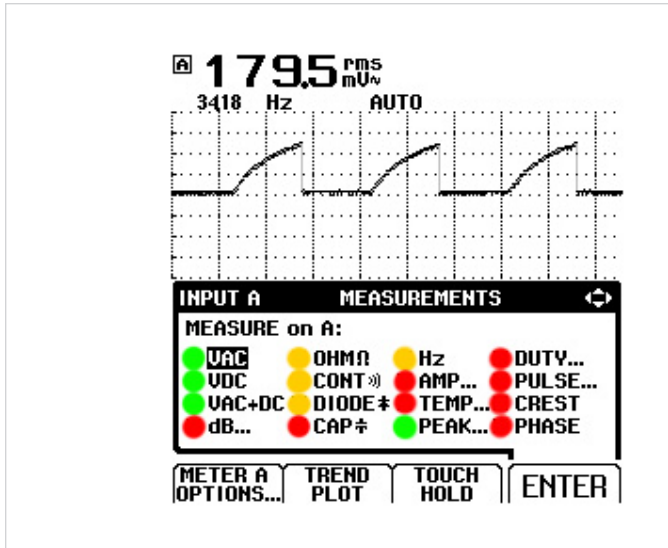


Figure 26: menu items of main menu



#### Arrangement of measurement menu options

The function analysis can be used to analyze whether the arrangement of the options in the measurement menu are in line with the importance of the measurement options. In order to provide insight into this arrangement, figure 27 is made. In this figure, the options are marked with a green, orange or red dot. Green corresponds with a frequently used measurement option, orange corresponds with the measurements options that are used now and then, and red corresponds with the less frequently used measurement options.

Figure 27: measurement options marked according to their importance

## Conclusions

### *Incorrect use of tab menu structure*

Because the menu items of the main menu look like tabs and the submenus look like file tabs, the general menu structure can be described as a tab menu structure. With that the structure contains the principle that another submenu can be opened by selection of another menu item in the 'main menu', i.e. one of the tabs. Nevertheless, there are two important differences in the menu structure of the ScopeMeter contrary to a tab menu structure. The first one is that not all tabs (menu items of 'main menu') contain a so called file tab (submenu). The second one is that a file tab is always visually connected to the most right tab (menu item of 'main menu') and not to the tab that 'opened' the corresponding file tab (submenu). This results in confusion of the place in the menu structure, especially by opening a submenu in another submenu. The guidelines to *follow real-world conventions* and with that *to obtain clear and correct mental models* are not followed.

### *No way out*

There is no way out of a popup menu, which does not follow the guideline that says to always allow a way out to encourage users to explorer the interface and to avoid that the user feels trapped<sup>[28]</sup>.

Some of the submenus do not provide an explicit way out, which may demotivate the user to explorer the interface.

One way out of a submenu is to press enter, i.e. confirm the current settings. After confirmation of the last option, all opened popup menus and submenus are closed. This means there is no way to return to a previous submenu, which indirectly means there is no way out and therefore is not in line with the guideline that says to *always allow a way out*.

### *Inconsistency*

The changing menu items of the main menu may result in a longer learning curve, because it does not follow the principle of consistency, which says that *if the users know what to expect, it will be easier for them to build a conceptual map of what should happen next*<sup>[27]</sup>.

The same goes for the alternating place of 'BACK...' in the main menu when a submenu is opened. From personal experience it became clear that the conceptual model, or structure, that is behind the changing place of 'BACK...' became clear after a relative long time.

When the cursor function is activated and the 'move cursor' menu item is selected, the user can toggle between the two cursors by using the function key, which is consistent with the rest of the interface. However, the user can also toggle between the two cursors by using the arrow keys, which is inconsistent with the rest of the interface and may result into an incorrect mental model of the system. More specific it was analyzed that the user can toggle between the horizontal cursors, which are arranged below each other, with the left and right arrow, which is not logical and which is not in line with the law of similarity<sup>[02]</sup>. Moreover, the possibility of toggling between options in the cursor menu with the arrow keys may result in the expectation that another cursor type can be selected by using the left and right arrow key, which is incorrect.

#### *General*

Although the instructions attached on the menu items in the main menu are visible all the time, they can be used only if the corresponding function, i.e. action, is activated. From own experience and usage observations it became clear that the visibility of the instructions lead to the critical usage of trying to follow these instructions before the corresponding function is activated.

There is a high contrast between selected and unselected items, which is consonant with the principle of discriminability.

### **Multimeter analysis**

From research on the user and its experiences it became clear that users are familiar with using multimeters. In order to design an interface that is consistent with the conventions users are familiar with, a short analysis on the user interface of multimeters is conducted.

Figure 28 (next page) represents a selection of digital multimeters. A number of similarities in the user interface of the multimeters can be noticed. The most general conventions can be formulated as follows:

- A knob is used to select or set a certain measurement option or setting.
- Symbols are used to communicate the concerning measurement option or setting.
- A shift key is frequently used to provide a larger number of measurement options or settings.
- The probe inputs are situated at the bottom of the device, on the front.

#### **Conclusion**

In order to design an interface that is consistent with the conventions users are familiar with, the user interface should be consistent with the conventions applied on multimeters, regarding the user interface.

### **Conclusion**

The analysis of the screen area showed that the reading area is inconveniently arranged, although arrangement of the signal information and waveforms is in line with the reading direction of most users. The keypad analysis showed a lack of univocal communication regarding the function of several buttons. With that, it has become clear that much space on the keypad is used for buttons related to signal B, in spite of the fact that these buttons are only used in 10-20 percent of the use case.

Most critical points arise from the menu structure analysis; incorrect use of the tab menu structure, no way out or no explicit way out of several submenus, and inconsistency within the main menu, where actions, functions or menus, that can be reached by the menu items, change a lot, which make the interface difficult to learn.

Furthermore, words are used instead of symbols in labels that correspond to measurement options, which is not in line with the conventions used in multimeters.



Figure 28: selection of multimeters

## 1.7 Conclusion

The ScopeMeter 123 can be described as a basic handheld oscilloscope which is mainly used for industrial troubleshooting. The user can be described as an electrical technician within the field of 'maintenance and repair' and with an intermediate or higher technical educational background. Because the user has to deal with time pressure, as well as a pressure to achieve, the ScopeMeter must be efficient, effective and error tolerant.

In most of the cases, a multimeter is sufficient to find the cause of a problem. That is why most users have little experience with using the ScopeMeter, as the ScopeMeter is only used once in a while. Therefore, every time the ScopeMeter is used may be interpreted as a first usage and so the ScopeMeter must be easy to learn. Because most users use a multimeter almost every day, following the conventions applied on multimeters may help the user to understand the ScopeMeter faster.

The analysis showed that the current product is not experienced as easy to use by users with less or no experience using the product. The user interface analysis gave insight in the improvements that can be made due to the learnability of the ScopeMeter 123.

The by Fluke conceived main goal in redesigning the user interface of the ScopeMeter 123, which says that the product should fulfill a task by the push of a single button, may clarify the problems that came up after analysis of the user interface of the current ScopeMeter. From the analysis it can be concluded that in the current user interface, the design guideline referred to as *the 111 solution* was not taken into account. The interface was made efficient by giving access to a function or menu within as few steps as possible without taking the real time it takes to reach the function or menu into account. Searching for the desired function or menu may take a lot of time if a lot of information is visible, which is partly the result of designing an interface that can fulfill a task by the push of a single button.

The by Fluke mentioned 'main goal' is in fact a solution for the requirement that says that the product, or user interface, should be efficient, i.e. provide in a quick usage. This requirement should be the starting point in designing the user interface, instead of the by Fluke mentioned solution.

Furthermore, Fluke mentioned the battery life to be one of the most critical aspects of the current product. However, it is plausible that users will mention problems with the battery capacities rather than problems they experience regarding the ease of use, because people have the tendency to blame themselves and not the product if it comes to usability of products.

All together it can be concluded that the learnability of the user interface should get attention, as important improvements can be made on this *user experience dimension*.

Although no specific problems came up regarding the efficiency and effectiveness of the product, they turned out to be important aspects to the user, who has to deal with a lot of time pressure and a pressure to achieve. However, improvements on the effectiveness of the product should rather be obtained in redesigning technical capabilities of the product. Therefore, this aspect should get less attention in redesigning the user interface of the ScopeMeter 123.

The proportions of the current product have an important contribution on the communication of the capacities and price of the product, as can be seen in figure 7. According to Fluke, it is important to keep the current proportions of the ScopeMeter 120 series, in order to maintain this communication. Next to this requirement, Fluke has formulated the requirement to not radically change the design, to ensure identification with the 120 series. Changing the product proportions radically may come at the expense of the identification with 120 series as well as a clear communication of the products capacities and price. It would require research in the field of product segmentation and marketing, in order to design a product that clearly communicates its capacities and price and is still identified with the Fluke ScopeMeter 120 series.

Another important requirement that has to do with the proportions of the product is the requirement that the product should be easy to carry, i.e. portable, as the product is used on different locations. However, it is not stated that the proportions of the ScopeMeter, which can be shortly described as long and small, are required to remain the same due to this portability. Nevertheless, radical changes on the proportions would require research in the field of ergonomics, not only to ensure portability, but also to ensure a good manageability. Unfortunately, research in these fields does not fit in the frame of this assignment, due to the chosen focus and time limitations of the assignment. Therefore, the current proportions will be conceived as baseline in redesigning the user interface of the ScopeMeter 123.

The primary persona showed experience of the user with using touch screens. Although the application of a touch screen may create important opportunities, for instance regarding easily zooming in on a glitch in a signal, the application would require research on the sturdiness and durability of touch screens, as the product should endure *extreme temperatures, moisture, dust, corrosives, and rough handling*<sup>[32]</sup>. Next to this, a study on the effect of a dirty environment and wearing gloves on the usability is needed to avoid critical use scenarios. Also the influence on the confidence of the user in the product should be investigated by implementing a touch screen, regarding the marketability of the product.

However, based on a quick estimation on the feasibility of a touch screen for the new ScopeMeter 123 it is assumed, implementing a touch screen will not be that beneficial given the current usage of a ScopeMeter. First, the user could use gloves. In this case a touch screen will not respond properly. Second, in the work environment of the ScopeMeter there is a lot of dirt like grease, oil or dust. Using a touch screen in this environment will significantly reduce the readability of the screen. Consequently, it was chosen not to include the use of a touch screen in this assignment. That is why the appearance of physical keys is chosen as a baseline in redesigning the user interface of the ScopeMeter 123.

The user interface of the ScopeMeter is a decisive factor in selling the product, as the product is exclusively sold via the internet or magazines. Because the focus of this assignment is on redesigning the user interface of the ScopeMeter, this marketability requirement cannot be ignored. Conceiving the requirement as a baseline in redesigning the user interface may come at the expense of the usability of the product, as the presence of certain buttons play an important role in both the communication of the capacity and function of the product as well as the usability of the product. In order to manage the focus on both aspects (usability and marketability), a weighting factor should be assigned based on the importance within this assignment.

## Requirements with weighting factor

The five dimensions of user experience in the framework for usability can be interpreted as five general design requirements. The priority that should be given to each dimension, represented in the framework of usability, can then be interpreted as the weighting factor of each requirement. Beside these general usability requirements, a requirement regarding the marketability and requirements conceived as baseline were formulated. Figure 29, on the next page, represents the relation of these requirements.

From the analysis, several requirements can be formulated, which can be classified as part of one of the six general requirements or as a baseline requirement. The division of requirements is represented in table IV in appendix F.

The formulated requirements with weighting factor will be used in the decisions that will be made during the concept generation.

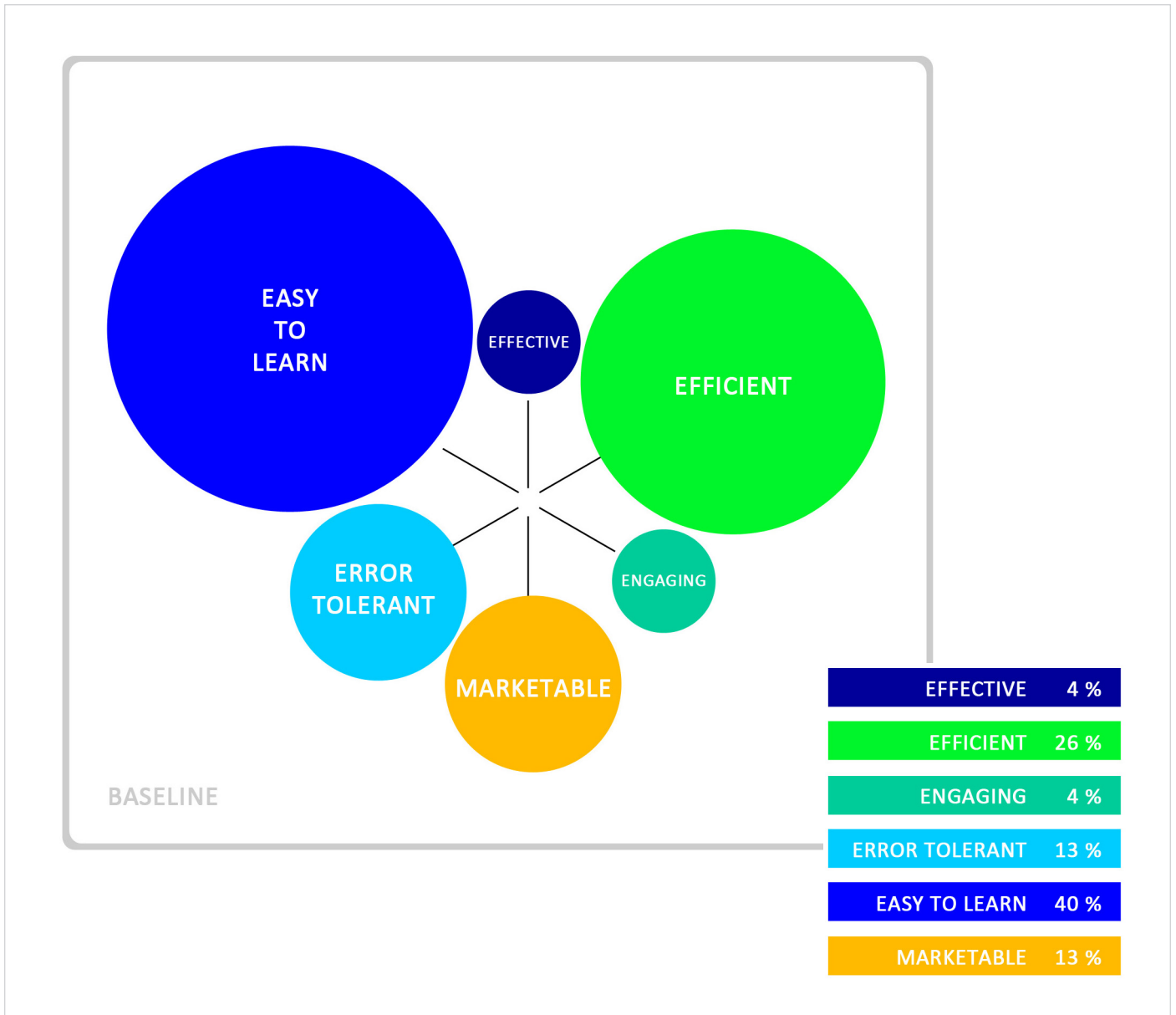


Figure 29: balance of usability and marketability requirements within a frame of baseline requirements

## 2 PART TWO | from ideation to concept choice

Part two contains an ideation from which three concepts are generated. Finally one concept is chosen. The ideation and concept generation are subsumed under the following headings:

- 2.1 **Screen design**
  - Use of color
  - Main screen area
  - Menu structure & navigation
  - Measurements menu
  - Visibility battery life
  - Summary
  
- 2.2 **Keypad design**
  - Content
  - Design
  - Arrangement
  - Concept choice

As mentioned in the conclusion of part one, the current product proportions of the ScopeMeter 123 will be conceived as baseline in redesigning the user interface. A concept design of the housing of the next generation of the ScopeMeter 120 series created by Benchmark will be used as starting point in redesigning the user interface of the product (figure 30). The dimensions of the display in this concept are 96 x 72 mm and the resolution will be 640 x 480 pixels.



Figure 30: concept design housing with new display (right)

## 2.1 Screen design

The ideations regarding the screen design are subsumed under four headings: ‘use of color’, ‘main screen area’, ‘menu structure and navigation’ and ‘visibility battery life’. Choices are made after the ideation of each part. Subsequently these choices are summarized at the end of the chapter.

### Use of color

As mentioned in the section ‘design guidelines’, color can be used to draw attention, to show status, to make information on the display clearer or to make the display more attractive. The focus within this ideation will be on the use of color to improve the arrangement of the information in the screen, as this is mentioned to be an important aspect in redesigning the user interface of the ScopeMeter.

From the user interface analysis it was concluded that the screen area was inconveniently arranged, particularly in the reading area. Color will be used in order to improve the arrangement of the reading area.

As can be seen in figure 31, the probes and the input of the probes are colored to clarify which signal is represented by the information and waveform labeled with A, and which signal is related to label B. In the current product, input A is colored red and input B is colored gray. The relation between the information on the screen and the measured signal can be made clearer by using the same colors in the screen as used for the input of the probes. Also the relation between the numeric information and the corresponding waveform can be made clearer using the same color. Besides this, the colors can be used to improve the arrangement of the reading area.

To determine which two colors can be used best, the discriminability of colors is analyzed. This is important since the colors should also be discriminable by people with color blindness. The discriminability of a single color on a white background is examined, as also the discriminability between two colors.

Although color will be applied in order to improve the arrangement of the information, it will also influence the attractiveness of the display. In order to design a display that will be general accepted, extreme or less general accepted colors should be avoided. Therefore only the basic colors red, blue, green and yellow are considered. With these colors also gray is analyzed, as the B input of the current product is gray.

In order to test whether the colors are discriminable, the colors are transformed to the corresponding gray tint. This makes clear the contrast between colors if colors cannot be perceived. The discriminability of the colors can be analyzed in figure 32.

Looking at the third column in figure 32, it can be seen that blue and yellow are best discriminable. However, yellow is difficult to distinguish from a white background, as can be seen in the first column. Therefore a combination of red and blue is chosen to use in redesigning the user interface. The colors are discriminable without color, and both red and blue are also clearly visible on a white background. Red will be related to the signal on input A, as this corresponds with the convention in the current product. Blue will be related to the signal on input B. Furthermore, it is recommended to give input B a blue color, to clearly communicate the relation. This should be taken into account in the developments after this assignment.



Figure 31: ScopeMeter 123 with colored probes

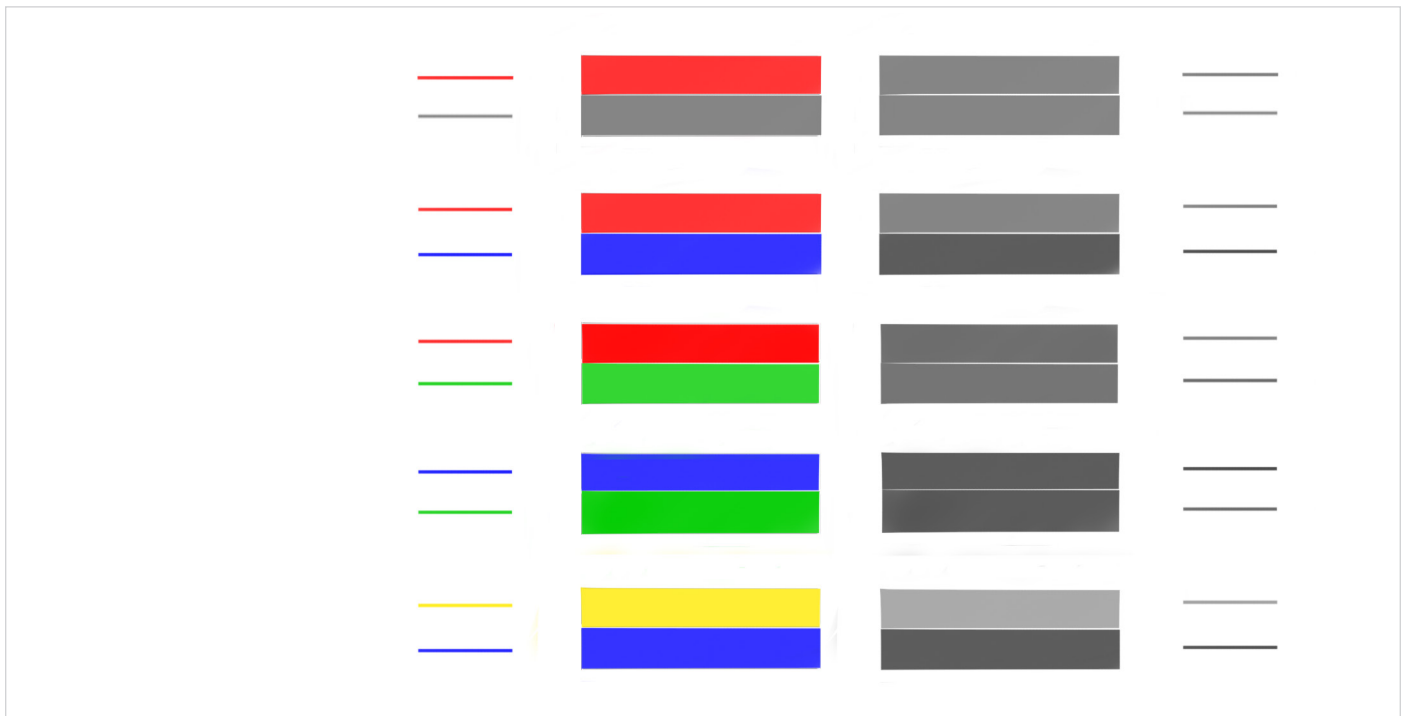


Figure 32: discriminability of colors

## Main screen area

The ideations regarding the main screen area are subdivided in ideations regarding the general arrangement and in ideations regarding the numeric readout area.

### Arrangement screen area

There is chosen to maintain the division into clear separated areas in the screen area. Full integration of the waveform and numeric information may come at the expense of the arrangement of the area. Moreover, the appearance of a clear numeric area may be desired by the user, as the user is familiar with multimeters.

An extra area at the top of the screen is added, to separate the information about the status of the device (AUTO, HOLD, MANUAL etc.) from the measurement information in the numeric reading area, as well as the information about the battery life from the waveform information at the bottom of the waveform area (rage per div, trigger information etc.). It gives the possibility to place the battery status in the upper right corner, which is in line with conventions the user is familiar with.

There are several options in the arrangement of the screen area. In order to improve the arrangement of information on the screen, an ideation is performed, which can be seen in figure 33.

The created options (figure 33) differ on two points. The first is the place of the numeric information in the reading area in relation to the waveform area. The second is the place of the numeric information of signal A in relation to the numeric information of signal B within the reading area.

There is chosen to place the numeric measurement information of the two signals below each other instead of next to each other. This is decided because only in 10-20 percent of the use cases, information of two signals will be attendant. Placing the information of one signal sideways will create a larger waveform area in 80-90 percent of the use cases.

The decision to place the numeric information of the signals below each other has reduced the number of options to three. Because it is desired to compare information if two signals are analyzed, the numeric information of the two signals should be placed near to each other. Arranging the numeric information on top of the waveform area will create a more conveniently arranged screen than if the reading area is placed below the waveform area, because in the second case a lot of numeric information is placed near to each other which may come at the expense of the arrangement. Therefore the numeric information of both signals will be placed on top of the waveform area.

In the drawings of figure 33, an area at the bottom of the screen is reserved for menu items corresponding with function keys. However, when these function keys will be left out, this area obviously will be left out to.

### Numeric readout area

The numeric readout area contains a lot of information. Color can be used to improve the arrangement of the area. Figure 34 shows some ideas of labeling the numeric area of one signal with a color.



Figure 34: ideation labeling numeric information

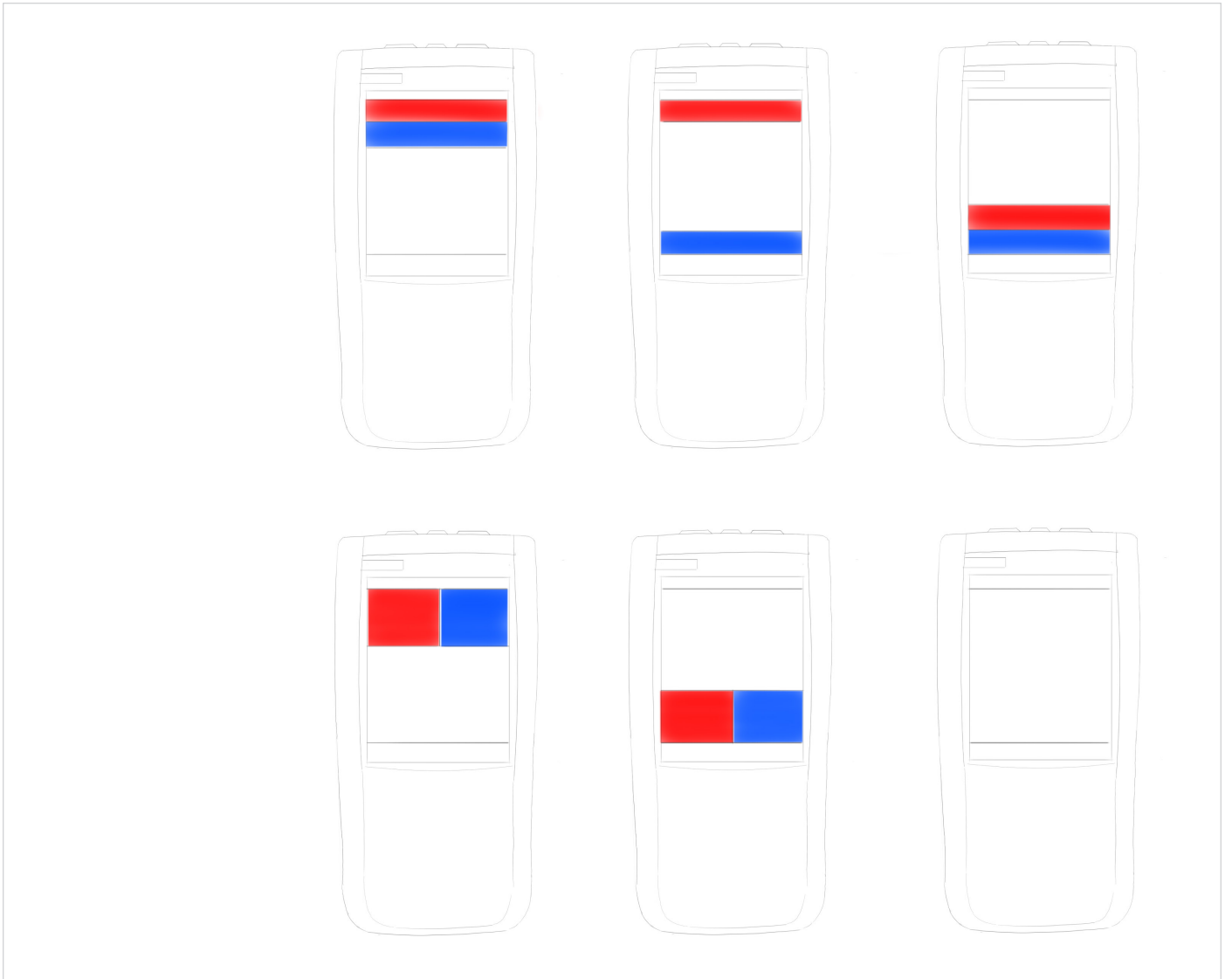


Figure 33: ideation arrangement screen area

Black letters on a white background are desired regarding the legibility of the information. Therefore the first option is not chosen. A broad line on the right (or left) side of the area gives the opportunity to visually separate the label A or B from the rest of the information, as can be seen in figure 36. The design with two sides of the area outlined is chosen, because it gives the opportunity to visually separate the area A and B from each other, as can be seen in figure 35.

Figure 35 represents several options of orientation, regarding the chosen design. The four options at the left provide more arrangement than the options at the right side. Although the reading direction of most users is from left to right, numbers may also be aligned at the right. Based on intuition, the two options presented in figure 36 are chosen from the left four ideations.

From the two chosen options, the left option presented in figure 36 is chosen as it is in line with the reading direction of the user.

In order to improve the arrangement of the information, a difference in contrast between the current and previous measurement information is provided. This can be seen in figure 36.

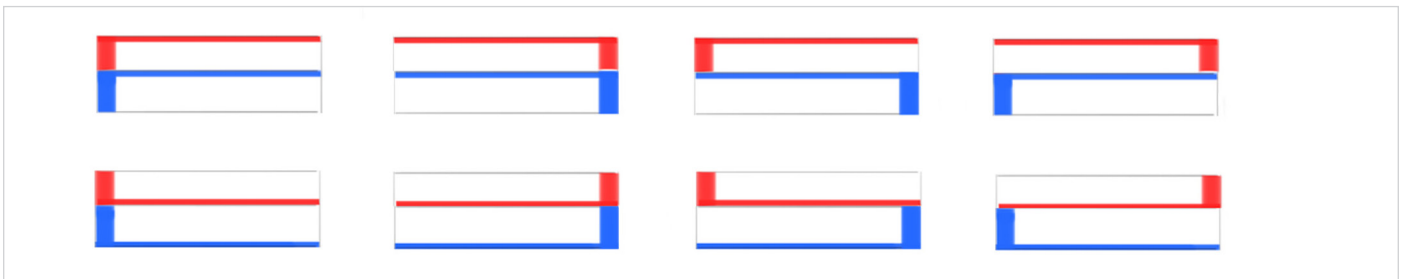


Figure 35: ideation design numeric readout area

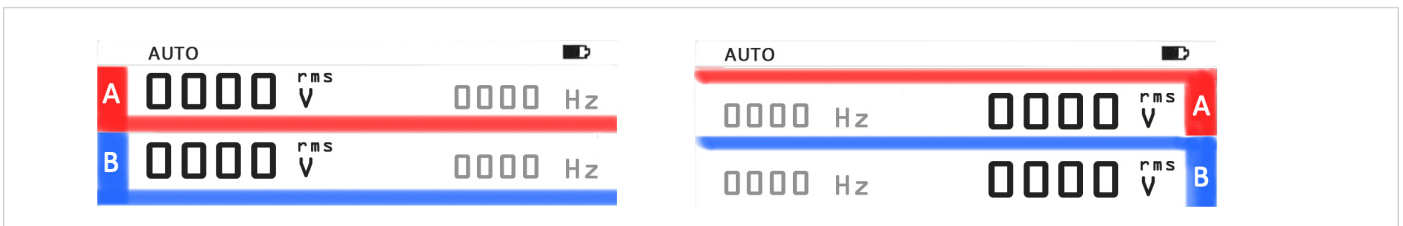


Figure 36: selection of the design of the reading area

## Menu structure and navigation

One of the conclusions drawn from the user interface analysis is that the metaphor that is used to clarify the menu structure is incorrectly applied, resulting in an interface that is inconveniently arranged and difficult to remember.

It is chosen to design a menu structure with more depth and less width compared to the current menu structure, to reduce the amount of information that is visible on the screen and to reduce the time users need to find a function or menu. In addition, this choice enlarges the possibilities to improve the menu structure, such that it is in line with real-world conventions and easy to remember.

To realize the above mentioned it is chosen to present one menu at a time. In a tab menu structure as applied in the current user interface, more than one menu is visible ; next to the

menu options in the file tabs a submenu corresponding to one of the file tabs is visible.

Although a minimum of visible information contributes to the arrangement of the screen, it remains important to communicate the place in the total menu structure.

Figure 37 represents two possible visualizations of the depth in a menu. The visualization of a system with submenus represented on the right in figure 37 is called a cascading menu<sup>[02]</sup>. Because this menu is exclusively used in combination with mouse control<sup>[02]</sup>, it should not be used in the user interface of the next generation of the ScopeMeter 120 series. Moreover, this design does not reduce the information visible on the screen and therefore should not be chosen. The design on the left in figure 37 visualizes the layering of menus and clearly visualizes the depth of the menu. Furthermore, it only shows one menu, which results in a minimum of information visible on the screen.

Figure 38 on the next page represents a visualization of navigation through a system of 'equal' menus, i.e. menus on the same level. These visualizations are rather used to visualize broad menu structures than deep structures.

All five visualizations refer to real-world conventions. In theory, a method of navigation through menus on the same level can be combined with a method of navigation through submenus. However, some combinations may be incorrectly understood and lead to an incorrect mental model, as they do not correspond with real world conventions. Therefore, it is chosen to only use the layering effect as represented in figure 37.



Figure 37: visualization of navigation through a system of submenus

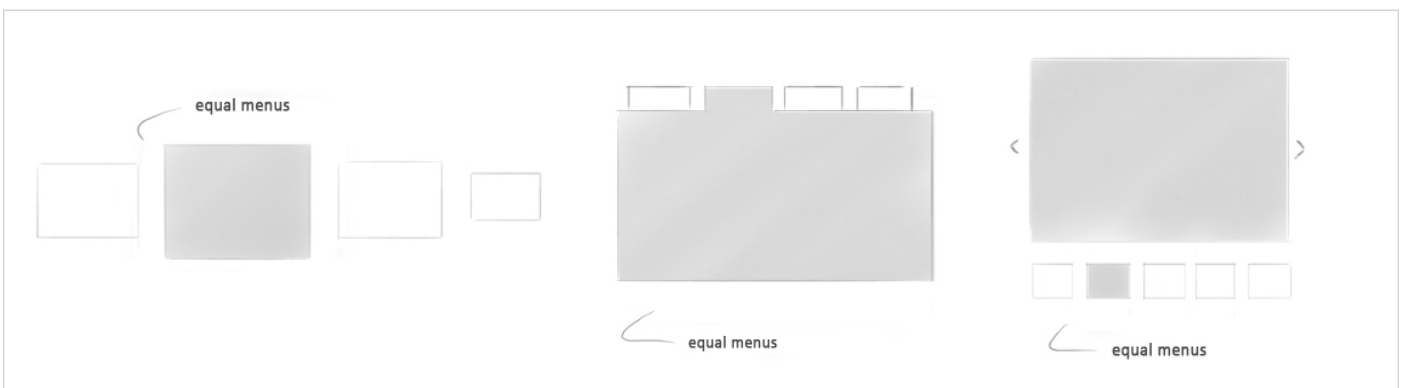


Figure 38: visualization of navigation through a system of 'equal' menus

Briefly, it is decided to use the layering of sheets as a metaphor to visualize a deep menu structure and to communicate a menu structure with submenus that follow on each other. This metaphor is solely used to minimize the amount of information on the screen and to avoid confusion from using several metaphors together.

In order to clearly communicate the exact place in the menu structure next to the depth, the titles of the menu beneath the visible menu should remain visible. Therefore, the menus are layered such that the top part of a previous menu remains visible. In order to improve the layering effect, a difference in contrast is created between the current active menu and the inactive menus beneath this menu (figure 39). In order to clearly communicate which of the menus (and thus which titles) are inactive and which is active, it is chosen to give the inactive menus a gray color (figure 39). It is decided to give the active menu a red, blue or black color to communicate whether the menu options are related to signal A (red), signal B (blue) or both (black).



Figure 39 design of layered menus

### General menu design

A menu consists of several options that can be selected. Two menu types can be distinguished: menus where only one option can be selected and menus where a combination of options should be selected. The second one is in fact a combination of menus where only one option can be selected. However, there is made a distinguish between the two, as combining menus that are functional related will contribute to insight in the possibilities of adjustment regarding a certain function of the ScopeMeter. Besides, combining several small menus avoids a complex system of many menus which is difficult to understand and to remember.

Figure 40 shows a menu with several options. In order to minimize the visible information in the screen, the menu can be designed such that only the information of the selected column is visible (figure 40, right). The drawings in figure 40 are very abstract, but led to more concrete and realistic ideas:

1. labeling of each option with a minimum of information, for instance a symbol, which is always visible, and attaching of extra information that only will be visible if the corresponding column is selected, i.e. opened, to minimize the amount of visible information and to ensure a clear and univocal communication about the option;
2. applying the possibility to directly navigate to the desired column by using physical keys just below the columns, like the function keys in the current user interface.

In addition, the design on the right in figure 40 improves the communication about the current selection, i.e. the current place in the menu.

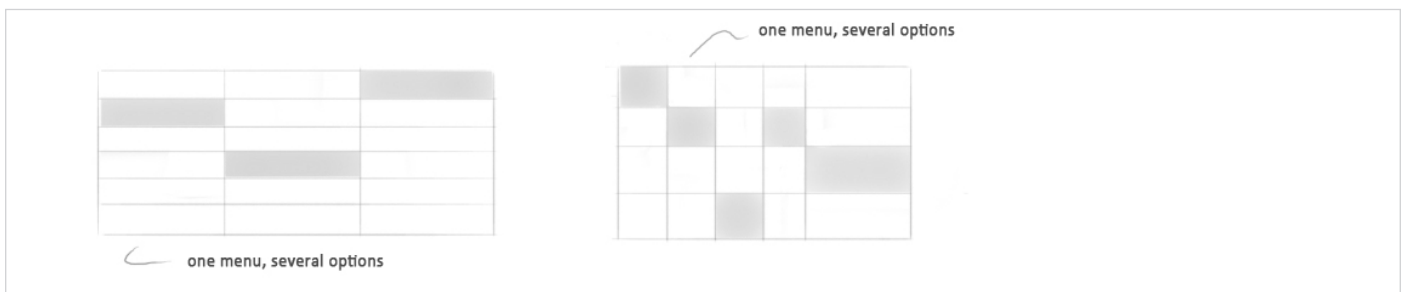


Figure 40: minimizing the information visible in a menu with several options

The menu design at the right of figure 40 with more concrete ideas can be applied on both menus with one option and menus with several options to select. Figure 41 on the next page represents an explanation of the design applied on a menu with one option. Figure 42 represents an explanation of the design applied on a menu with more options. In figure 42, distinguish is made between the current selection and the current setting. Furthermore, the right drawing in figure 42 shows a concept where the columns have a different number of options.

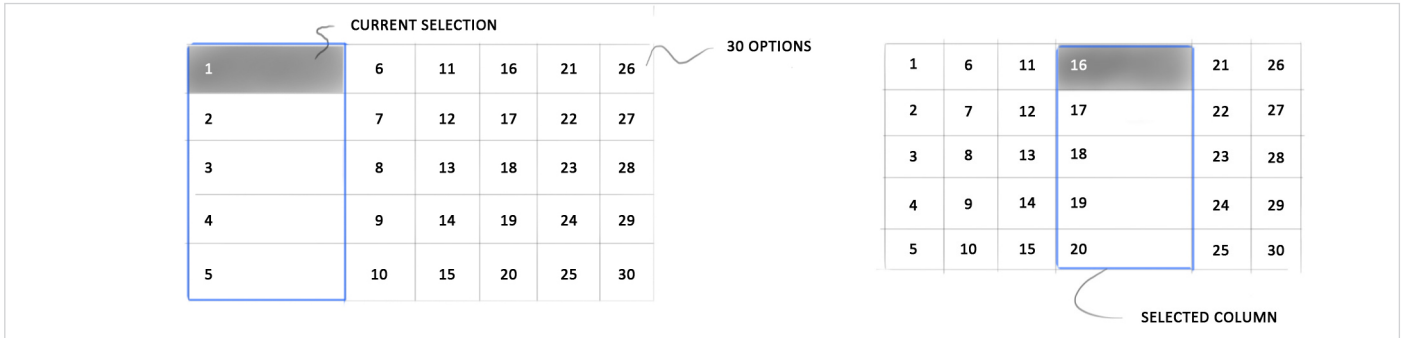


Figure 41: design of a menu with one option

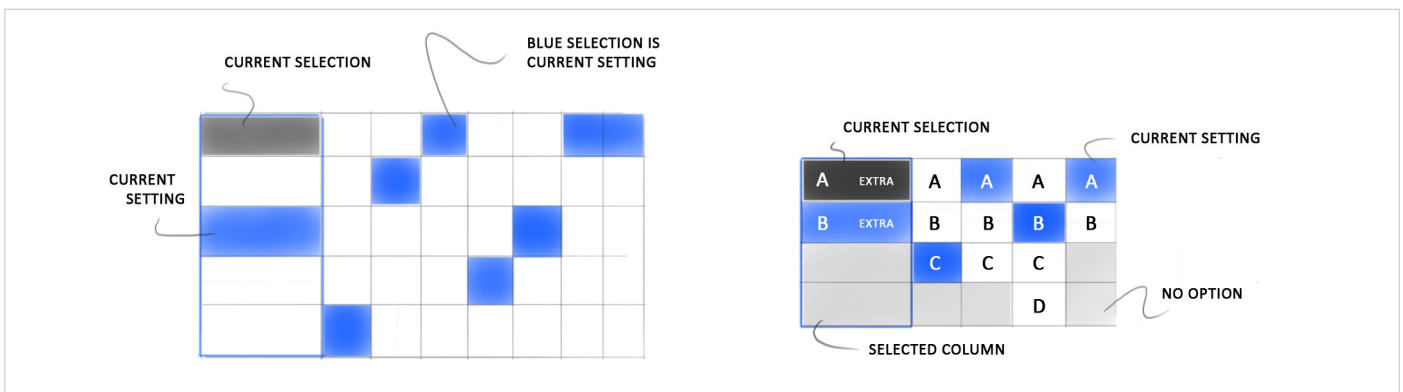


Figure 42: design of a menu with more options

The figures 43, 44, 45, and 46 show an ideation on the design of a menu with more than one option.

The design at the right in figure 43 most clearly communicates that the menu exists of four small menus of which one options should be selected. Therefore this design is chosen.

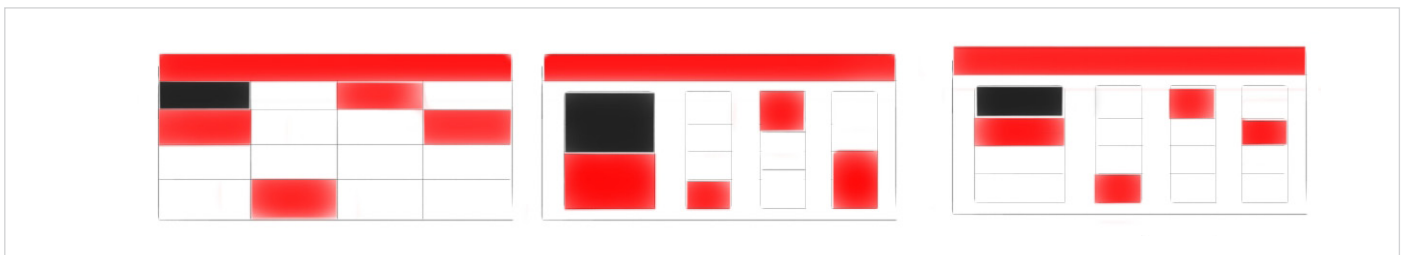


Figure 43: design of a menu with more than one option

Figure 44 shows three designs of columns with an unequal number of options. Again the design at the right provides the most clear and confidently arranged menu and is therefore chosen.

Figure 45 shows a menu design with a white background and a menu design with a colored background. In the first design (left), the red marked menu options stand out. In the second design (right) the menu options with a white background stand out. However, a white label (textual or graphical) on the red colored menu options will also let these options stand out in the design with a colored background. Therefore it is chosen to use a colored background.

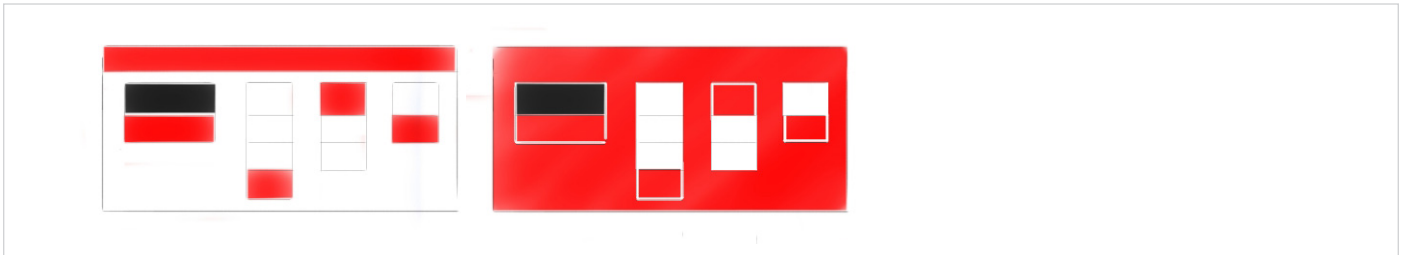


Figure 45: menu design; white background versus colored background

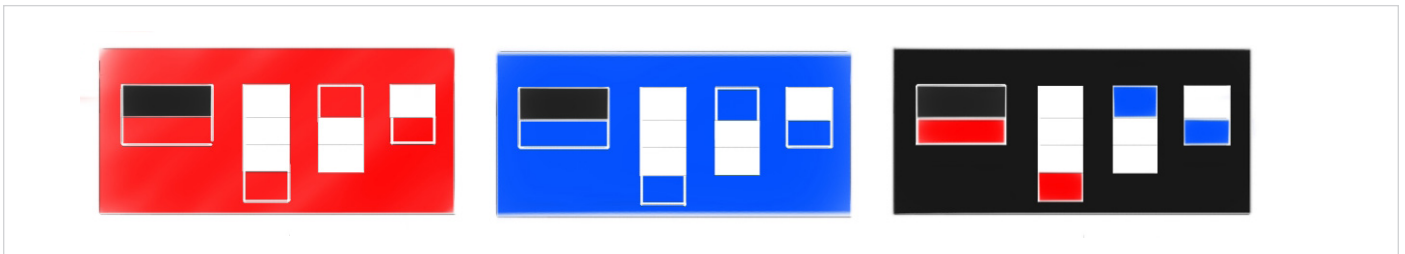


Figure 46: design of menu related to signal A (left), signal B (middle) and to both signals (right)

It is decided to give the active menu a red, blue or black color to communicate whether the menu options are related to signal A (red), signal B (blue) or both (black). Regarding the legibility, the menu options should be discriminable from their background. Furthermore, there should be a clear difference between the currently set menu option(s), the other menu options and the currently selected menu option. Therefore it is chosen to use white on red or blue for the menu options related to the current settings and black on white for the other menu options (figure 42, right).

Figure 46 shows the design of a menu related to signal A, signal B and to both signals. If the current setting is related to signal A, the background color of this menu option is red, if the setting is related to signal B, the option is blue colored. If more than one option can be selected or set and all options are related to signal A, the menu is red labeled as also all currently set menu options (figure 46, left). If all options are related to signal B, the menu and all currently set menu options are blue labeled (figure 46, middle). If a part of the options is related to signal A and another part to signal B, the menu is black labeled and the menu options are red and blue labeled (figure 46, right). The currently selected menu option is colored white on black (figure 42).

The mentioned design choices can be applied on a menu with one menu option, with exception of the division in separated columns.

### Measurements menu design

The measurements menu is a frequently used menu. However, not all menu options in this menu are equally frequently used. The arrangement of the menu options should be in line with the importance of the menu options, to provide efficient usage.

#### *Use of symbols*

In order to design an interface that is consistent with the conventions users are familiar with, symbols should be used to communicate the concerning measurement option or setting. The symbols should be in line with the symbols used in multimeters. Figure 47 shows a selection of the chosen symbols. The selection is made based on an analysis of the symbols used in the multimeters represented in the analysis phase.

The words PEAK and DUTY are well known terms within the field of electrical engineering and therefore clearly communicate their function. As there are no well known symbols that represent these functions, it is chosen to use the words PEAK and DUTY and no symbols.

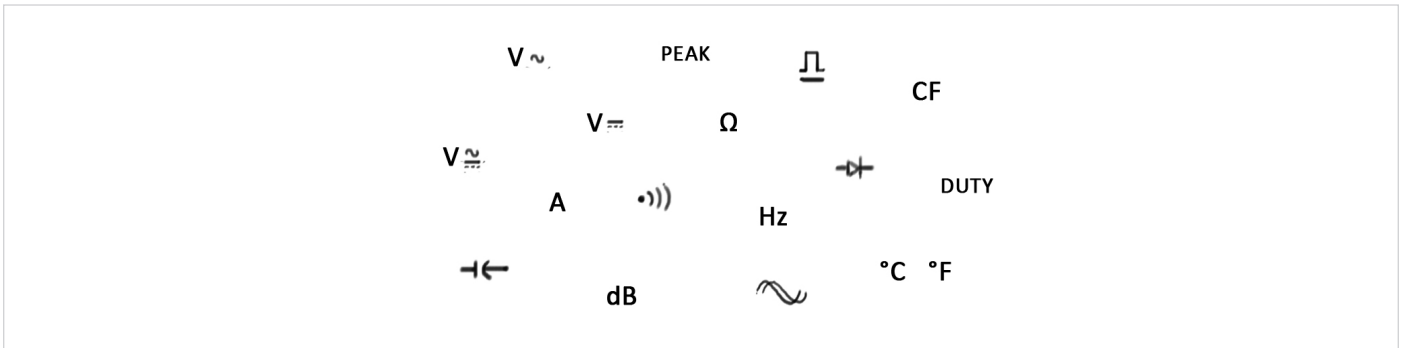


Figure 47: chosen symbols

#### *Arrangement of options*

The ideal arrangement of menu options depends on the method of navigation. Following from the ideation of the general menu structure, two conceptual navigation methods can be distinguished: navigation with arrow keys and navigation with function keys.

In order to evaluate the generated ideas regarding the arrangement of menu options in the measurements menu, the menu options are colored by their importance as assigned in the function analysis. Frequently used menu options are green colored, less frequently used menu options are orange colored and rarely used menu options are red colored. In addition, each place in the menu is colored according to its accessibility.

When using the arrow keys for navigation, the accessibility depends on the beginning position. It is assumed that the most frequently used option should be placed in the left upper corner, as the reading direction is from left to right and from top to bottom and this position therefore will be perceived at first. Therefore this position is taken as starting point regarding the evaluation of the arrangement of the menu options in the different concepts.

The accessibility of the different positions is represented in figure 48 on the next page. The green outlines positions are direct accessible or accessible after one action, the light orange options are accessible in two steps, the dark orange options in three steps and so on.

When using the function keys for navigation, all options in the upper row can be reached at once. This is because the desired column can be reached by pressing the function key below the corresponding column and the upper option will be selected by 'opening' a column. The options in the second row can be reached in two steps, with exception of the second option in

the column of the currently selected menu option, which then can be reached at once. The options in the third row can be reached in at least three steps and the options in the fourth row can be reached in at least four steps. The accessibility of the different positions using the function keys is represented in figure 49.

In addition to the physical accessibility of each position, the perceptual accessibility should be taken into account. Figure 50 represents the perceptual accessibility of the positions, based on the reading direction of most users. The light green outlined column is assumed to be perceived first, followed by column at the right of this first column and so on. This perceptual accessibility is the same for both navigation methods.

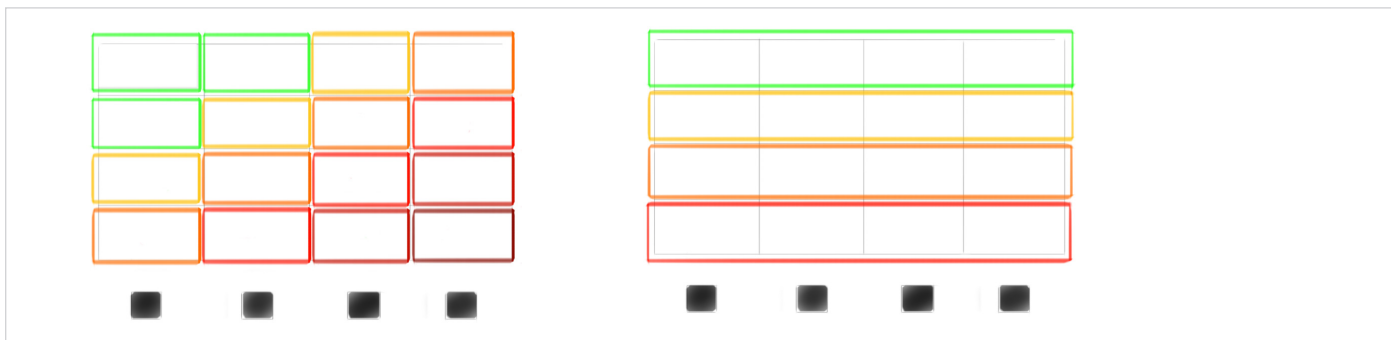


Figure 48: accessibility of the menu options from navigation with arrow keys

Figure 49: accessibility of the menu options from navigation with function akeys

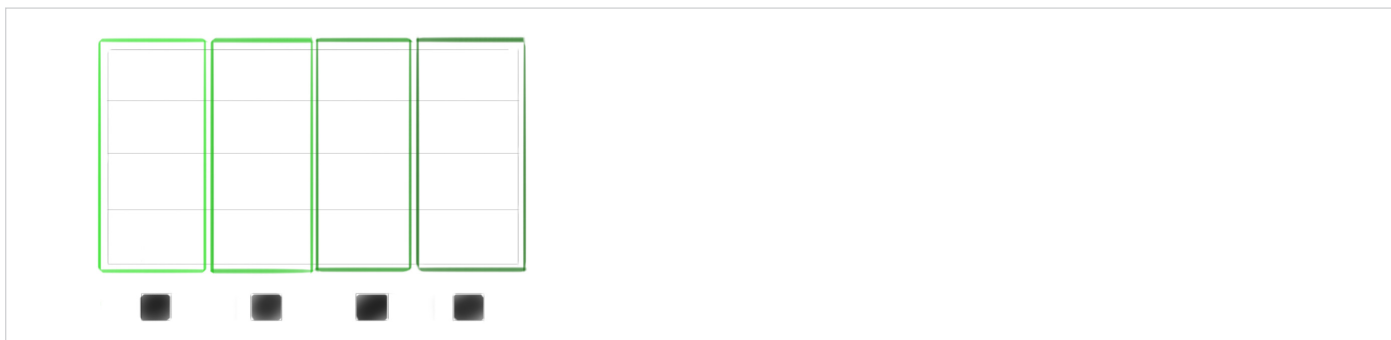


Figure 50: perceptual accessibility of the menu options

Figure 51 represents the ideation on the arrangement of menu options. In this ideation six positioning alternatives for the menu options are elaborated.

The use of color in this figure is twofold. First the symbols themselves are colored, with respect to their frequency of use. Secondly, the colored line around a symbol or a group of symbols represents the accessibility from navigate with arrow keys (column 1) or navigate with function keys (column 2). This way it can be checked whether the arrangement of menu options can be ideal from both navigation perspectives. Next to the individual arrangement of the menu options, the arrangement of the options with respect to each other is taken into account. Several menu options are clustered regarding their function.

The ideal arrangement from each perspective individually is chosen and outlined in black. As can be seen in figure 51 both perspectives result in different ideal arrangements. This implies that the ideal arrangement of menu option depends on the (main) way of navigating that will be chosen.

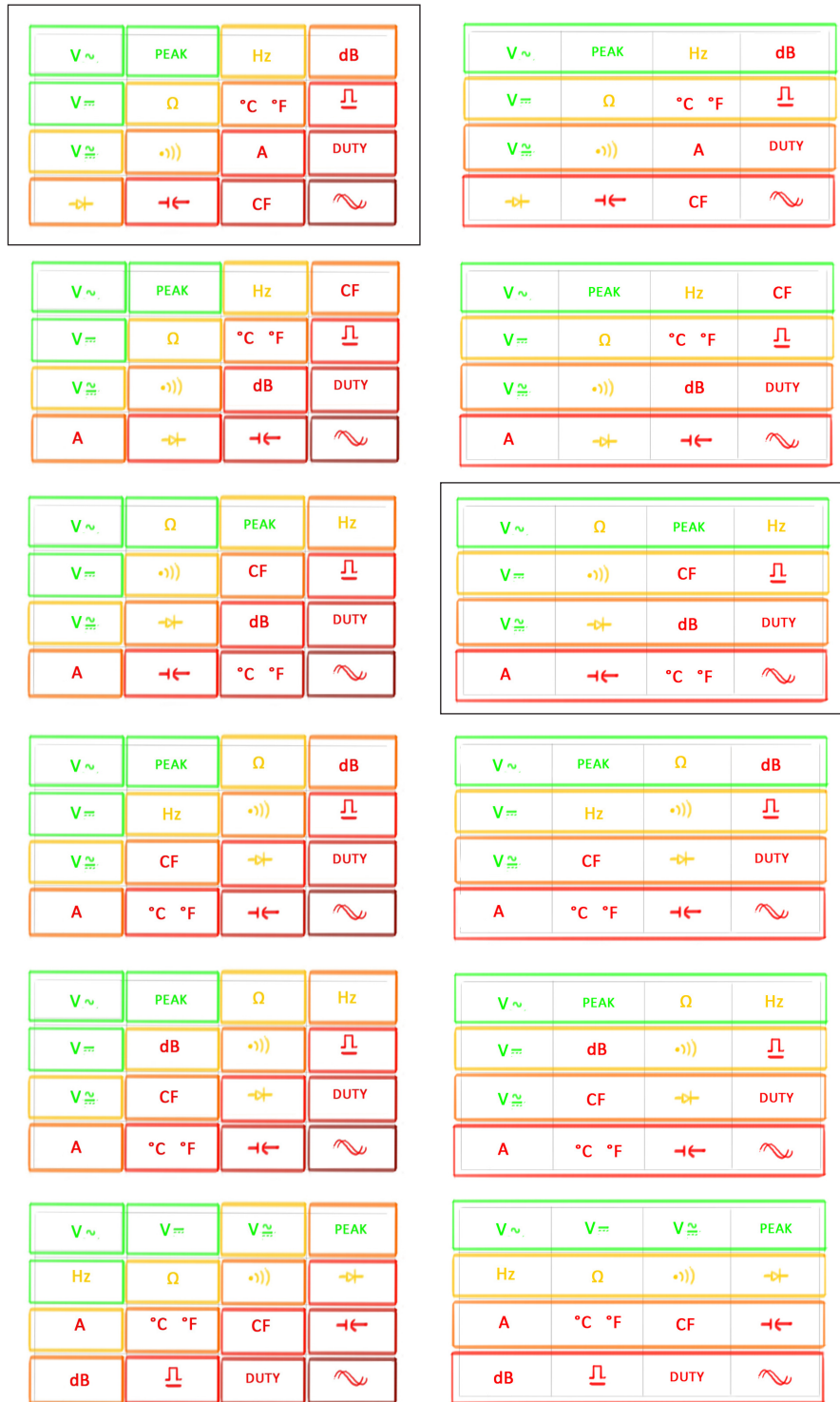


Figure 51: ideation on arrangement of measurement options

## Visibility battery life

In order to prevent the critical use scenario of an empty battery to occur, an ideation on the visibility of the battery life is provided.

In this ideation on the communication of the battery life, two ideations can be distinguished; an ideation on the communication of the battery life in general and the communication of a critical battery status.

### General communication of battery life

In almost all products with a battery and a display, the battery life or power status is communicated through a symbol that visually communicates the remaining power. A symbol provides a quick and easy indication of the remaining battery life. However, it only gives an indication of the relative battery status, as the symbol only communicates the remaining percentage or part of the total battery life.

From the user and usage analysis it has become clear that the ScopeMeter is infrequently used. Therefore it is plausible that the user does not exactly know how long the ScopeMeter can be used if the battery is fully charged, which makes it difficult for the user to correctly estimate the remaining hours the ScopeMeter can be used without charging. Because of this, it is decided to give an absolute indication of the remaining battery life. To maintain a quick and easy indication of the remaining battery life also a symbol will be used to communicate the relative remaining battery life.

### *Absolute communication of battery life*

The detail of the absolute information should be considered, in order to efficiently communicate the remaining battery life. The detail should fit the user needs. For example, if the by the device estimated remaining battery life is 6 hours, 19 minutes and 52 seconds without charging, communication about this exact number of minutes and seconds is useless as they will not influence the users behavior. In addition, the communicated accuracy is not in line with the accuracy of the estimation, as the actual remaining battery life depends on the actions that will be performed. In case of 6 hours, 19 minutes and 52 seconds remaining battery life without charging, communication of whole hours only will fit the user needs. However, in case of 1 hour, 35 minutes and 28 seconds remaining, communication of 2 hours round does not fit the desired accuracy. Within this remaining period of time, an indication in whole and half hours better fits the desired accuracy. 1 hour and 35 minutes should clearly be rounded down to 1½ hour. However, in order to avoid the critical use case of an empty battery to occur, the estimation of a remaining battery life of 1 hour en 46 minutes should also be rounded down to 1½ hours. In order to avoid the critical use case of an empty battery to occur, it is decided to round down all estimated remaining battery time with an accuracy of half hours. However, from a remaining time less than one hour, it is assumed that an accuracy of half hours does not fit the desired accuracy. Although the estimation still may be influenced by the actions that will be performed, an estimation of the remaining time in minutes is assumed to be desired as it provides a more clear and univocal indication of the severity of the situation. In addition, an indication of the remaining time in minutes instead of hours will stimulate the user to charge the device. Therefore it is decided to give an indication of the remaining time in minutes if the remaining time is less than one hour.

### *Relative indication of battery life*

As mentioned before, a battery symbol is widely used to give an indication of the remaining battery life. Therefore, this battery symbol is used in the redesign of the ScopeMeter 120 series. However, many variations can be distinguished in the design of this symbol.



Figure 52: two battery symbols with a different visualization of the content

Figure 52 represents two different visualizations of the content of the battery. If the battery is positioned horizontal and the content of the battery is interpreted as a liquid, the right symbol in figure 52 fits the metaphor best, as it better visualizes the liquid to flow away. However, it is easier to interpret the remaining battery life from the left symbol in figure 52, as all parts that imaginary can be distinguished are equal, contrary to the parts that can be distinguished in the right symbol (figure 53). Therefore it is chosen to use the visualization represented in the left symbol of figure 52.

It is mentioned that the content of the battery symbol can be imaginary divided in equal parts, as visualized in figure 53. A division of the content in parts may improve the ease with which the remaining battery life is perceived. However, figure 54 shows that this does not hold in case of a division in five parts.



Figure 53: division of content in parts

Figure 54: division of content in different parts

The battery symbol is used to provide a quick and easy indication of the remaining battery life. Additional absolute information about the remaining battery life provides a more specific indication of the remaining battery life. Therefore, it is not needed to provide a specific indication of the remaining battery life through the battery symbol. A visualization of running down of the battery in four or three steps will be enough and so a division in five steps is not needed. As four steps is more specific than three steps but still easily perceived it is chosen to visualize the running down of the battery in four steps. In addition, it is chosen not to visually divide the content of the battery symbol in parts, as it does not fit the idea that the symbol just gives a rough indication of the remaining battery life.

It is chosen to position the battery symbol horizontal, as it then fits best in the horizontal area at the top of the screen. Figure 55 shows a horizontal oriented battery symbol and a vertical oriented battery symbol.



Figure 55: horizontal (left) and vertical oriented battery symbol (right)

Color can be used in order to communicate the severity of the situation. Figure 56 represents possible ideations on the use of color to communicate the severity of the situation. In this case, color is used to show status. However, in case of a critical battery life, it is desired to use color to draw attention. The use of color for all possible battery life statuses may decrease the attention drawn in case of a critical battery life. Therefore, it is chosen to only use an eye-catching color in case of a critical battery life and not for all possible battery life statuses.

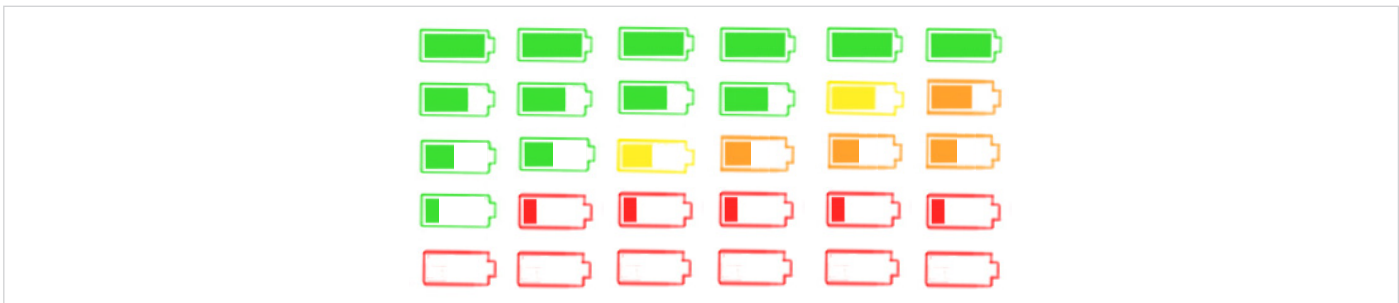


Figure 56: ideation on use of color to communicate the severity of the situation

### Communication of critical battery status

In the ideation on the use of color to communicate the severity of the situation (figure 56), a difference can be noticed in the point from where the battery status is interpreted as critical. In order to avoid a critical use case to occur, it is important to inform the user in time. However, a signal should not be given too soon, as it will decrease the by the user interpreted importance of the signal. It is decided to attach an eye-catching color to the battery symbol if the remaining time is less than 1 hour. When the remaining time is less than 10 minutes, attention will be drawn by flashing the battery symbol.

The last step, i.e. most empty battery in the ideations in figure 56 are red colored. However, this color does also refer to signal A. Therefore, red should not be used as warning color. Next to red, yellow is widely used as warning color.

It is chosen to add a yellow colored symbol to the battery symbol instead of giving the battery symbol a yellow color, as yellow is difficult to distinguish from a white background (figure 57). Figure 58 represents the concept that combines all design decisions.

In addition to this always visible information there is thought about reminding the user on recharging the battery by the use of popup screens. One option is to show a popup screen after the user has pressed the power button to power down the ScopeMeter with the information: 'please recharge after usage'. As it is decided to not test the influences of this, further research on this point is recommended.

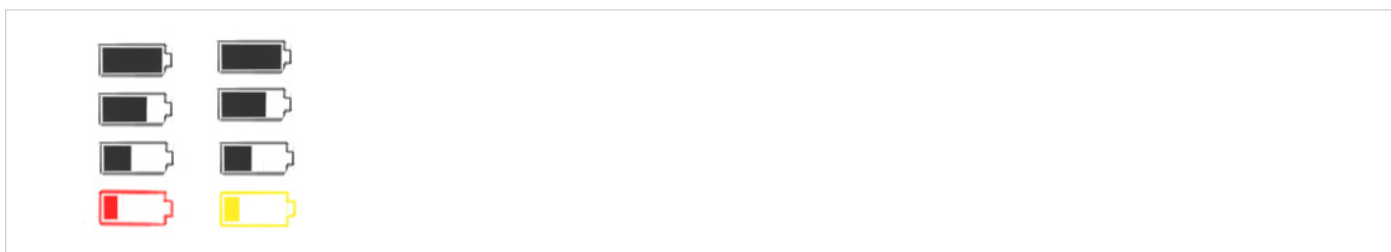


Figure 57: red versus yellow battery symbol

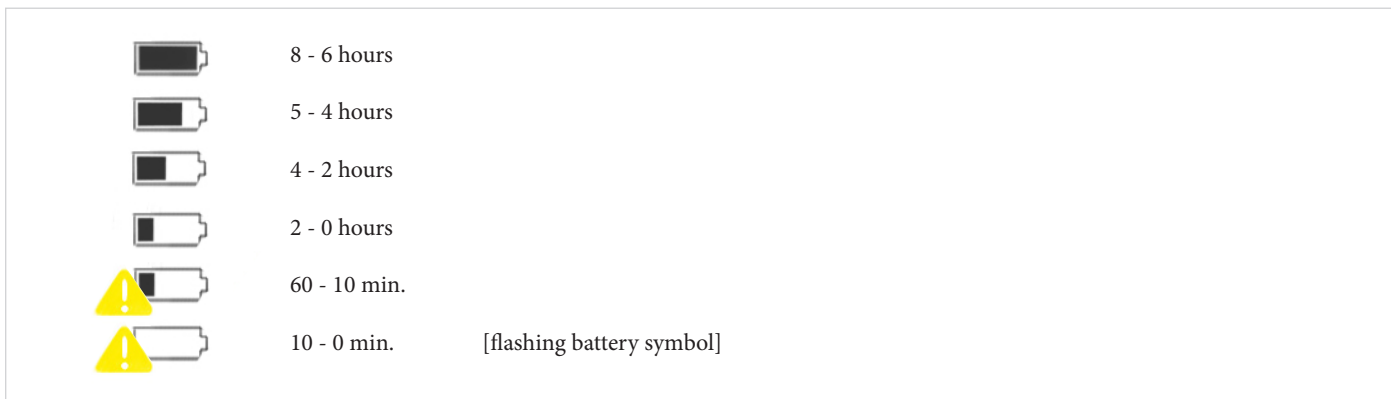


Figure 58: concept visibility battery status

## Summary

Before discussing the keypad design, several keypad independent design aspects are chosen:

- use of the colors blue & red for signal representation;
- arrangement of the numeric information of both signals below each other (figure 59);
- arrangement of the numeric information at the top of the display (figure 59);
- design of the readout area as represented in figure 59;
- layering of menu's (figure 59);
- leaving out of menu items that specifically correspond with the function keys;
- design of the menus as represented in figure 59;
- communication of battery status as represented in figure 59;

Dependent aspects are chosen during discussing the keypad design. This consists of the arrangement of the measurement options. One of the two options represented in figure X is chosen.

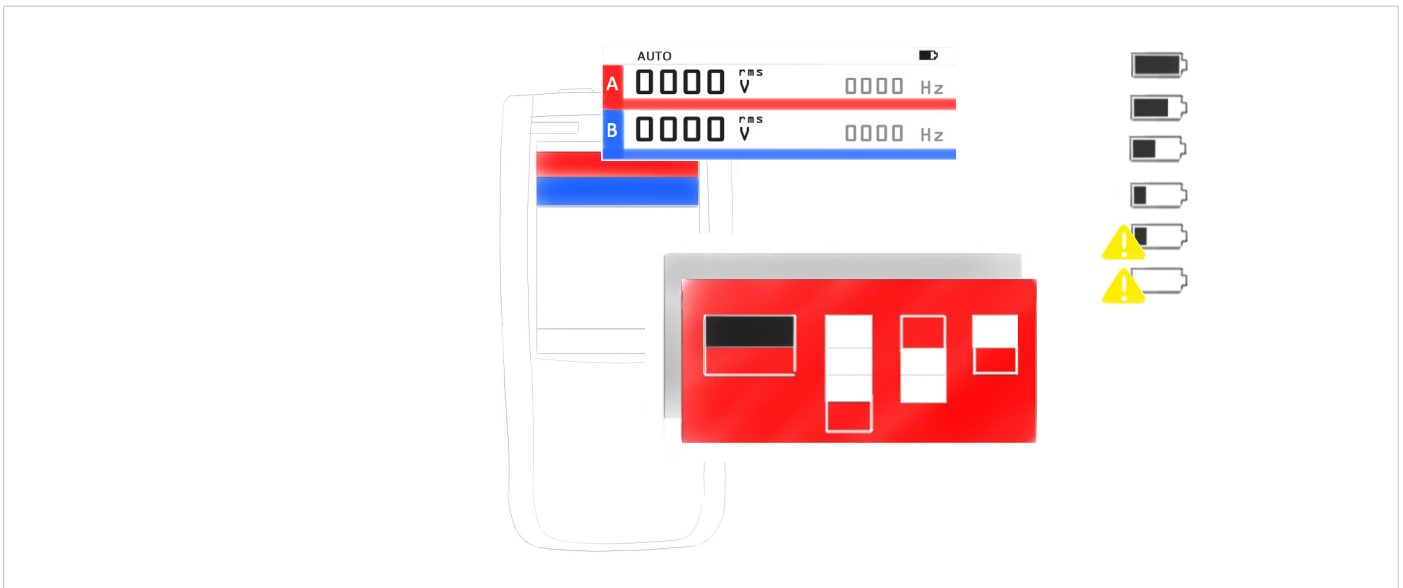


Figure 59: independent design aspects

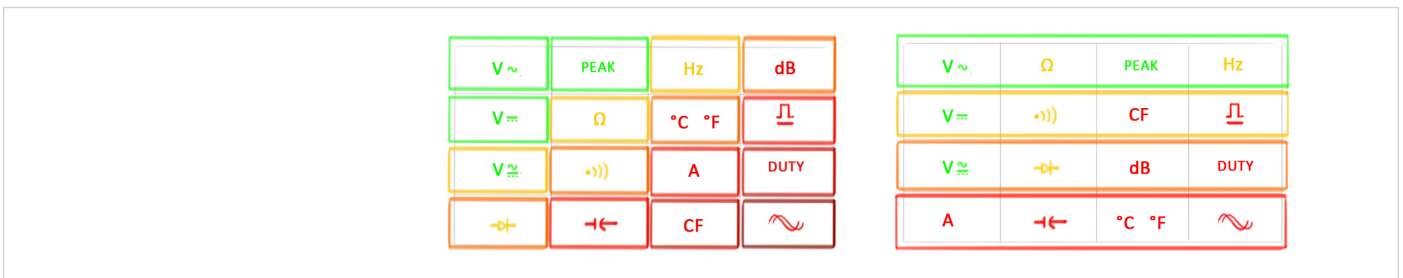


Figure 60: dependent design aspects

## 2.2 Keypad design

First, decisions are made regarding the content of the keypad. Choices regarding the screen design are taken into account as they have influence on these decisions. Secondly, an ideation regarding the design of the keypad is represented, followed by decisions. This includes aspects as 'use of symbols' and 'use of colors'. The third part consists of ideations and iterations on the arrangement of the keypad. Choices regarding the content and design of the keypad are influencing the arrangement and are taken into account. Finally, three concepts regarding the arrangement of the keypad are chosen. Taking the requirements and weighting factor into account, one concept is chosen. Only the keypad is judged on the requirements as the other aspects, like menu structure and navigation, menu design et cetera, are already chosen and therefore the same in these three final concepts.

### Content of the keypad

Several aspects of the content of the keypad are discussed.

#### Settings button

It is chosen to design a menu structure with more depth and less width and to present one menu at a time. To realize this, it is decided to subsume the following menus under one button called 'settings':

- meter A options
- meter B options
- scope options
- scope inputs
- probe options
- trigger options

These menus are subsumed under several buttons in the current user interface, which cost the user a lot of cognitive capacity to reach one of the menus. It is expected that putting the menus under one button called 'settings' will make it easier for the user to remember or find the place of the menu. Putting all settings but the measurement settings under one button will result in more but easier choices.

The user first needs to choose whether he wants to adjust a measurement setting or another setting. Adjustment of a measurement setting is a frequently performed action. Therefore it is assumed that the user knows the content of the measurements menu. Adjustment of another setting is a less frequently performed action, as this will be adjustment of a scope, meter, probe, or trigger setting. Therefore it is assumed that the user does not know where to find these settings at first sight. However, if there is only one other option next to the well known option the user will choose this other option.

Secondly, the user needs to choose whether he wants to adjust a meter setting, scope setting, probe setting, or trigger setting. Choosing between these four options will be easier than choosing between the six options mentioned above. It is assumed that the user does not know whether the setting he wants to adjust is a scope options setting or a scope inputs setting, but that he does know whether the setting he wants to adjust is a scope setting or not. On the next page an overview is given of the choices (figure 61).

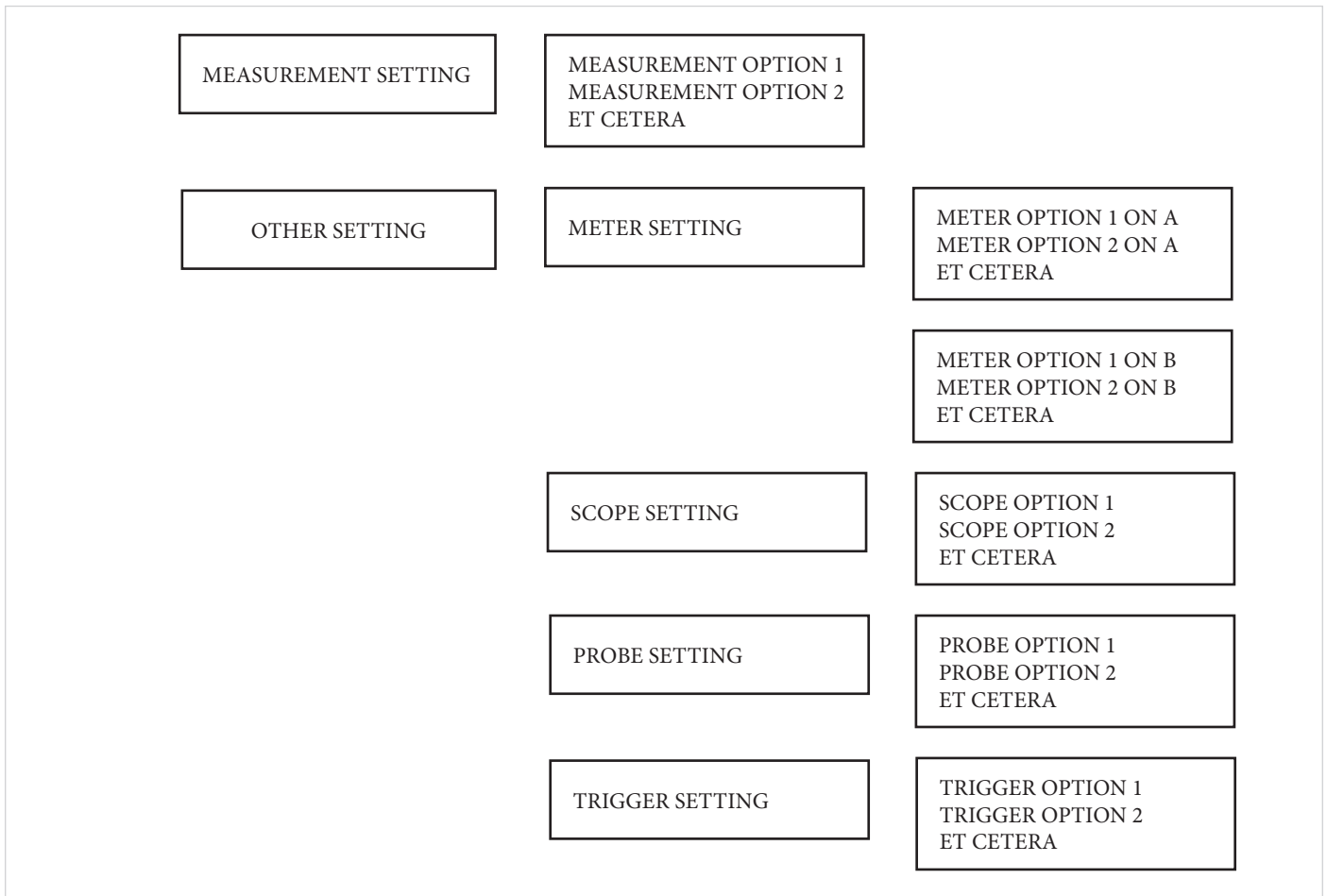


Figure 61: overview menu structure

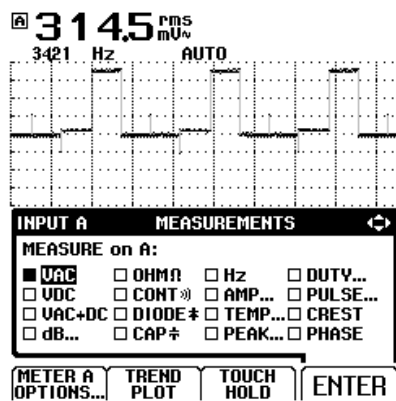


Figure 62: measurements menu

### Trent plot & touch hold function

In order to realize a menu structure that presents one menu at a time, the functions 'trend plot' and 'touch hold' should be removed from the current measurements menu (figure 62). This will thereby improve the consistency of the interface, as only settings can be found under a 'menu' button and not also functions. To realize the before mentioned, the functions should be positioned on the keypad or in the menu items on the main screen. However, there is no space to just add buttons, as there must be enough space between the buttons in order to maintain easy usage with gloves. Therefore space must be created by rearranging the keypad and menus.

### Buttons related to signal B

Because the buttons related to signal B are only used in 10-20 percent of the use cases, it is decided to add a button with which the user can select signal A or signal B and to merge buttons corresponding to a signal specific menu or action. Combining the buttons will create space for other functions.

### Back & enter button

In order to encourage users to explore the interface it is decided to add a physical back button to the user interface. This provides a clear way out of all menus. In addition, a physical enter button is required as there is decided to not use file tabs. For this reason, also a physical enter button is added to the concepts.

### Function keys & arrow keys

The choice to present one menu at a time gives the possibility to leave the function keys out of the user interface. Leaving them out of the interface gives the opportunity to add functions to the keypad. In addition, space on the display is created which can be used to enlarge the waveform area. Another option is shorten the display, which will create even more space to add functions to the keypad. Figure 64 shows a concept with function keys and a concept without function keys.

If the function keys will be left out of the interface, the arrow keys are needed for navigation. If the function keys can be used for navigation, the arrow keys are not necessary for navigation any more. However, they are still required to move the cursors or trigger if one of these functions is active. Using the function keys to move these two is considered (figure 63). However, there is not enough space to take over the function of the arrow keys, as all four directions should be represented. Therefore the arrow keys cannot be left out of the user interface.

As navigation with function keys may be an important advantage regarding the efficiency of the user interface, it is chosen to add function keys to the user interface. Whether this indeed is an important advantage will prove from the usability test.

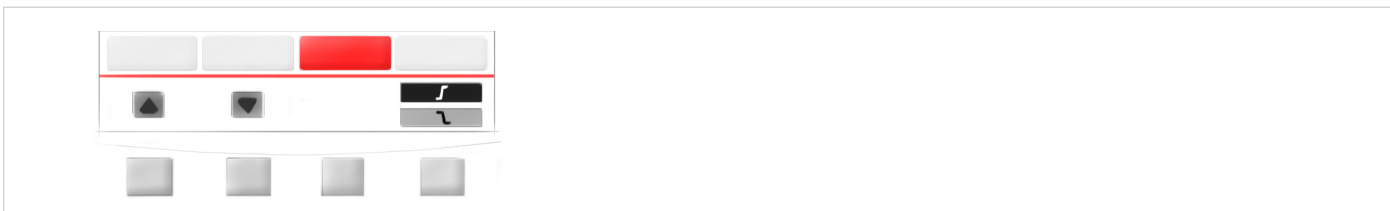


Figure 63: using function keys to move the trigger

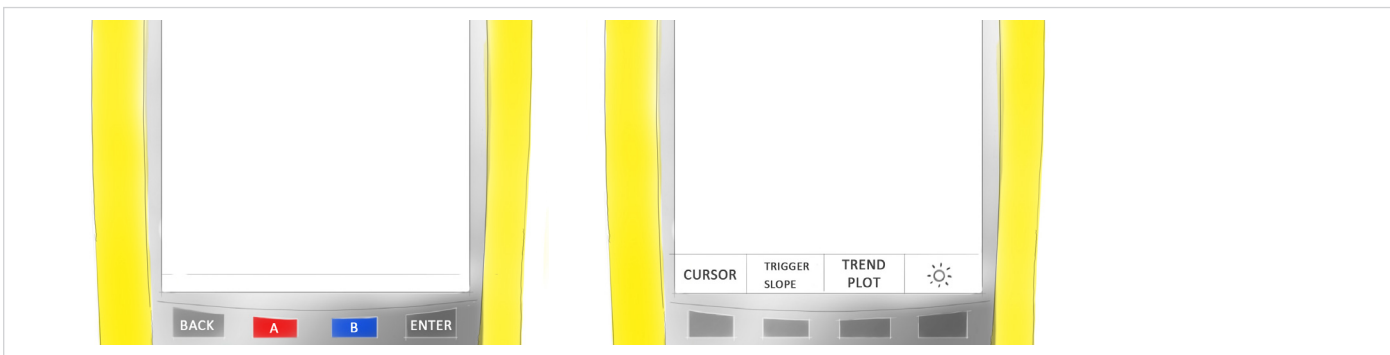


Figure 64: concept without function keys (left) and with function keys (right)

## Summary

The following decisions are made:

- it is decided to subsume several menus under one button called 'settings';
- the functions 'trend plot' and 'touch hold' should be positioned on the keypad or in the menu items on the main screen;
- it is decided to add one or more buttons with which the user can select signal A or signal B and to merge buttons corresponding to a signal specific menu or action;
- it is decided to add a physical back and enter button to the user interface;
- the arrow keys cannot be left out of the user interface;
- it is chosen to add function keys to the user interface;

## Design of the keypad

This section contains ideations on methods to add multiple functions to one button, ideations of the use of color in the keypad and ideations of the use of symbols on the keypad.

### Multiple functions

Figure 65 represents an ideation on methods to add multiple functions to one button.

A knob is frequently used in many basic multimeters. Although the user is familiar with this principle, applying it on the ScopeMeter may come at the expense of the desired product appearance. In addition, it would be difficult to add all measurement options to the knob in a clear and conveniently arranged way. Therefore it is decided to not use this principle.

From the multimeter analysis it has become clear that a shift key is frequently used to activate less frequently used functions. As the user is familiar with this principle, applying a shift key to the ScopeMeter should be considered.

In the current ScopeMeter 120 series, multiple functions can be reached with one button by toggling between the functions. Although toggling between functions is quicker than if a shift key is used, there is little space on the buttons to communicate the functions as two functions should be represented. Nevertheless, this method should be considered.

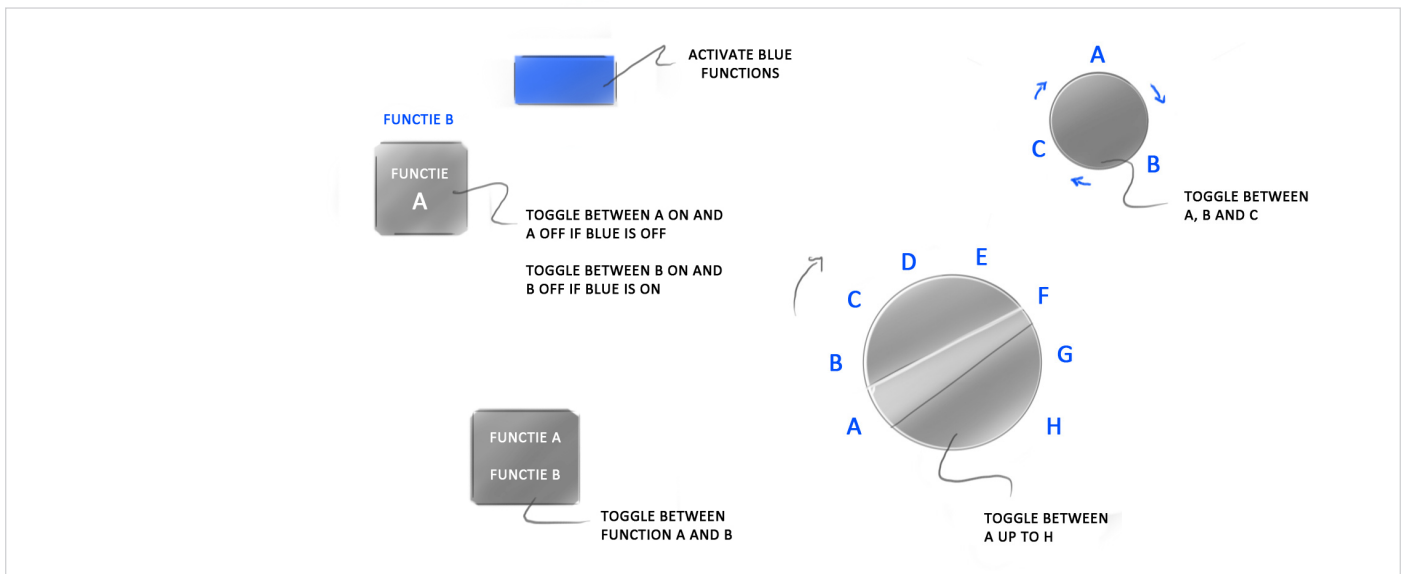


Figure 65: concepts to add multiple functions to one button

### Use of color

Use of many colors may result in an unpleasant keypad. However, color can attribute to the communication of the function or importance. Therefore it is decided to use the colors as applied on the current user interface of the ScopeMeter 120 series.

As it is decided to merge the signal specific buttons and to add a signal selection button, an indication of which signal is selected should be added to the user interface. This can be communicated through the display or through the keypad by the use of light. It is expected that the communication both ways will result in the clearest communication. However, with adding a colored light to the keypad, yet another color is added to the keypad. In addition, application of light is likely to be too expensive. As it is assumed that communication through the screen may be clear enough if correctly applied, it is decided to not use light in the keypad to communicate which signal is selected. If communication through the display only will not be clear enough, applying light should be considered. Whether the communication will be clear enough will become clear from the usability test.

### Use of symbols

In order to reduce the amount of information available and in order to improve the efficiency, an ideation on the use of symbols to communicate specific functions and actions is performed. Figure 66 on the next page shows the ideations on the use of symbols to communicate the trigger function, cursor function, trend plot function and the back action. However, contrary to the use of symbols to communicate measurement options, using symbols to communicate functions like these is less usual. This makes it difficult to guarantee a clear and univocal communication through these symbols. In addition, words like 'record', 'trigger' and 'cursor' are widely used and understood by users all over the world. Therefore it is decided to not use symbols to communicate the functions 'trigger', 'cursor' and 'trend plot'.

Figure 66 shows that different words can be used to express the trend plot function as well as the back action. Because the word 'record' is more frequently used and assumed to be better understood than 'trend plot', it is decided to use 'record' instead of 'trend plot' to communicate the 'trend plot' function.

The words 'back', 'close', and 'clear' are considered to communicate the 'back' function. From those words, the word 'clear' does not correctly communicate the meant action, as 'clear' may be interpreted as 'closing' all opened menus or as 'removing' all extra information but the waveforms from the screen to gain a 'clear' view on only the graphical signal representation. Therefore the word 'clear' is not chosen.

Both the words 'back' and 'clear' can be used to communicate the meant action. Sometimes the word 'close' better fits the situation, as a menu will be closed by using the 'back' button. However, it can also be interpreted as 'going back' to the main screen. If a submenu is opened, 'back' better fits the situation as the user will go back to the previous menu. However, this can also be interpreted as 'closing' the current menu. Nevertheless, the user may think that all menus will be closed by pressing a button labeled with 'close'. Therefore the word 'back' is chosen to communicate the 'back' function.

CURSOR		=	↑	↔	↑	↑↑	I			{ }	∧	∧	∧	∧	∧	∧	∧	∧
TRIGGER	TRIG	∫	∩	∩	∩													
TREND PLOT	TREND	RECORD	REC.	↖	↖	↖	↖	↖	▶	◻	◻	◻	◻	◻				
BACK...	BACK	CLOSE	CLEAR	←	←	↶	↷	↶	↷	◻	↶	⌘	⌘	⌘	⌘	⌘	⌘	⌘

Figure 66: ideation on symbols

From the analysis of the keypad of the ScopeMeter 123 it has become clear that the labels on the time base and amplitude button are not intuitive. It is concluded that the labels should be in line with the by the user perceived effect and not with the technical correct effect. Therefore, an ideation on the design of a symbol for the time base button is performed (figure 67), as well as an ideation on the design of a symbol for the amplitude button (figure 68). As they most clearly visualize the effect, the outlined symbols are chosen from the ideations.

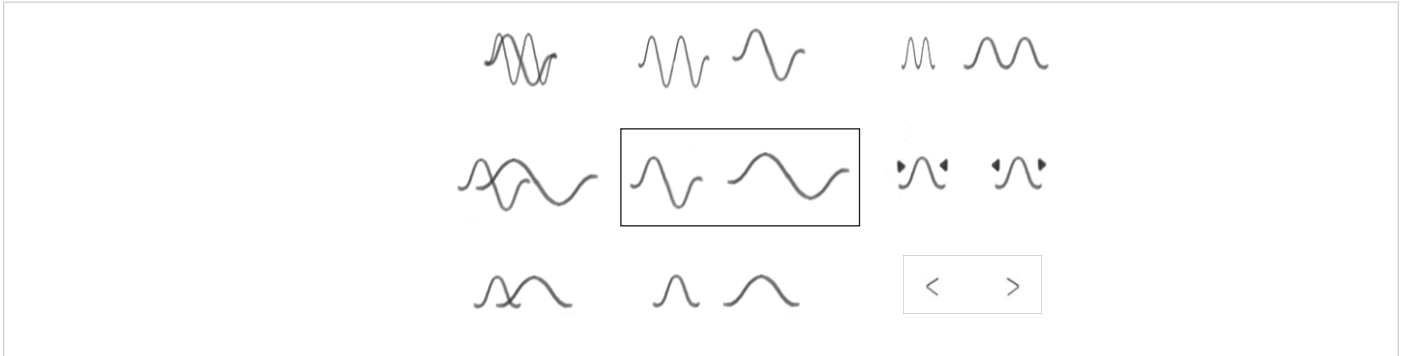


Figure 67: ideation design time base adjustment symbols

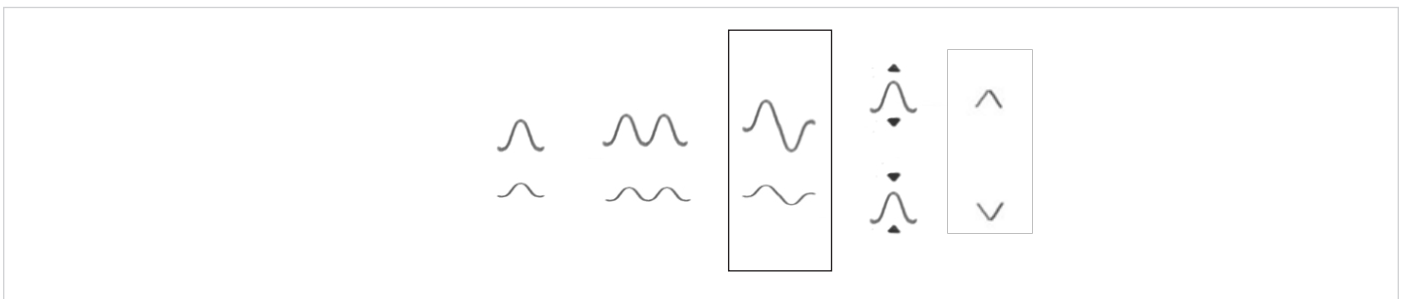


Figure 68: ideation design amplitude adjustment symbols

## Arrangement

This part consists of ideations and iterations on the arrangement of the keypad. The decisions regarding the arrangement of the keypad depend on the choices made so far regarding the content and design of the keypad.

The buttons on the keypad can be divided into three different groups; to navigate, to activate a function or to open a menu. Since the arrangement of the keypad forms a major part of the total assignment, only the main aspects about arranging buttons are mentioned in this ideation. In the third part, the possible arrangements will be further elaborated.

The navigation buttons should be placed near to the display as there is a lot of interaction between the display and the keypad during navigation. Therefore the function keys and the back- and enter button should be placed near to the display. It is a point of discussion if the arrow keys should be placed near to the display, as they may not be used for navigation because of the created opportunity with function keys. However, they still can be used for navigation. This should be taken into account in the ideation on the arrangement of the keypad.

The function and menu buttons should be arranged according to their frequency of use. However, still many different concepts can be generated by taking this into account, as several functions are classified as equally frequently used.

The choice to merge signal specific buttons influences the symmetry of the keypad and requires attention on the application of a signal selection button.

Two options can be distinguished in realizing the function to select one of the signals; a single button for selection of each signal separately, or one button for selection of one of the two signals by toggling between the signals. The first option costs relatively much space while the buttons are only used in 10-20 percent of the use cases. However, the attendance of two buttons labeled with 'A' and 'B' clearly communicates the products capacities.

The functions and menus that are activated or opened by using the function keys will only be available if all menus are closed. These functions or menus should therefore not be desired to be used if another function or menu is active or open. Therefore the save function, as well as the hold and the cursor function should not be placed in the menu items on the display corresponding to the function keys. However, if the functions can be added to the specific menus, like adding save to the cursor menu if save is not added to the keypad, there should be no problem adding the functions to the function keys instead of a specific button on the keypad.

An overview of the iterations made regarding the arrangement of the keypad is represented in figure 69 on the next page. The detailed pictures of the iterations can be found in appendix G. Figure 70 on page 70 represents 6 iterations in order to visualize the progress that is made during the ideation and the detail of differences between the iterations.

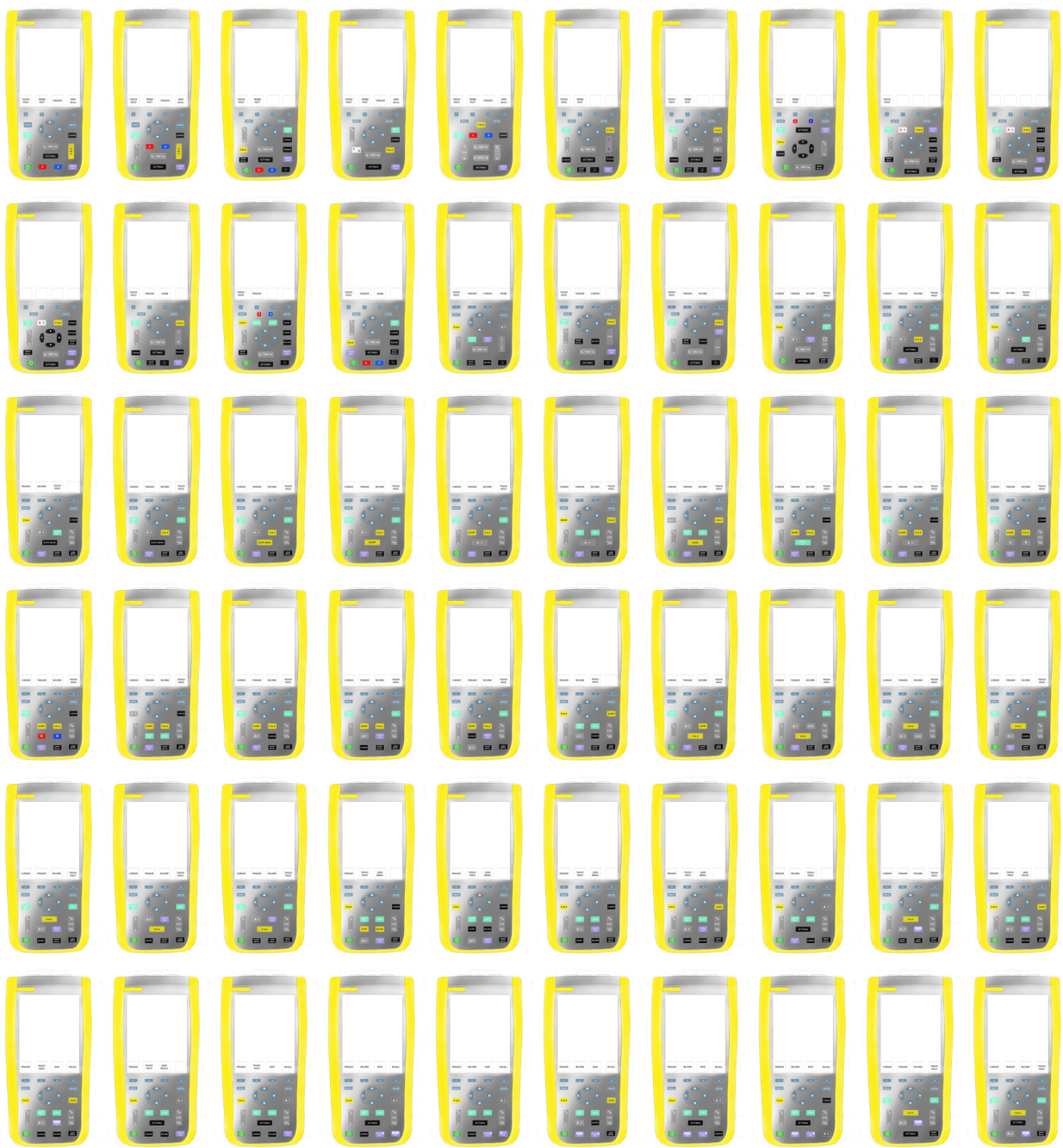


Figure 69: overview iterations made regarding the ideation on the keypad design

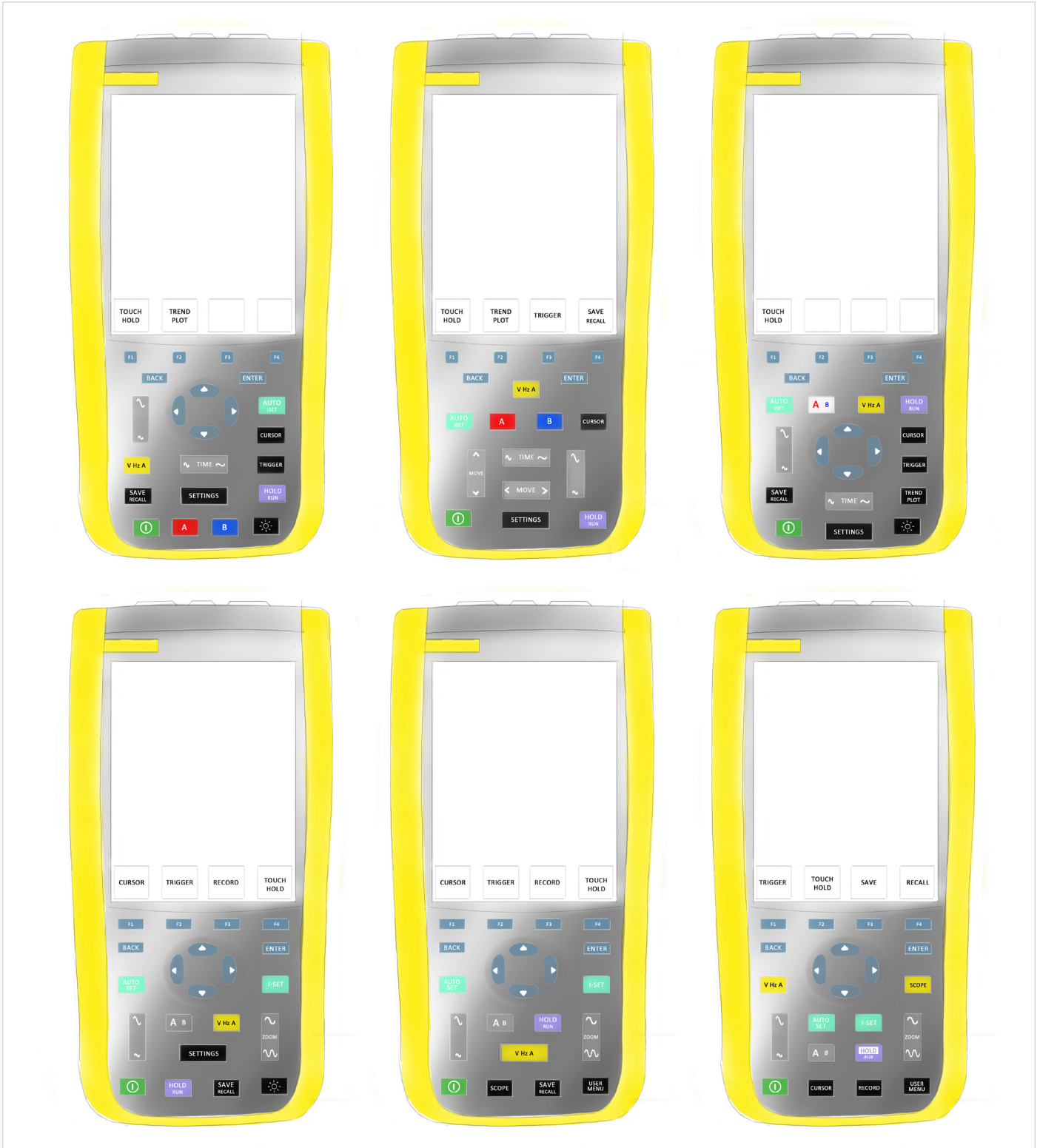


Figure 70: selection of 6 iterations out of 60

## 2.3 Concept choice

The ideation regarding the arrangement of the keypad resulted in a large amount of concepts. Considering all requirements for all of these concepts would make the concept choice very demanding. Furthermore, during the ideation a form of progress was made towards more convenient concepts. Therefore, a selection is made from the best concepts generated in the ideation. The three selected concepts are represented in figure 71. The concepts were chosen both because the idea behind each concept is expected to have potential and because there are clear differences between the concepts. The next step will be to check how each of these concepts suits the requirements. This will result in a hypothesis on the best concept. This hypothesis will then be tested during a usability test.



Figure 71: three chosen concepts; concept 1 (left), concept 2 (middle), and concept 3 (right)

From the analysis, six main requirements are obtained and weighted against each other. They are represented in table 2.

Requirement	Weighing factor
The user interface is effective	0.04
The user interface is efficient	0.26
The user interface is engaging	0.04
The user interface is error tolerant	0.13
The user interface is easy to learn	0.40
The user interface is marketable	0.13

Table 2: requirements with weighting factor as obtained from the analysis

All concepts provide the same way out as a physical back button is applied on each concept. Therefore it is assumed that the concepts are equally error tolerant. This requirement is therefore not taken into account regarding the concept choice. Also the requirement regarding the effectiveness of the user interface is not taken into account as it is assumed that there are no variables between the concepts that influence the effectiveness.

In order to decide which concept should be chosen, the concepts are evaluated regarding the formulated requirements. It is determined which of the three concepts best suits each requirement. After this, the importance of each requirement is considered and a concept is chosen.

**The user interface is efficient**

To decide which of the three concepts is most efficient, the buttons are marked regarding their importance (figure 72). Concept 3 contains most green marked buttons near the display and therefore can be judged as most efficient. However, it is not established if the labels corresponding to the function keys will be perceived rather than the labels on the physical keys. Moreover, it is assumed that the labels on the physical keys will be perceived rather than the labels presented on the display corresponding to the function keys. Taking this into account, concept 2 best suits the requirements regarding the efficiency of the keypad.

In addition, all setting menus, with exception of the measurements menu, are subsumed under one clearly visible 'settings' button in concept 2. In concept 1 and 3 this 'settings' button is subdivided into a scope menu and a user menu, where the scope menu contains the scope options and inputs menu as well as the meter, trigger and probe options. Although the only difference between concept 2 and concept 1 and 3 is whether the user menu is separated or not, it is assumed that the realization of one clearly visible settings button has important implications regarding the efficiency of the user interface. Taking *the 111 solution* into account it is assumed that concept 2 will cost the user the least cognitive capacity and therefore will result in most efficient usage.



Figure 72: analysis arrangement keypad on importance functions and menus

**The user interface is engaging**

All three concepts look equally advanced. Therefore, distinguish regarding the engagement of the ScopeMeter based on the requirement 'the product looks more advanced than a multimeter' cannot be made. However, a difference in symmetry between the three concepts can be noticed, which influences the engagement of the concepts. In addition, the attendance of one larger button in the middle of the keypad results in a more conveniently arranged keypad. Based on these two aspects, concept 3 is judged as most engaging.

### The user interface is easy to learn

Concept 2 and 3 are most conveniently arranged therefore are assumed to be easier to remember than concept 1. As all setting menus, with exception of the measurements menu, are subsumed under one clearly visible 'settings' button in concept 2, it is assumed that this concept is most easy to learn.

### The user interface is marketable

Concept 1 clearly communicates the scope function of the ScopeMeter because of the attendance of the yellow button labeled with 'scope'. In addition, also the cursor and record functionality of the ScopeMeter are communicated through the keypad of concept 1. Although the cursor function is clearly visible in concept 2, concept 1 is evaluated to be the best from a marketing point of view.

As there is not one concept that best suits all formulated requirements, the importance of each requirement is taken into account in order to choose one of the concepts. The balance between the requirements regarding the importance within this assignment is visualized during the analysis phase by using the framework of usability. In order to decide which of the concepts should be chosen, the generated concepts are added to the framework, which is represented in figure 73.

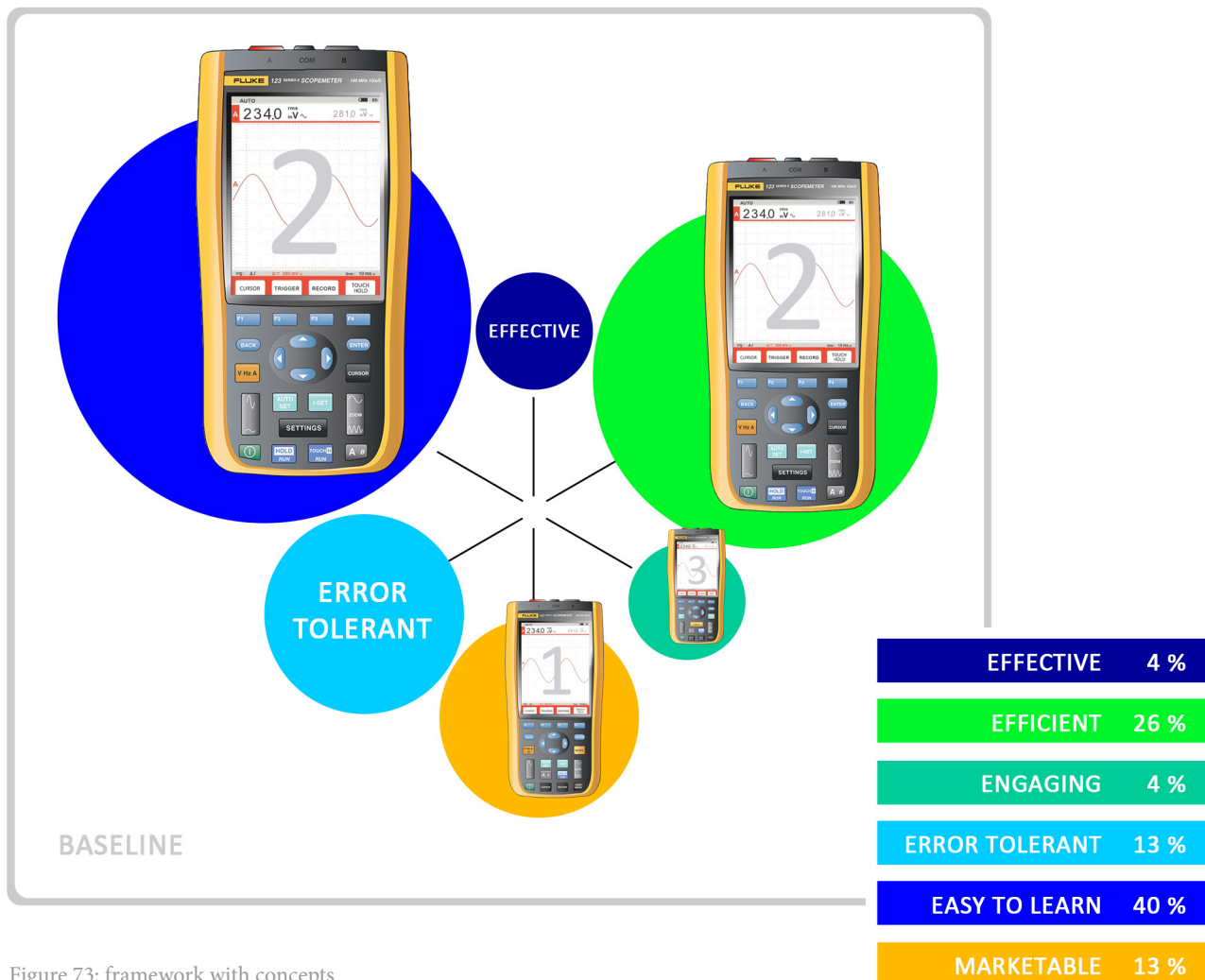


Figure 73: framework with concepts

### 3 PART THREE | usability test

A usability test is conducted in order to find the advantages and disadvantages of the generated concept. This section contains the methodology, information about the participants, the procedure, task list, results, and evaluation of the performed test.

#### 3.1 Methodology

As the test is performed in an early stage in the design process, it is decided to perform a qualitative test. In choosing a methodology to perform a usability test within the scope of this assignment, several constraints are taken into account:

- Limited time; the test should be performed within one week
- Limited means; there is no money available for reward
- Limited accessibility of target group; the target group does not work at one place as they go to clients. In addition, the target group does work as troubleshooter and therefore can be called any time to solve a problem.
- Inconsistent test surrounding; the test cannot be performed without external influences, i.e. distractions, as the test will be performed at a location preferred by the user. Therefore the test will be inconsistent between participants and will be difficult to reproduce. In addition, the setting is not representative to the real setting which may influence the results.

#### A comparative usability test

In order to evaluate the task performance regarding the chosen concept, a comparison is made with the task performance regarding an update of the current concept. This updated concept is based on the current ScopeMeter as well as a concept created by Fluke. It contains the menu structure and navigation method as applied on the current ScopeMeter but a keypad created by Fluke. Next to application of the I-set function, a yellow scope and a yellow record button are added to the keypad on behalf of the marketability of the product. As the concept that is developed for this assignment and the updated concept have the same functions the usability of the concepts can be compared in the usability test. Figure 74 shows the current ScopeMeter 123 and the updated concept.



Figure 74: current ScopeMeter 123 (left) and updated concept (right)

Figure 75 represents the two concepts that are compared in the test. On behalf of the readability, the updated concept based on the current ScopeMeter is called 'original' and the generated concept within this assignment is called 'redesign'. Figure 76 represent the differing menus of the two concepts.



Figure 75: original (left) and redesign (right)

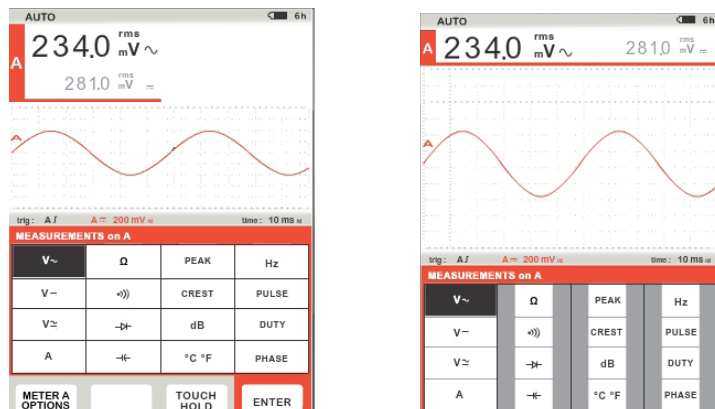


Figure 76: menu original (left) and menu redesign (right)

The variables considered in the comparison are summarized in table 3. This table indicates what variables are tested but constant in both concepts and what variables are tested but are variable in the two concepts.

	Constant	Variable
Housing	dimensions, shape and color	
Display	capacities and size	
Keypad	dimensions, colors, symbols, font and font size	content and arrangement
Screen	general arrangement, colors, font and font size	arrangement reading area
Menus	general design, colors, arrangement, symbols	structure and navigation

Table 3: constant and variable variables

## Validity & reliability

In order to create valid comparable test results, each participant should perform the same tasks with both concepts. As it is assumed that experience with the first concept will influence the task performance of the second concept, it is decided to vary the order in which each participant performs the test. That means that half of the participants first performs the tasks using the original concept and that the other half of the participants first performs the tasks using the redesign.

### Product simulation

As it is not possible to perform a test using a tangible prototype that perfectly simulates the assigned functionalities and design, the two concepts are simulated with Adobe Flash Professional. In order to obtain a usability test that best fits the reality, a touch screen is used with which the user can actually press the simulated buttons. As a touch screen that can be controlled without using a pen was not available, a touch screen with pen is used for the usability test.

A simulation of all functions and menus would result in a test that best correspond with the reality. However, because of limited time, not all functions and menus are realized in the simulation. Nevertheless, as many as possible functions and menus are simulated in order to create a concept than can be explored. This means that, for instance the scope menu can be opened and discovered during the task to measure the peak-to-peak value, which should be accomplished using the measurements menu and not by using the scope menu. Feedback on actions that are not realized in the simulation is given using a popup screen as presented in figure 77.



Figure 77: feedback

### **Think out loud & record**

Regarding the reliability of the test results, the participants are asked to think out loud. The task performances are recorded in order to make it possible to analyze the results afterwards and to maintain full attention on the test itself instead of the test results.

## **3.2 Procedure**

During the usability test, two forms of information are gathered; information that is used for evaluation of the generated concept and information that is used to evaluate the gathered information on validity and reliability. More specific, the information can be subdivided into four types:

- information regarding evaluation of the generated concept;
  - (1) task performance;
  - (2) opinion of the participant on the generated concepts.
- information regarding evaluation of the gathered information;
  - (1) general information about the participant;
  - (2) experience of the participant with performing the tasks.

In order to maintain a constant procedure, the test is divided into six parts:

1. introduction;  
inform participant about the test  
gather general information about the participant
2. 1st part;  
task performance 1st concept
3. break;  
examine understanding of information in reading area
4. 2nd part;  
task performance 2nd concept
5. 3th part;  
opinion on both concepts and preferences  
opinion on use of touch screen
6. closure;  
evaluation of the test

### **Introduction**

Each test starts with an explanation on the test and what will follow. The user is informed about the occasion of performing a usability test, the purpose of the test and how this will be achieved; test two concepts and compare the test results. After this, general information about the user is gathered as well as information about the users' experience with multimeters, handheld oscilloscopes and the Fluke ScopeMeter 120 series. An overview of the questions is presented in the section 'pre-questionnaire' on page 70. In conclusion, the user is informed about the limitations of the simulation and how to use the touch screen with pen. Regarding the reliability of the test results, the user is asked for permission recording the test and to think out loud.

### 1st and 2nd part

The user is asked to perform several tasks in the first and the second part of the test. The tasks in both parts are the same, in order to create comparable test results. The order of the concepts with which the tasks are performed differ per participant. The participants are not told which of the concepts is the 'redesign' and which the 'original' concept.

For each concept two different simulations are made; a simulation of a ScopeMeter with one signal and a simulation with an input of two signals. Regarding the first one, the user is asked to adjust the time base of the signal, to measure the peak-to-peak value of the signal and to change the signal representation into 'roll mode'. Regarding the simulation with two signals, the user is asked to measure the pulse duration of signal B. An overview and substantiation of the tasks is presented in the section 'task list' on page 70.

### Break

A break between the first and second part is created to minimize the influence from experience with the first concept on the second concept. In this brake the user is asked to know the differences between the larger current measurement setting and the smaller previous measurement setting.

### 3th part

After the task performances the participant is asked for its preference regarding the design of the reading area and its opinion about the application of a touch screen in the next generation of the ScopeMeter 120 series.

### Closure

Finally, the test is evaluated through a closing questionnaire. The participant is asked for his opinion about the clearness of his expectations, the clearness of the task descriptions, the ease of the tasks, the duration of the test and the satisfaction in performing the test.



## Pre-questionnaire

A pre-questionnaire is conducted to verify the validity and reliability of the test results. An overview of the questions is presented below. The complete questionnaire can be found in appendix H.

### General

- gender
- age
- education
- current profession
- working experience

### Product use experience

- use multimeter
  - professional or in leisure time
  - frequency of use
  - digital or analogue
  - brand and type
  - last use
- use handheld oscilloscope
  - professional or in leisure time
  - frequency of use
  - digital or analogue
  - brand and type
  - last use
- use Fluke ScopeMeter 120 series
  - professional or in leisure time
  - frequency of use
  - digital or analogue
  - brand and type
  - last use

## Task list

Because there is no money available for reward, the duration of the test should be limited; duration of, for instance, four hours would be too long. Therefore there is decided to set up a test with a maximal duration of 30 minutes. This means that decisions should be made about which aspects will be examined and which will not.

An important difference between the original concept and the redesign is the place of the less frequently used menus like the scope options and input, meter options, probe options, and trigger options menu. In the redesign these menus are placed under one button labeled with 'settings'. To examine the attendance of the 'settings' button, one of the examined tasks is to change something in one of the mentioned menus. It is chosen to ask the participant to change a setting in the scope options menu, as the options are expected to be known by the participants despite of the expectation that the menu is less frequently used. In addition, this menu is chosen as it is placed equally deep in the menu structure in both concepts; the menu can be reached in two steps in both concepts.

Another important difference between the two concepts is the attendance of a physical back and enter button and the possibility to navigate with the function keys. To examine the influence of the attendance of these buttons, one of the examined tasks is to change the meter input of the signal; a frequently and well known task. In order to examine the clearness of the measurements button, the user is asked to measure the peak-to-peak value of the signal. This measurement options is a well known and frequently used option but also an option that is not communicated through the label of the measurements button (figure 78).



Figure 78: label measurements button

The third important difference between the two concepts is whether there is a division in buttons related to signal A and signal B (original) or not (redesign). As this difference has resulted in a difference in the place and orientation of the time base adjustment button, one of the examined tasks is to change the time base of the signal. The fourth and last examined task is to measure the pulse duration of signal B if two signals are attendant.

An overview of the task list is presented below. The complete task list can be found in appendix I.

- zoom in on signal A by adjusting the time base;
- measure the peak-to-peak value;
- adjust the signal representation by setting 'roll mode' in the scope options menu;
- measure the pulse duration of signal B if two signals are attendant.

## Closing questionnaire

A closing questionnaire is conducted in order to evaluate the test results of each participant. Five propositions are formulated with which the participant can agree or disagree using a scale from 1 (disagree) – 5 (agree) (figure 79). The complete questionnaire can be found in appendix J.

- clearness of expectations
- clearness of task descriptions
- ease of tasks
- duration of the test
- satisfaction in performing the test
- remarks or suggestions

**2. It was clear what I had to do, set or change.**



Disagree

Agree

Figure 79: example questionnaire from closing questionnaire

### 3.3 Participants

In a description of a usability test with the Fluke ScopeMeter 123, performed by Fluke and Pacific Usability Laboratories, participants are classified as high-end, average or low-end user based on the sophistication of the instruments they used at work<sup>[06]</sup>. They described the user types as follow:

- High-end** those who have experience working with scopes, meters, and Fluke products
- Average** those who have experience working with meters and Fluke products
- Low-end** those who have little or no experience with meters, scopes, or Fluke products

This classification in high-end, average or low-end is used to obtain a quick and clear view on the participants and the meaning of the rest results.

12 participants have performed the test, of which one did not complete the test. These results are not taken into account.

No.	Profession	Employer	Gender	Age	
1	Instrumentation Technician	University Medical Centre	Male	52	Average
2	Team Leader Medical Technology & Clinical Physics	University Medical Centre	Male	49	High-end
3	Building Management System Administrator	University Medical Centre	Male	43	Low-end
4	Technical Employee Energy Supply	University Medical Centre	Male	51	Average
5	Energy Coordinator	University Medical Centre	Male	48	Average
6	Maintenance Technician Electronics	University Medical Centre	Male	53	Average
7	Commissioning Engineer / Inspector	Croon Elektrotechniek	Male	41	Average
8	Technical Engineer	University of Twente	Male	54	High-end
9	Senior Engineer	Brusche Elektrotechniek	Male	48	Average
10	Commissioning Engineer	Imtech	Male	32	High-end
11	Technical Engineer	Benchmark Electronics	Male	58	Average
12	Technical Engineer	Benchmark Electronics	Male	48	Average

Table 4: participants

1 out of the 11 participants is classified as a low-end user, 7 out of 11 participants are classified as average user and 3 participants are classified as high-end user. Figure 80 represents a graph of the division of the participants on their experience.

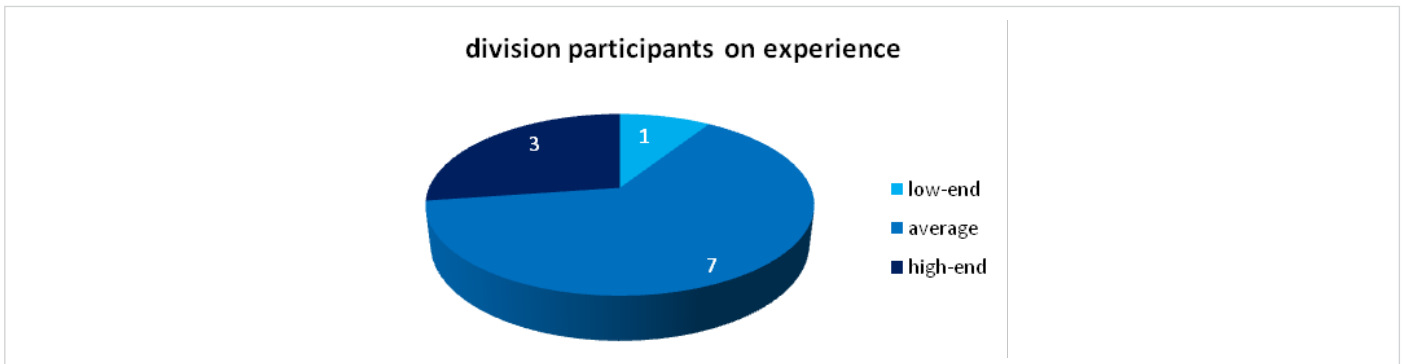


Figure 80: division of participants on experience

### 3.4 Results

All test results are recorded on video. The videos are analyzed and the findings are reported and discussed per task.

#### Time base adjustment

One of the goals of the test was to find out whether the orientation of the time base button influences the usability. In the original concept the time base button is oriented horizontal, in the redesign the time base button is oriented vertical (figure 81).

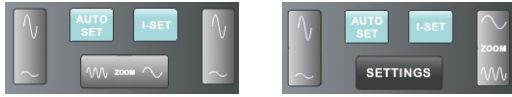


Figure 81: amplitude and time base buttons of original concept (left) and redesign (right)

Overall, no influence is found of the orientation of the time base button on the task performance. However, not all tasks were performed without any problems. These problems are mainly caused by a lack of information on the amplitude button which resulted in confusion between the amplitude button and the time base button.

One of the participants [#1] did use the amplitude button with the intention to zoom in on the signals, i.e. adjust the time base, *after* the time base button was used to zoom out and thus was used correctly. This confusion between the amplitude and the time base button occurred despite a difference in orientation between the two buttons. Another participant [#3] mentioned not to understand the function of the amplitude button without using it. From 3 other tests it became clear that the function of the amplitude button was not clear before the button was used. This makes 6 out of the 11 analyzed tests that showed confusion between the amplitude button and time base button.

One of the participants did mention not to expect that the button labeled with 'zoom' should be used to adjust the time base. However, other participants did not have any problems with using the button labeled with 'zoom' if they were asked to adjust the time base of the ScopeMeter.

#### Discussion

Several aspects may have influenced the test results of the task to adjust the time base of the signal. At first, the use of the word 'zoom' in explaining the task may have influenced the task, as it gives away which button should be used in accomplishing the task. In avoiding the use of the word 'zoom', several users were asked to *'adjust the time base of the signal resulting in more pulses in the screen'*. However, during this explanation, manual gestures were used to support the explanation of 'more pulses', which clearly refers to the symbol on the time base button.

Both task descriptions give information away about which button should be used to accomplish the task and result in a situation that does not fit the real situation. To verify the test results, the test should be repeated with a task that describes a problem and a purpose instead of a specific action that should be performed in order to accomplish a task without a formulated purpose. It is possible that repetition of the task this way may result in different results, as the user may search for a button labeled with 'time' to reach his goal. However, if the user does not relate the word 'time' to his goal, that could be formulated as 'to zoom in on the signal', it is possible that a button labeled with 'zoom' results in a higher usability and that the orientation of the button does not influence the usability. If the word 'time' better fits the mental model of the user, a test should be performed to verify if the combination of 'time' and a vertical button is understood.

### Conclusion

The orientation of the time base button labeled with 'zoom' does not seem to have a significant influence on usability. However, many factors may have influenced this result. Therefore, subsequent tests are needed to confirm this finding.

## Meter input on A adjustment; measure peak-to-peak value or frequency

Another goal was to find out whether measuring the peak-to-peak value was easier using the redesign compared to the original design.

From the task to measure the peak-to-peak value or frequency, results regarding three different things can be distinguished; the general task performance, the navigation method used and results regarding confirmation of the selection. The results are reported and discussed per part. Figure 82 represents the measurements menu of the original concept and of the redesign.

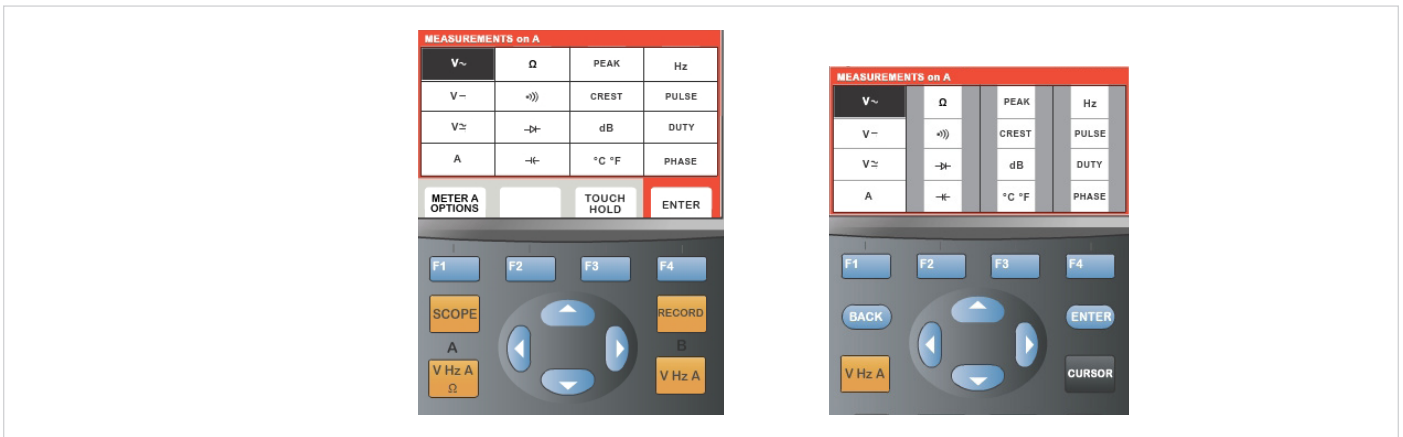


Figure 82: measurements menu of the original concept (left) and the redesign (right).

### General task performance

All participants that were asked to measure the peak-to-peak value of signal A had difficulties with performing the task the first time, as they could not easily find the measurements menu where the meter input on A can be adjusted. One of the participants [#4] could not accomplish the task and therefore was asked to measure the frequency, which he accomplished easily. To verify if this task is more easily accomplished than the task to measure the peak-to-peak value by more participants, it is decided to adjust the task description of the last four participants [# 9 -12]. Table 5, on the next page, gives an overview of the task performance per participant during the first tested concept and the second tested concept.

7 out of 7 participants had difficulties performing the task to measure peak-to-peak the first time. 4 out of 6 participants could easily perform this task the second time. The other 2 participants had difficulties with performing this task the second time, although they had accomplished the task before and the color, position and label of measurements button is equal in both concepts.

Only 1 out of 5 participants had difficulties performing the task to measure the frequency the first time, which is clearly better compared to the performances of the task to measure the peak-to-peak value.

	PEAK-TO-PEAK		FREQUENCY	
	1 <sup>st</sup> time	2 <sup>nd</sup> time	1 <sup>st</sup> time	2 <sup>nd</sup> time
# 1	× [original]	× [redesign]		
# 2	× [original]	√ [redesign]		
# 3	× [original]	√ [redesign]		
# 4	× [redesign]		√ [redesign]	√ [original]
# 5	× [redesign]	√ [original]		
# 7	× [redesign]	× [original]		
# 8	× [redesign]	√ [original]		
# 9			√ [original]	√ [redesign]
# 10			√ [redesign]	√ [original]
# 11			× [redesign]	√ [original]
# 12			√ [original]	√ [redesign]

Table 5: overview task performance meter input on A adjustment

Table 6 gives an overview of the task performances for each concept. The results show little differences in the task performances regarding the original concept and the redesign. 4 out of 11 participants had difficulties in adjustment of the meter input on A in the original concept, compared to 5 out of 11 participants that had difficulties in adjustment of the meter input on A in the redesign.

	ORIGINAL	REDESIGN
# 1	× [peak]	× [peak]
# 2	× [peak]	√ [peak]
# 3	× [peak]	√ [peak]
# 4	√ [Hz]	√ [Hz]
# 5	√ [peak]	× [peak]
# 7	× [peak]	× [peak]
# 8	√ [peak]	× [peak]
# 9	√ [Hz]	√ [Hz]
# 10	√ [Hz]	√ [Hz]
# 11	√ [Hz]	× [Hz]
# 12	√ [Hz]	√ [Hz]

Table 6: task performance meter input on A adjustment in original concept and redesign

Table 6 indicates little influences of the total concepts on the concerning task performance, as the position, color, and label of the measurement button is the same in both concepts. However, little influence of the settings button, present in the redesign, on the task performances is noticed. It is expected that the attendance of an eye-catching 'settings' button in the redesign has influenced the task performance of both participants that had difficulties with measuring peak-to-peak a second time (table 5). The first participant [# 1] mentioned that he expected to find all settings under the 'settings' button, including meter input settings which can be found in the measurements menu. The second participant [# 7] did search for a settings button which was attendant in the previous concept (redesign) but not in this second concept (original).

Analyzing the overall difficulties in measuring the peak-to-peak value, it is expected that a lack of information or the degree of detail of the information on the 'measurements' button caused the difficulties with adjustment of the meter input on A. This is expected because the tasks to measure frequency were performed significantly better than the tasks to measure the peak-to-peak value (table 5) and because Hz was explicit attendant on the label of the measurements button contrary to 'peak'.

Although both the attendance of the settings button and a lack of information on the measurements button did cause the difficulties with measuring the peak-to-peak value, it is assumed that a lack of information on the measurements button had a greater contribution on the task performance as there were also difficulties in performing the task with the original design, where no settings button was attendant.

One of the reasons for removing the menu items corresponding with the function keys in the redesign was an expected improvement of the arrangement of the screen resulting in an easier to use interface. However, nothing can be concluded regarding the design of the screen of the two concepts based on the test results from the analyzed task performances so far. However, no difficulties with performing the task in the original concept seem to be influenced by the design of the screen, which could indicate a positive influence of the use of color on the arrangement of the screen.

#### *Discussion*

The difference in performance between the task to measure the peak-to-peak value and the task to measure the frequency may be caused by a difference in experience with using both measurement options. However, from the function analysis the peak-to-peak measurement option turned out to be more frequently used than the frequency measurement option. To verify the influence of experience with the concerning measurement options on the test results, the user should be asked for its experience with the measurement option in a subsequent test. Another plausible cause for the difficulties with accomplishing the task to measure the peak-to-peak value is a lack of knowledge about the possibility of 'automatically' measuring the peak-to-peak value. Several participants did mention to rather use the cursor function to measure the peak-to-peak value, which is possible in a real situation. Therefore they had difficulties with performing the task in another way.

A third possible influence on the performances of the task to measure the peak-to-peak value is a fear of failure. It is plausible that the participant may be reserved in searching for a peak-to-peak measurement setting under a button labeled with only three specific measurements (V, Hz and A) during the test.

#### *Conclusion*

There is no general significant difference established in adjusting the meter input on A using the original concept and the redesign. Nevertheless, a negative influence of the settings button on the task performances was found. Next to this, a significant difference was found regarding measuring the peak-to-peak value and measuring the frequency of a signal in both concepts. From the given explanations, the lack of information on the measurements button is expected to be the most important one.

## Navigation

Another result that was aimed for by doing the test was finding out what way of menu navigation was preferred by the participants, using the arrow keys or using the function keys.

Only 2 out of 11 participants [#7 and #10] used the function keys for navigation using the redesign. One participant [#8] did discover the possibility of navigation with function keys but did not use the function keys for navigation and another participant [#1] used the function keys only once for navigation without noticing it and after using the arrow keys for navigation. Table 7 on the next page represents an overview of the navigation method used per participant.

### Discussion

The use of a touch screen during the test may have influenced the method used for navigation, as it results in a first tendency to press the screen to select the desired option. When this seems not to work, the participant is stimulated to think about how to navigate, which results in navigation with arrow keys instead of function keys, as this is the most common navigation method used in products. In several task performances a tendency to press the function keys for navigation was noticed, after which the user started to think about his action resulting in navigation with arrow keys.

The function keys are not used for navigation intuitively if arrow keys are present, despite of the design of the menu (figure 83) and the absence of menu items corresponding to the function keys. However, a preference for navigation with function keys instead of arrow keys is not excluded. A subsequent test should be performed to draw conclusion regarding the preference for navigation. In addition, a test can be performed where only function keys can be used for navigation, in order to get more insight in the use of function keys for navigation.

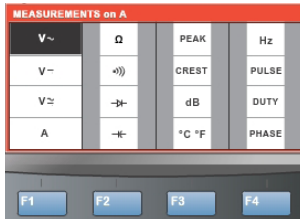


Figure 83: menu design that was intended to stimulate the use of function keys for navigation

### Conclusion

It can be concluded that the function keys are not used for navigation intuitively if arrow keys are present. Next to intuitive preference for arrow key navigation, little can be concluded since the users were not explicitly asked to use and evaluate the function keys for navigation.

	1 <sup>st</sup> time ORIGINAL	2 <sup>nd</sup> time REDESIGN	1 <sup>st</sup> time ORIGINAL	2 <sup>nd</sup> time REDESIGN
# 1				
# 2				
# 3				
# 4				
# 5				
# 7				
# 8				
# 9				
# 10				
# 11				
# 12				

1: used navigation method may be influenced by manual gesture

Table 7: overview of navigation method used per participant per concept

## Confirmation of selection

Another question to be answered is whether there is any difference in using a function key or a physical enter button for confirmation of a selection.

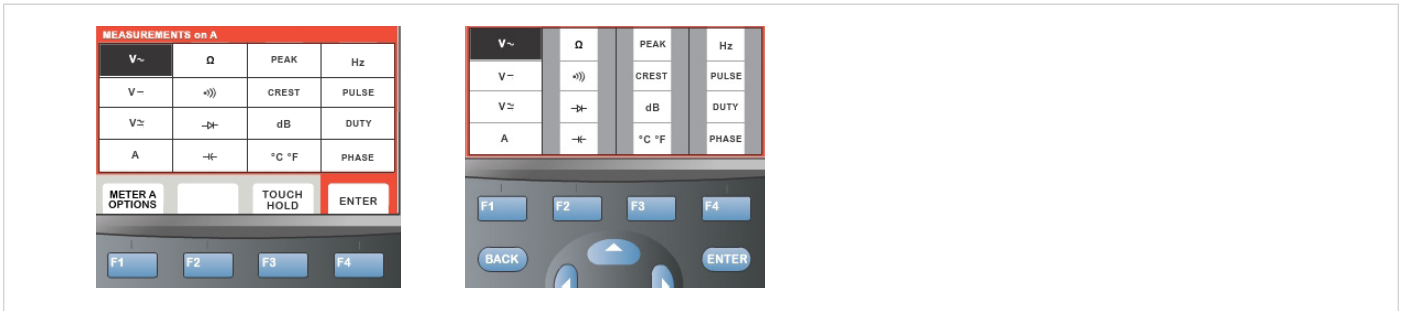


Figure 84: confirmation of selection with function key (left) and with physical enter button (right)

A difference can be mentioned between the original concept and the redesign in the ease of conformation of a selection (table 8). In general, participants had more difficulties with confirming a selection using the function key than using a physical enter button. 4 out of 11 participants had difficulties with confirmation of a selection using the original concept, compared to 0 participants that had difficulties with confirmation of a selection using the redesign. However, most of the difficulties with the original concept occurred when the original concept was used after the redesign was used and the users expected a physical enter button.

### Conclusion

The test results indicate more difficulties with confirmation using the original design. Therefore the use of a physical button is recommended. However, as most difficulties occurred just after usage of a physical enter button, a negative influence on the usability of the use of a function key for confirmation is expected to be little.

	1 <sup>st</sup> time ORIGINAL	1 <sup>st</sup> time REDESIGN
# 1	✓	✓
# 2	✗	✓
# 3	✓	✓
# 4	✗	✓
# 5	✓	✓
# 7	✗	✓
# 8	✓	✓
# 9	✓	✓
# 10	✓	✓
# 11	✗	✓
# 12	✓	✓

Table 8: confirmation of selection

	1 <sup>st</sup> time ORIGINAL	2 <sup>nd</sup> time REDESIGN	1 <sup>st</sup> time REDESIGN	2 <sup>nd</sup> time ORIGINAL
# 1	✓	✓		
# 2	✗	✓		
# 3	✓	✓		
# 4			✓	✗
# 5			✓	✓
# 7			✓	✗
# 8			✓	✓
# 9	✓	✓		
# 10			✓	✓
# 11			✓	✗
# 12	✓	✓		

Table 9: confirmation of selection 1st and 2nd time

## Waveform representation adjustment; set roll mode or single shot

As previously discussed in the analysis phase and the design phase the ‘having one button for each function’ philosophy, as applied in the original concept, may not be the best solution from a usability perspective. It was argued that adding a button which clearly clusters similar functions or menus may be easier to use. This was achieved by adding a ‘settings’ button in the redesign. In order to examine the presence of the ‘settings’ button, one of the tasks is to change a setting in the scope options menu. Including this task in the test, exposes the user to two concepts with different ways of reaching the scope options menu. Following from the results it is tried to find evidence for one of the two design philosophies.

In table 10 an overview is given of the task performances regarding adjustment of the waveform representation. The last two columns inform about which task is performed; set roll mode or set single shot mode. Initially, the intention was to ask each participant to change the scope mode into ‘roll mode’. However, during the test it became clear that the task was not correctly understood because the simulated signal did not fit the real situation and the task therefore was without any purpose and difficult to understand. In addition, the participants had a lack of experience and knowledge in performing the task. Therefore the third participant was asked to set the scope into single shot mode instead of roll mode, as it was expected that this should better fit the situation and may be better understood. However, also this task turned out to be too difficult and not correctly understood by most of the participants.

	1 <sup>st</sup> time ORIGINAL	2 <sup>nd</sup> time REDESIGN	1 <sup>st</sup> time REDESIGN	2 <sup>nd</sup> time ORIGINAL	1 <sup>st</sup> time	2 <sup>nd</sup> time
# 1	√ [quite good]	√ [good]			roll mode	roll mode
# 2	× [poor]	× [poor]			roll mode	roll mode
# 3	√ [quite good]	× [poor]			single shot	single shot
# 4			× [not very well]	× [poor]	single shot	roll mode
# 5			√ [good]	× [not very well]	single shot	roll mode
# 7			√ [quite good]	√ [good]	roll mode	roll mode
# 8			× [poor]	× [poor]	roll mode	roll mode
# 9	× [poor]	√ [quite good]			single shot	single shot
# 10			× [poor]	× [poor]	single shot	single shot
# 11			× [poor]	√ [quite good]	roll mode	roll mode
# 12	× [poor]	√ [quite good]			roll mode	roll mode

Table 10: overview set ‘roll mode’ or ‘single shot’ performance

Only 1 out of 11 participants could accomplish the task good the first time. Three other participants did accomplish the task quite good the first time. The other participants had great difficulties in performing the task; 6 out of 11 performances are classified as ‘poor’, one performance was classified as ‘not very well’.

Although the place of the desired setting differs in both concepts, it was expected that performing the task a second time should be easier because the name of the menu that contains the option is the same in the both concepts. However, five participants could accomplish the task good or quite good the second time, which is only one more than the first time (table 11, next page).

	1 <sup>st</sup> time	2 <sup>nd</sup> time
# 1	√ [quite good]	√ [good]
# 2	× [poor]	× [poor]
# 3	√ [quite good]	× [poor]
# 4	× [not very well]	× [poor]
# 5	√ [good]	× [not very well]
# 7	√ [quite good]	√ [good]
# 8	× [poor]	× [poor]
# 9	× [poor]	√ [quite good]
# 10	× [poor]	× [poor]
# 11	× [poor]	√ [quite good]
# 12	× [poor]	√ [quite good]

Table 11: 1st and 2nd time

Comparing the task performances of the original concept to the redesign, a reasonable difference between the two concepts can be mentioned. 3 out of 11 participants could accomplish the task good or quite good when the original concept was used. 6 out of 11 participants could accomplish the task good or quite good when the redesign was used (table 12).

One important aspect that should be taken into account is whether the user has discovered the concerning menu during a previous task performance. About one third of the participants has discovered the scope options menu during the task to adjust the meter input on A (table 13).

	ORIGINAL	REDESIGN
# 1	√ [quite good]	√ [good]
# 2	× [poor]	× [poor]
# 3	√ [quite good]	× [poor]
# 4	× [poor]	× [not very well]
# 5	× [not very well]	√ [good]
# 7	√ [good]	√ [quite good]
# 8	× [poor]	× [poor]
# 9	× [poor]	√ [quite good]
# 10	× [poor]	× [poor]
# 11	× [poor]	√ [quite good]
# 12	× [poor]	√ [quite good]

Table 12: original concept vs. the redesign

	MENU ALREADY DISCOVERED?	ORIGINAL	MENU ALREADY DISCOVERED?	REDESIGN
# 1	yes	√ [quite good]	yes	√ [good]
# 2	yes	× [poor]	-	× [poor]
# 3	-	√ [quite good]	-	× [poor]
# 4	-	× [poor]	-	× [not very well]
# 5	-	× [not very well]	yes	√ [good]
# 7	yes	√ [good]	-	√ [quite good]
# 8	-	× [poor]	yes	× [poor]
# 9	-	× [poor]	-	√ [quite good]
# 10	-	× [poor]	-	× [poor]
# 11	-	× [poor]	yes	√ [quite good]
# 12	-	× [poor]	-	√ [quite good]

Table 13: task performance with information about prior knowledge

From table 13 it can be noticed that only one participant did accomplish the task quite good without prior knowledge using the original concept. Three participants did accomplish the task quite good without prior knowledge using the redesign. In each concept one participant had difficulties in performing the task although he had already discovered the menu during a previous task.

Remarkable in the task performances is the number of participants that were under the impression that the trigger function should be used to accomplish the task. 7 out of 11 participants first tried the trigger function with the intention to set roll more or taking a shingle shot. 4 of these 7 participants used the trigger function again the second time. This may indicate a lack of understanding of the task.

From the analysis of the task performances it can be concluded that the settings menu in the redesign does not tempt for exploration, as several participants did not explorer the menus. One of the participants mentioned not to expect that the menu options in the settings menu, labeled with 'meter', 'scope', 'user', 'probe', and 'trigger' would open a menu (figure 85). This may be caused by a lack of information on the labels of the menu options.

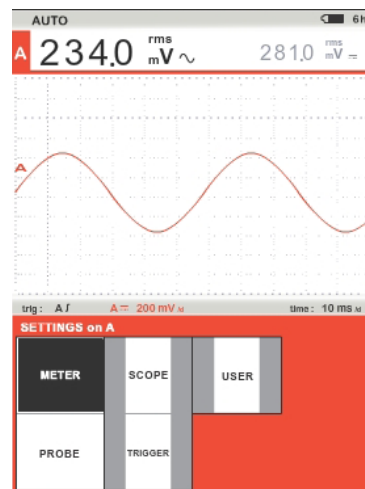


Figure 85: settings menu in the redesign

### Discussion

A second test should be performed to check the results, as the suspected lack of understanding make the test results less reliable. In addition, a difference between the concepts of two participants that accomplished the task without difficulties and without prior knowledge is insufficient to draw a reliable conclusion. It is recommended to perform the test with users that understand the task and have experiences with performing the task. In addition, a test should be set up to test the learnability of the task, i.e. the ease with which the place of the settings is remembered.

### Conclusion

The results indicate that clustering similar functions under a 'settings' button makes it easier to reach scope options in comparison with a dedicated button for scope options. This implies that the design philosophy of clustering similar functions under one button should be applied rather than using dedicated buttons for each function or menu. What cannot be concluded is that the 'settings' button as suggested in the redesign should be applied as some drawbacks of using a 'settings' button are found as well. Subsequent tests should be performed to check the results, as the suspected lack of understanding make the test results less reliable.

## Meter input on B adjustment; measure the pulse duration of signal B

The participants are asked to adjust the meter input on B to test if the 'signal selection button' (figure 86) could easily be found and understood.

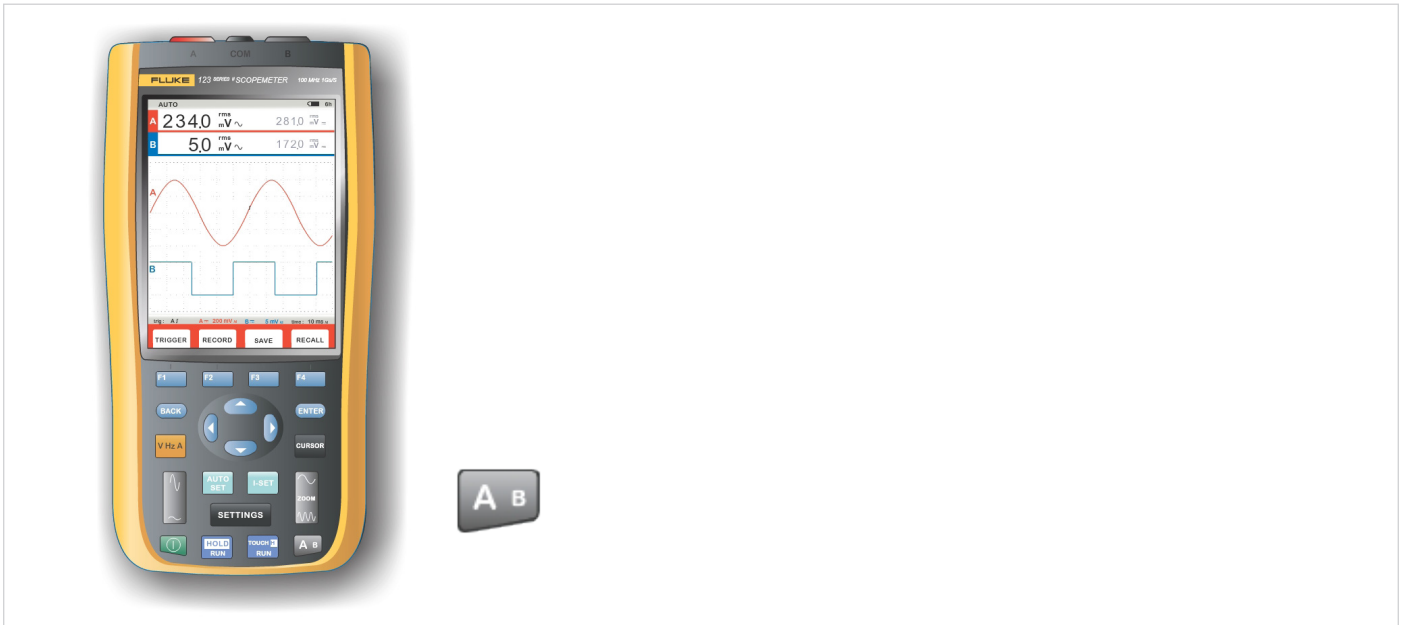


Figure 86: signal selection button in the redesign

2 out of 11 participants had difficulties with the task regarding the original concept against 5 out of 11 participants that had difficulties with accomplishing the task regarding the redesign. One of these 2 and 5 participants had difficulties with both concepts. 1 participant [# 3] had difficulties with performing the task using the original concept and not with performing the task using the redesign. Strikingly this participant is the only 'low-end' user and therefore probably had no experience with the concept with an A-side and B-side at all. 4 participants had difficulties with the task regarding the redesign and not with performing the task using the original concept. 2 of these used the redesign the first time and the other 2 used it the second time. 2 of the 4 participants [# 11 and 12] had experience with the ScopeMeter 123, which may explain their problems with the redesign concept.

Initially, the intention was to ask each participant to measure the pulse duration of signal B. However, after the first tests it has become clear that problems arise because the participants did not know how to measure the pulse duration. As the intention was to test the understanding of selection of one of the two signals by using the 'signal selection button' compared to the attendance of an A- and B-side, it is decided to change the task to measure the pulse duration into the task to measure the frequency of signal B.

Table 14 on the next page shows the task performances of the task to measure the pulse duration of signal B. Table 15, also on the next page, shows the task performances related to the specific performed task; measure pulse duration or frequency.

	1 <sup>st</sup> time ORIGINAL	2 <sup>nd</sup> time REDESIGN	1 <sup>st</sup> time REDESIGN	2 <sup>nd</sup> time ORIGINAL
# 1	× [poor]	× [poor]		
# 2	√ [good]	× [poor]		
# 3	× [not very well]	√ [good]		
# 4			× [poor]	√ [good]
# 5			√ [quite good]	√ [good]
# 7			√ [quite good]	√ [good]
# 8			√ [good]	√ [good]
# 9	√ [good]	√ [good]		
# 10			√ [good]	√ [good]
# 11			× [poor]	√ [good]
# 12	√ [good]	× [not very well]		

Table 14: task performance of meter input on B adjustment

		ORIGINAL		REDESIGN
# 1	Pulse	× [poor]	Pulse	× [poor]
# 2	Pulse	√ [good]	Pulse	× [poor]
# 3	Pulse	× [not very well]	Pulse	√ [good]
# 4	Hz	√ [good]	Hz	× [poor]
# 5	Pulse	√ [good]	Hz	√ [quite good]
# 7	Hz	√ [good]	Hz	√ [quite good]
# 8	Hz	√ [good]	Hz	√ [good]
# 9	Hz	√ [good]	Hz	√ [good]
# 10	Hz	√ [good]	Hz	√ [good]
# 11	Hz	√ [good]	Hz	× [poor]
# 12	Hz	√ [good]	Hz	× [not very well]

Table 15: measuring pulse duration (pulse) or frequency (Hz)

3 of the 11 participants did not mention the feedback on the screen after signal selection during the test with the redesign. Figure 87 on the next page represents the feedback that is given; a changing background color in the main menu area.

Several participants were under the impression that ‘move B’ in the original concept (figure 88 on the next page) had to be activated before the settings of signal B could be adjusted, which is not correct. This incorrect mental model may be influenced by experience with the previous used concept where signal B had to be selected before the settings regarding this signal could be adjusted. However, as ‘move B’ was also used by those participants that used the original concept before the redesign, it is expected that ‘move B’ was used because of the eye-catching red label of ‘move A’.

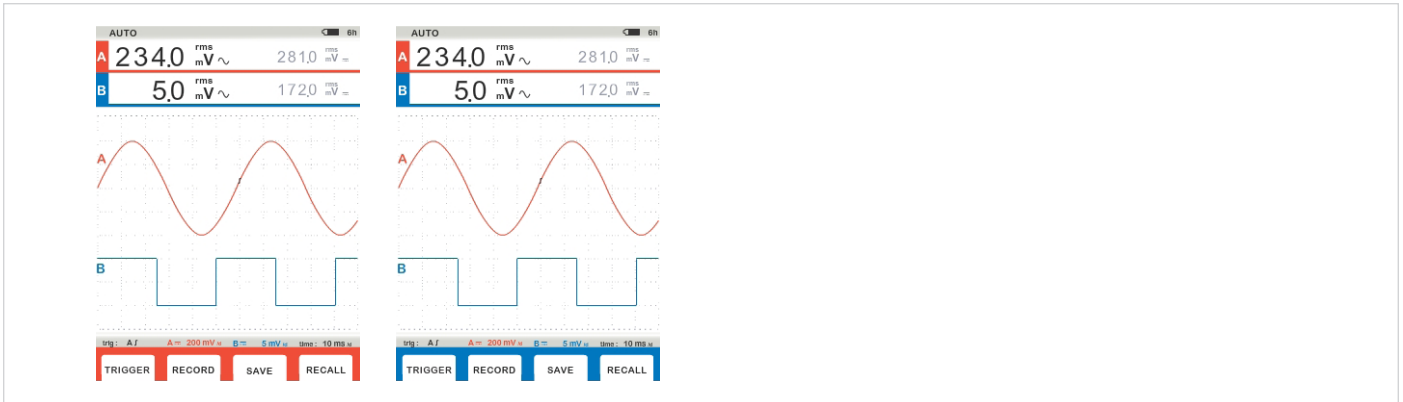


Figure 87: feedback after signal selection

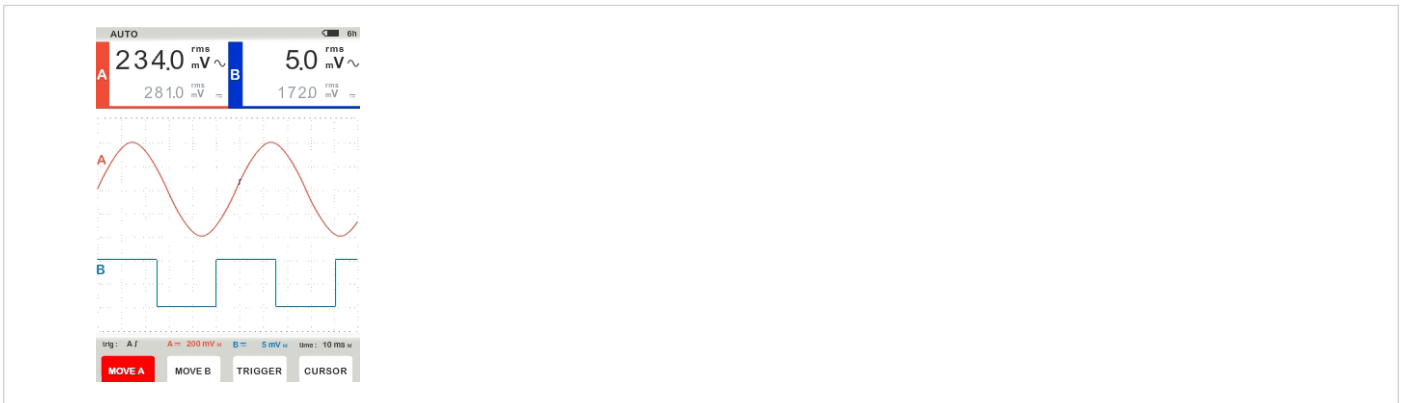


Figure 88: eye-catching 'move A' button in original concept

### Discussion

The test results show that the original concept results in less critical use situations than the redesign regarding adjustment of the meter input of signal B. However, the number of participants that had difficulties with adjustment of the meter input on B using the redesign is not very large, taking into account that the first two test performances were also influenced by the task to measure the pulse duration which was not correctly understood. Because the task will be performed only in 10-20 percent of the use cases, a signal selection button as suggested in the redesign should still be considered in further product development, because the button saves a lot of space on the keypad. However, another, more eye-catching, position of the button should be considered in order to improve the design. In addition, the feedback after selection of one of the two signals should be improved.

### Conclusion

A signal selection button as suggested in the redesign should still be considered in further product development, despite more difficulties in performing the task using the redesign. Fewer difficulties are expected with a more eye-catching position of the button.

## Reading area preference

2 out of 12 participants preferred the design of the reading area of the original concept if only signal A is attendant (figure 89), as can be seen in table 16 on the next page. If both signals are attendant (figure 90), 4 out of 12 participants preferred the design of the original concept.



Figure 89: reading area with one signal in the original concept (left) and the redesign (right)



Figure 90: reading area with two signals in the original concept (left) and the redesign (right)

Several participants mentioned to prefer the design of the reading area of the redesign if one signal is attendant because it results in a larger waveform area. All participants that preferred the design based on the original concept are 'average' users.

One of the participants mentioned to prefer the design of the reading area of the original concept, where the numeric information of the two signals is placed near to each other, because of the larger font size. However, as the font size in both concepts is the same, no difference was expected regarding this aspect. Nevertheless, looking at the two concepts (figure 90), it can be noticed that the numbers look larger in the original concept.

### Conclusion

The design of the reading area as applied in the redesign should be used in the next generation of the ScopeMeter 120 series, for both the representation of one signal and the representation of two signals, as most users preferred this design.

# 1	<div style="border: 1px solid black; padding: 5px;"> <div style="border-bottom: 1px solid red; display: flex; justify-content: space-between; align-items: center;"> <span style="background-color: red; color: white; padding: 2px;">A</span> <div style="text-align: center;"> <p>234.0 <sup>rms</sup> mV ~</p> <p>281.0 <sup>rms</sup> mV =</p> </div> </div> </div>	<div style="border: 1px solid black; padding: 5px;"> <div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border-bottom: 1px solid red; display: flex; justify-content: space-between; align-items: center;"> <span style="background-color: red; color: white; padding: 2px;">A</span> <div style="text-align: center;"> <p>234.0 <sup>rms</sup> mV ~</p> <p>281.0 <sup>rms</sup> mV =</p> </div> </div> <div style="border-bottom: 1px solid blue; display: flex; justify-content: space-between; align-items: center;"> <span style="background-color: blue; color: white; padding: 2px;">B</span> <div style="text-align: center;"> <p>5.0 <sup>rms</sup> mV ~</p> <p>172.0 <sup>rms</sup> mV =</p> </div> </div> </div> </div>
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## Physical back button

Several participants mentioned to prefer the physical back button as applied in the redesign. Some of the participants mentioned this several times. Table 17 and table 18 represent the performances regarding closing menus during the test.

	1 <sup>st</sup> time ORIGINAL	2 <sup>nd</sup> time REDESIGN	1 <sup>st</sup> time REDESIGN	2 <sup>nd</sup> time ORIGINAL
# 1	× [poor]	√ [good]		
# 2	× [not very well]	√ [good]		
# 3	√ [quite good]	√ [good]		
# 4			× [poor]	-
# 5			√ [good]	× [poor]
# 7			-	√ [quite good]
# 8			√ [good]	√ [quite good]
# 9	× [not very well]	-		
# 10			√ [good]	√ [good]
# 11			√ [good]	√ [good]
# 12	√ [good]	√ [good]		

Table 17: performances regarding closing menus during the test

	ORIGINAL	REDESIGN
# 1	× [poor]	√ [good]
# 2	× [not very well]	√ [good]
# 3	√ [quite good]	√ [good]
# 4	-	× [poor]
# 5	× [poor]	√ [good]
# 7	√ [quite good]	-
# 8	√ [quite good]	√ [good]
# 9	× [not very well]	-
# 10	√ [good]	√ [good]
# 11	√ [good]	√ [good]
# 12	√ [good]	√ [good]

Table 18: closing menus during the test

A reasonable difference can be mentioned in the ease of closing menus in both concepts. 4 out of 11 participants had difficulties with closing menus using the original concept. 1 out of 11 participants had difficulties with closing menus using the redesign. Three times no menus were closed; once using the original concept, twice using the redesign.

In the evaluation of the performances regarding closing menus only the ease with which the users could close menus was taken into account and not the specific way they closed the menus. Strikingly, a majority of the participants closed the menus by pressing the button with which they opened the concerning menu, also in the original concept where a physical back button was present.

### Conclusion

The attendance of a physical back button is preferred. This has become clear from both the task performances and feedback from the participants.

### 3.5 Conclusion

In addition to the specific discussion points mentioned in the previous paragraph some general aspects that influenced the validity and reliability of the results are discussed. Secondly, the most important conclusions that can be drawn from the test are summarized.

#### General discussion

A closing questionnaire is conducted in order to evaluate the test results. Figure 91 represents the results of the closing questionnaire. Some comment should be made regarding the interpretation of the results. The results are converted from a 1-5 scale to a 2-10 scale. Initially all results seem very positive. However, it should be taken into account that the evaluation was not totally anonym because of the one-to-one setting and therefore rather be positive than negative. When interpreting the results on a relative scale, it can be noticed that the ease of the tasks is judged relatively negative compared to the other aspects. Figure 92 represents the specific results of the evaluation regarding the ease of the tasks.

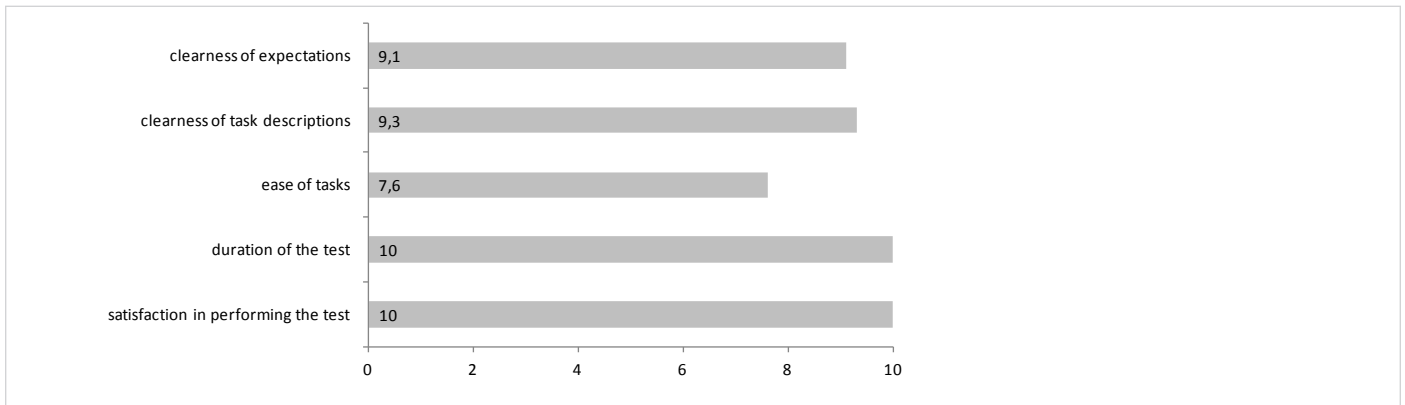


Figure 91: evaluation of several aspects of the test by 11 participants

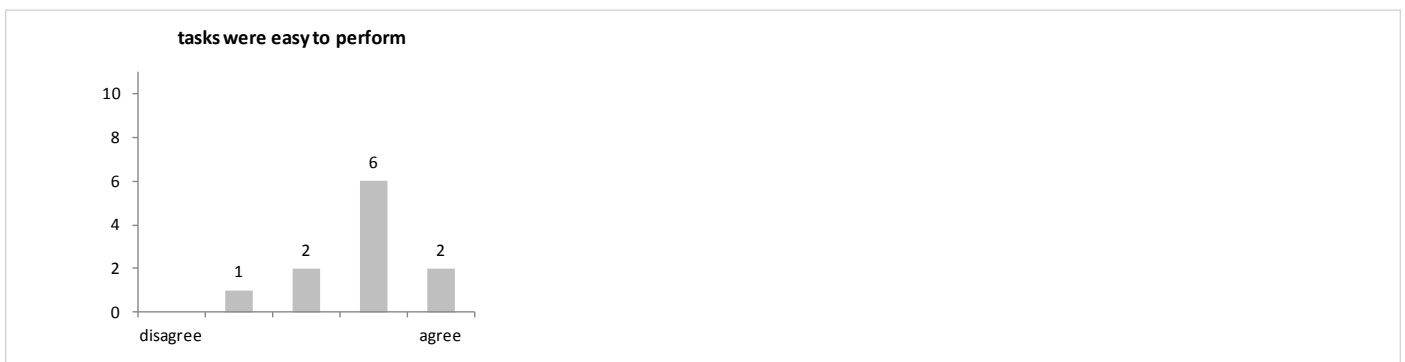


Figure 92: evaluation of the ease of the tasks by 11 participants

The evaluation regarding the ease of the tasks by the participants is consistent with the expectations based on the analysis of the task performances.

In order to maintain a constant procedure the test was structuralized and the sequence of explanations, questions, and tasks was determined beforehand. However, still some parts were missed during the test. Several times the participants were not asked to think out loud. Although some of these participants thought out loud themselves, it has resulted in less insight into the thoughts and motivations for the behaviors. In addition, some participants were not informed about the limitations of the simulation, which resulted in more problems regarding the tasks performances. These aspects should be taken into account in the evaluation of the test results. In addition, it is recommended to perform following tests with more than one researchers in order to avoid misses during the test.

In addition to a structuralized test, it is important to maintain consistency regarding the task description. Although the task descriptions were laid down in writing, it turned out to be important to determine which words should be used and which should not. The influence of manual gestures on the test results was unforeseen, as also was the influence of the use of specific words. Although the influences are taken into account in analyzing the test results, it is possible that they have influenced the results such that some of the results become less reliable. This should be taken into account in evaluation of the results. Next to this it is recommended to make a list of words, explanations, and actions like certain manual gestures that may influence the test results and should therefore be avoided.

It was decided to not ask the participants for their thoughts and expectations on the concepts beforehand, as it was expected that this would influence the test results. However, asking the participants for their thoughts and expectations on the concepts beforehand may give important insights into whether the expectations regarding the functions and menus corresponding to the buttons on the keypad are correct or not. To determine the influence on the task results it should be figured out how the user approached the ScopeMeter in a real situation. If he first observes the keypad before he starts using the ScopeMeter, the influence of asking the participants for their thoughts and expectations on the concept beforehand may be less than if the user immediately starts using the product without observing it. Depending on the real situation and the influences on the task performances, asking the participant for his thoughts and expectations should be considered in subsequent usability tests.

## General conclusion

The test is performed to get insight into the strengths and weaknesses of different design aspects in both concepts and not with the intention to choose one of the two concepts based on the test results. Therefore, the conclusion exists of advises regarding different design aspects of the ScopeMeter that are derived from the conclusions mentioned in the previous sections. Taking into account the discussion points as mentioned in the specific sections, the following advices can be derived from the conclusions:

- The time base button labeled with 'zoom' can be oriented horizontal or vertical as the orientation seem not to have a significant influence on the usability.
- The amplitude button should be labeled to avoid confusion with the time base button.
- The label on the measurements button should give an indication that the measurements menu contains more options than to measure voltage, frequency and ampere.
- The measurement button should be more eye-catching than an eventually attendant settings button.
- The arrow keys are rather used for navigation than the function keys. Therefore, removing the possibility of navigation with arrow keys is not recommended without further research on the use of function keys for navigation.
- A physical enter button for confirmation is preferred.
- A physical back button is preferred.
- Clustering menus under one button should be considered as the test results indicate that this makes it easier to reach one of the menus than if the menus are placed under separated buttons.
- A signal selection button as suggested in the redesign should be considered in further product development if it is placed on a more eye-catching position compared to the tested concept.
- The design of the reading area as applied in the redesign should be used in the next generation of the ScopeMeter 120 series, for both the representation of one signal and the representation of two signals.

## 4 RECOMMENDATIONS

The findings from this assignment are the first step in developing the next generation of the ScopeMeter 120 series. Next to design specific recommendations, also several general recommendations are formulated, as well as recommendation regarding subsequent usability tests.

### 4.1 General

Within this assignment, a redesign is created based on an analysis of the user, usage, and user interface of the ScopeMeter 123. Because of the focus and limitations of the assignment, the ideations and created concepts fit the general concept of the ScopeMeter; the proportions are maintained as well as the navigation and control technique using a keypad and normal display. However, research on total new concept ideas are recommended as the developments within the field of displays and navigation techniques go fast, and the techniques used in the ScopeMeter are now outdated. There can be thought about a concept where the waveform and meter results can be readout on a smart phone. However, research on product segmentation and identification is required to map the possibilities and opportunities and to maintain the Flukes position on the market.

Because the touch screen technology has become a common used technique within the field of electrical devices and user interfaces, research on the use of a touch screen is recommended. However, as mentioned in the analysis phase, research is required on the use of a touch screen with gloves and in dirty environments, as well as research on the influence of a touch screen on the product appearance regarding the solidity.

### 4.2 Design specific

It is recommended to consider the design aspects as applied in the redesign, taking into account the test results and discussion regarding the usability test. It is important to pay attention to the label on the measurements button and the presence of the settings button. In addition the signal selection button should be positioned on a more eye-catching place. Further research on the possibilities of navigation with the function keys is recommended, as well as research on the new I-set function as this was not conducted in this assignment.

Furthermore, it is recommended to give priority to the usability of the product in redesigning the user interface and to check the influence on the usability from decisions based on marketing requirements. It is expected that there are more possibilities to communicate the capacities of the ScopeMeter than through the keypad. To focus on both usability and marketability, it is recommended to research the possibilities of communicating the capacities of the ScopeMeter through aspects that have less influence on the usability than the keypad.

The user interface analysis as well as the test results showed that improvements can be made regarding the ease of use in changing the design of the interface of the ScopeMeter. However, creating an interface that can be used without difficulties the first time or after a long period not using the product will be difficult. In order to improve the ease of use it is recommended to research the possibilities and drawbacks of informing the user about how to use the ScopeMeter if the ScopeMeter is not used for more than a particular number of weeks or months. This can be realized by creating popup screens or adding an info button with, for instance, the following information:

- use the [measurements button] to measure something else;
- use the [auto set button] for automatic triggering;
- use the [I-set button] for automatic measuring;
- use the [signal selection button] to select signal A or B;
- use the [touch hold button] to hold the signal after connection.

The information between the square brackets can be replaced with a picture of the concerning button.

As applying a function that keeps the time the ScopeMeter is powered off may influence the use of energy while the ScopeMeter is powered off, a research on the advantages and disadvantages is recommended.

In addition to the power indication though a battery symbol in the screen, it is recommended to consider additional things that prevent the critical use case of an empty battery to occur, as this turned out to be an important critical aspect. There can be thought about developing an external battery or a holder that charges the ScopeMeter after usage.

### 4.3 Usability test

Next to insight into the usability of the tested concepts, analyzing the performed usability test has resulted in important insights regarding aspects of the approach that may have influenced the test results and into improvements than can be made in performing a subsequent usability test. As the aspects are discussed in the previous sections, a short description will do in this paragraph.

General recommendations regarding the usability test:

- The usability test should consist of result-oriented tasks. This means that the participant should be given the task to solve a problem (that fits a real-world situation) instead of a task to set, adjust or change something without any purpose.
- It is recommended to make a list of words, explanations, and actions like certain manual gestures that may influence the test results and should therefore be avoided.
- It is recommended to perform the tests with more than one researcher in order to avoid misses during the test.
- It is recommended to give the users more time to evaluate the created concepts.

Specific recommendation regarding a subsequent usability test:

- It is recommended to perform a subsequent test with a vertical button labeled with 'time' to verify if the combination of 'time' and a vertical button is understood.
- It is recommended to perform a subsequent test were the measurement options are added to the settings menu, to verify if this may improve the usability.
- It is recommended to perform a subsequent test in order to check the possibilities of the use of function keys for navigation. A test can be performed where only function keys can be used for navigation or a test can be performed where the user is informed about the possibility of using the function keys for navigation beforehand. In addition, it is recommended to ask the participant for his meaning about using function keys for navigation.

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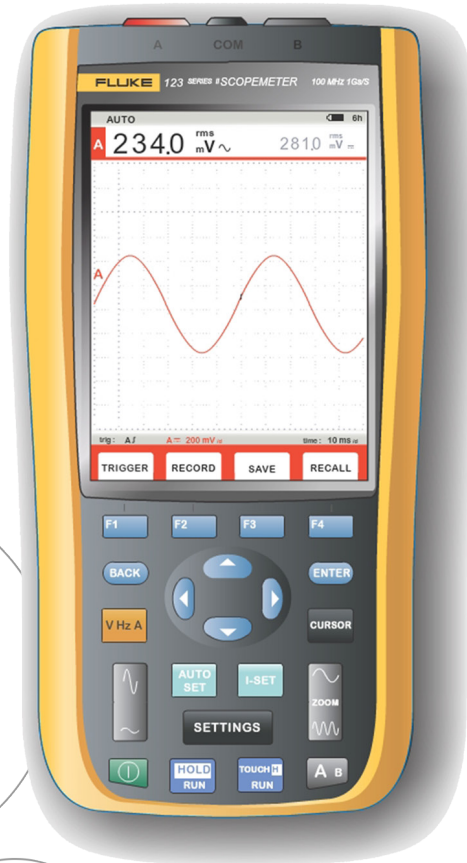
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37. B. Kottier (personal communication, July 24, 2012)
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# APPENDIX

User Interface Design  
of the next generation Fluke ScopeMeter 120 Series



ERROR  
TOLERANT

EFFICIENT

EFFECTIVE

ENGAGING

MARKETABLE

EASY  
TO  
LEARN

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## A | Oscilloscope vs. multimeter

Both an oscilloscope and multimeter are electronic test instruments. In 'Plant Engineering Handbook', Barber (2001) describes an oscilloscope as an instrument for *monitoring electrical signals, for diagnostic testing and for studying time-varying phenomena* <sup>[01]</sup>. An oscilloscope presents a graphical representation of a signal change over time <sup>[08]</sup> and with that enables a (continue) waveform readout. A multimeter presents a single precise measured value <sup>[08]</sup> and enables a numerical (discreet) readout of a signal characteristic in one moment, like voltage, current and resistance <sup>[01]</sup>. So briefly, the difference between a multimeter and oscilloscope can be described as the difference between numbers and pictures. But as appropriately mentioned by Fluke Corporation (2012); *what does that mean in any real-world testing or troubleshooting environment?* <sup>[20]</sup>

Assuming that they are handheld and digital, multimeters are typically used for *front-line testing and general purpose measurements* <sup>[20]</sup>. Oscilloscopes on the other hand are designed for testing or troubleshooting *systems that might contain complex systems* <sup>[20]</sup>. Where oscilloscopes have the ability to *visually display complex signals*, they do not have *the accuracy and resolution of a high-accuracy multimeter* <sup>[20]</sup>. Over all you can say that *a multimeter doesn't give enough detail to determine the cause of a fault and that signal anomalies, dropouts and glitches that might cause a machine to go down, are best displayed with an oscilloscope* <sup>[20]</sup>.

## B | FAST diagram <sup>[31]</sup>

In a FAST diagram (figure I) distinguishes are made between higher order functions, product functions and lower order functions. The higher and lower order functions are placed outside the dotted lines in the FAST diagram. Between the dotted lines the product functions are placed. These product functions can be subdivided in basic functions, secondary functions, dependent critical functions and independent (supporting) functions <sup>[31]</sup>.

For the ScopeMeter 123, the higher order function is 'analyze information'. To analyze information, this information must be displayed. The *basic function* of the ScopeMeter is 'display information'. According to Borza (2011), the basic function *describes the characteristic or task, which, from the user's point of view, is the primary reason for the existence of an item. It is what the product or process was designed to do* <sup>[31]</sup>.

To display information, a signal must first be transmitted. This function, 'transmit signal', is the function of the probes that are connected to the ScopeMeter and can be seen as one of the lower order functions. Both 'analyze info' and 'transmit signal' do not belong to the product functions and therefore are placed outside the dotted lines.

After transmitting the signal, the signal must be received, converted and measured before (measurement) information can be displayed. These functions can be described as *secondary functions*. According to Borza (2011), secondary functions *are those designed-in functions which are required to cause or allow the Basic Function to occur. It is any function that directly contributes to accomplishing the Basic Function* <sup>[31]</sup>.

The independent (supporting) functions *are those which help the Basic Function to be delivered better, faster, longer. etc.* <sup>[31]</sup> Those independent functions are placed above the basic or dependent critical functions. The independent (supporting) functions of the ScopeMeter are; improve info representation, improve display performance, print or save info, recall info and store energy. Those functions are not necessary for the product to function, but they help the function 'display info' to be delivered better (by improving the info representation and the display performance, by printing the info or save the info on the pc and by recall info to compare information) or to be delivered longer (by storing the energy).

Next to the higher order, lower order and product functions, 'design criteria' and 'all-the-time' functions can be discriminated. Those 'function' are not connected to the basic function in the FAST diagram, but they are direct or indirect related to the realization of the basic function or higher order function. Design criteria are *performance requirements* like 'maximize ease of use' and 'maintain portability' and are directly related to the basic function (display info). 'All-the-time' functions are not usually directly related to the basic function. 'All-the-time' functions of the ScopeMeter are: 'enhance aesthetics', 'prevent injury', 'inform customer' and 'maximize product life'. Often, these 'all-the-time' functions *are items assumed in the market place as being delivered by the product or process* <sup>[31]</sup>.

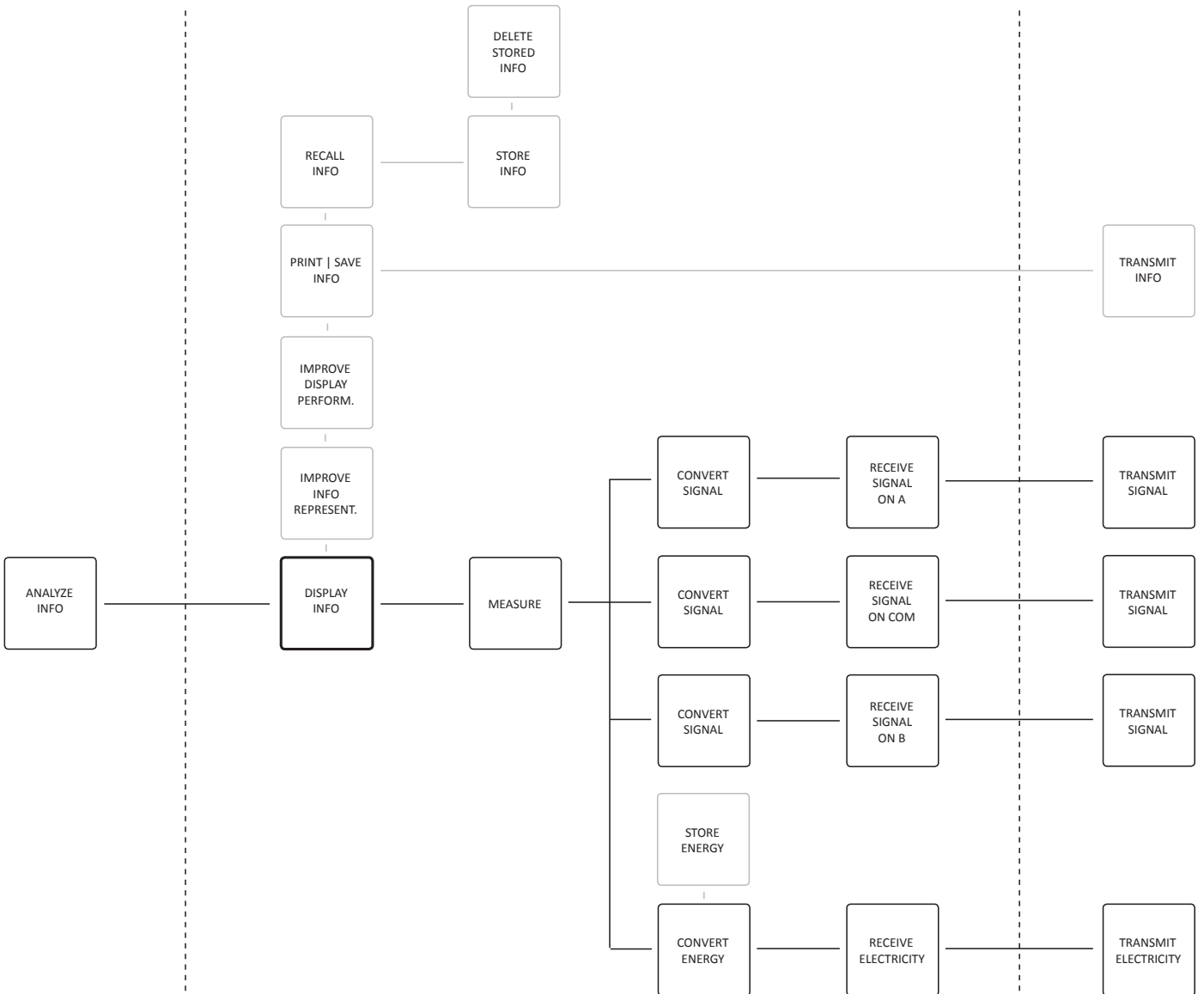


Figure I: FAST diagram of the ScopeMeter 123

## C | Product functions

In table I the product functions are presented. The first column contains the general product function as represented in the FAST diagram. The realization of these product functions can be found in the second column. The name or symbol corresponding with the product function can be found in the third column.

### Importance

The product functions can be divided into primary, secondary and tertiary functions. The functions are ordered by their frequency of use. Primary functions are most frequently used and therefore can be called most important, and the tertiary functions are less frequently used and therefore least important. This does not mean that tertiary functions can be left out by definition. The classification gives insight in whether the functions are in the right place in the current product and in the way the functions should be placed in the next generation of the 120 series. In general, the tertiary functions can be placed deeper in the menus because they are less frequently used.

Several meetings with Peter Deverson have given insight into the importance of several product functions of the ScopeMeter. The automatic trigger function can be classified as primary, because it is the selling point of the ScopeMeter 120 series<sup>[33]</sup>. The function is applied to meet the needs of the user of the ScopeMeter; quick and easy usage. It is plausible that this function is therefore frequently used. Although functions like manually triggering and amplitude and time base adjustment seem to be unnecessary because of this automatic trigger function, this in fact is incorrect. During the first meeting with Bertus Kottier, senior engineer at Brusche Elektrotechnik and user of the ScopeMeter 123, it became clear that he did not now this automatic triggering function and therefore frequently used the manual triggering function and the amplitude and time base button. Next to this single example, Peter Deverson explained that manual triggering is still desired and frequently used in spite of the existence of the auto function. People have the tendency to rather rely on their own skills than on full automatic technologies like the automatic triggering function. The manually triggering function, amplitude, and time base adjustment are therefore also classified as primary functions. According to Peter Deverson, the cursor function is frequently used<sup>[34]</sup>. This function is needed to gather specific measurement information; information that cannot be gathered in another way. Also the hold function is, according to Deverson, a frequently used function<sup>[35]</sup>. The function to directly print measurement results is according to Deverson rarely used and therefore classified as tertiary function. These days everyone has a computer or laptop to save the measurement results and it is not desired too directly print from the ScopeMeter<sup>[34]</sup>. The save and recall function, on the other hand, are still important and relatively frequently used<sup>[34]</sup>.

<b>Product function</b>	<b>Realization</b>	<b>name   symbol</b>
Display information	Support numeric readout of signal A	multimeter function on A
	Support waveform readout of signal A	oscilloscope function on A
	Support numeric readout of signal B	multimeter function on B
	Support waveform readout of signal B	oscilloscope function on B
Improve info representation	Support parameter adjustment of signal A	input A measurements menu
	Support parameter adjustment of signal B	input B measurements menu
	Support parameter measuring adjustment of signal A	meter A options menu
	Support parameter measuring adjustment of signal B	meter B options menu
	Support specific parameter measurement adjustment	autoset adjust menu
	Support waveform representation adjustment of signal A	scope inputs on A menu
	Support waveform representation adjustment of signal B	scope inputs on B menu
	Support waveform representation adjustment	scope options menu
	Support trigger options adjustment	trigger menu
	Support waveform time base adjustment	time adjustment function
	Support waveform amplitude adjustment of signal A	amplitude A adjustment function
	Support waveform amplitude adjustment of signal B	amplitude B adjustment function
	Support specific numeric readout of signal A	cursor function
	Support specific numeric readout of signal B	cursor function
	Support manual triggering	trigger function
	Support trend plotting	trend plot function
	Support automatic triggering	auto function
	Support holding measurements	hold function
	Support holding measurements after connecting	touch hold function
	Support waveform place adjustment of signal A	move A function
	Support waveform place adjustment of signal B	move B function
	Support grid adjustment	grid menu
Improve display performance	Support backlight adjustment	brightness menu
	Support contrast adjustment	brightness menu
Print or save information	Support saving measurement settings	save function
	Support saving measurement results	save function
	Support printing measurement settings	print function
	Support printing measurement results	print function
Recall information	Support recalling measurement settings	recall function
	Support recalling measurement results	recall function

<b>Design criteria</b>	<b>Realization</b>	<b>name   symbol</b>
Maximize ease of use	Support language adjustment	language select menu
Maintain portability	Support saving use of energy	power down menu

<b>All-the-time function</b>	<b>Realization</b>	<b>name   symbol</b>
Inform the customer	Inform about version information	version & calibration menu
	Inform about power indication	battery symbol
	Inform about date of measurement	date adjust menu
	Inform about time of measurement	time adjust menu
Maximize product life	Support battery refreshment	battery refresh menu

Table I: product functions of the Fluke ScopeMeter 123

In addition to the information from Peter Deverson, a selection of the product functions of the ScopeMeter was classified by Bertus Kottier. Kottier was asked to classify the product functions as 'frequently used' (Dutch: veel gebruikt), 'used now and then' (Dutch: af en toe gebruikt) or 'rarely or never used' (Dutch: amper tot nooit gebruikt). He made the following classification:

**Frequently used**

- Hold function

**Now and then used**

- Cursor function
- Touch hold function
- Auto function
- Save and recall measurement results

**Rarely or never used**

- Trend plot function
- Save and recall measurement settings
- Print measurement results

Although the ScopeMeter has the functionality to display two signals at the same time, this function is only used in 80-90 percent of the cases <sup>[40]</sup>. In 10-20 percent of use cases the user analysis one signal at a time. Therefore, the functions and menus that are specifically related to signal B are classified as a 'secondary functions'.

Other functions classified as secondary are those that are less frequently used as they are more advanced functions and used by more experienced users; those people who are used to more advanced oscilloscopes. They are not classified as tertiary function, because the tertiary functions are even less frequently used. Most of the tertiary functions are used only once or twice, like language, time or date adjustment.

Table II on the next page presents the classification of the product function as primary, secondary or tertiary.

<b>Primary functions</b>	<b>name   symbol</b>
Support numeric readout of signal A	multimeter function on A
Support waveform readout of signal A	oscilloscope function on A
Support automatic triggering	auto function
Support manual triggering	trigger function
Support waveform time base adjustment	time adjustment function
Support waveform amplitude adjustment of signal A	amplitude A adjustment function
Support parameter adjustment of signal A	input A measurements menu
Support specific numeric readout of signal A	cursor function
Support holding a measurement	hold function
Support holding a measurement after connecting	touch hold function
Inform about power indication	power indication symbol

<b>Secondary functions</b>	<b>name   symbol</b>
Support trend plotting	trend plot function
Support saving measurements	save function
Support recalling measurement settings	recall function
Support parameter measuring adjustment of signal A	meter A options menu
Support waveform representation adjustment of signal A	scope inputs on A menu
Support waveform representation adjustment	scope options menu
Support trigger options adjustment	trigger menu
Support waveform place adjustment of signal A	move A function
Support numeric readout of signal B	multimeter function on B
Support waveform readout of signal B	oscilloscope function on B
Support parameter adjustment of signal B	input B measurements menu
Support parameter measuring adjustment of signal B	meter B options menu
Support waveform representation adjustment of signal B	scope inputs on B menu
Support waveform amplitude adjustment of signal B	amplitude B adjustment function
Support specific numeric readout of signal B	cursor function
Support waveform place adjustment of signal B	move B function

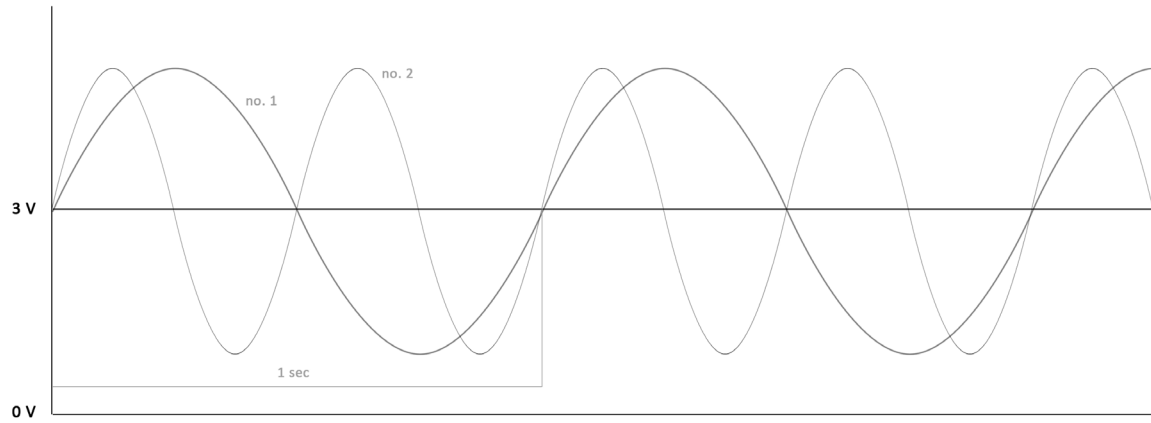
<b>Tertiary functions</b>	<b>name   symbol</b>
Support grid adjustment	grid menu
Support backlight adjustment	brightness menu
Support contrast adjustment	brightness menu
Support saving measurement results	save function
Support printing measurement settings	print function
Support printing measurement results	print function
Support recalling measurement results	recall function
Support language adjustment	language select menu
Support specific parameter measurement adjustment	autoset adjust menu
Support saving use of energy	power down menu
Inform about version information	version & calibration menu
Inform about date of measurement	date adjust menu
Inform about time of measurement	time adjust menu
Support battery refreshment	battery refresh menu

Table II: classification of product functions by frequency of use

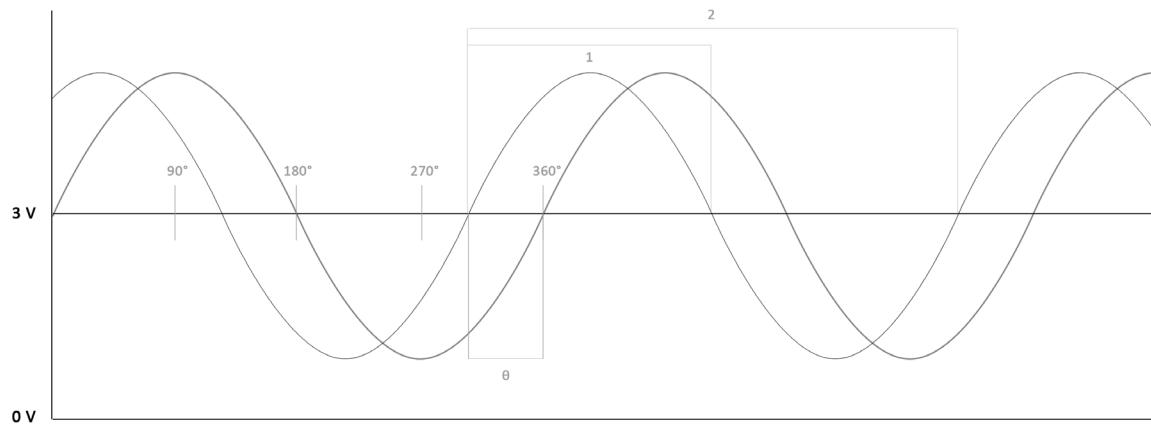
## D | Measurement options

Parameter	More specific...	Explained...	Expressed in...
voltage	voltage in alternating current ( $V_{AC}$ )	<i>the average potential energy caused by the alternating component of a current; the RMS value</i>	volt (V)   decibel (dB)
	voltage in direct current ( $V_{DC}$ )	<i>the average potential energy of a current compared to the ground (0V) and without taking the alternating component into account</i>	volt (V)   decibel (dB)
	voltage in alternating current and direct current ( $V_{AC+DC}$ )	<i>the average potential energy of the signal taking both VAC and VDC into account</i>	volt (V)   decibel (dB)
	peak max	<i>the highest measured electrical tension</i>	volt (V)
	peak min	<i>the lowest measured electrical tension</i>	volt (V)
	peak-to-peak	<i>the difference between the highest and lowest measured electrical tension</i>	volt (V)
	peak-to-average ratio   Crest Factor	<i>the peak power (V) divided by the average power (V)</i>	Crest Factor (CF)
frequency		<i>the number of cycles per unit time</i>	hertz (Hz)
continuity		<i>whether a current is passing or not</i>	sound & ohm ( $\Omega$ )
direction	'diode test'	<i>the direction of the current flow</i>	ohm ( $\Omega$ )
resistance		<i>the opposition of the passage of the current</i>	ohm ( $\Omega$ )
capacity		<i>the amount of stored energy in an element</i>	farad (F)
ampere	ampere in alternating current ( $A_{AC}$ )	<i>the amount of electric charge passing a point in an electric circuit per unit time</i>	amps (A)
	ampere in direct current ( $A_{DC}$ )	<i>the amount of electric charge passing a point in an electric circuit per unit time</i>	amps (A)
	ampere in alternating current and direct current ( $A_{AC+DC}$ )	<i>the amount of electric charge passing a point in an electric circuit per unit time</i>	amps (A)
temperature		<i>the temperature</i>	degree Celsius ( $^{\circ}C$ )   degree Fahrenheit ( $^{\circ}F$ )
pulse duration	positive pulse duration	<i>the duration of a positive pulse; a part of a signal</i>	time
	negative pulse duration	<i>the duration of a negative pulse; a part of a signal</i>	time
event duration   Duty Cycles	positive event duration	<i>the ratio between the positive pulse duration and the total period of a signal</i>	percentage (%)
	negative pulse duration	<i>the ratio between the negative pulse duration and the total period of a signal</i>	percentage (%)
phase		<i>the angle between the origin of two signals</i>	degree ( $^{\circ}$ )

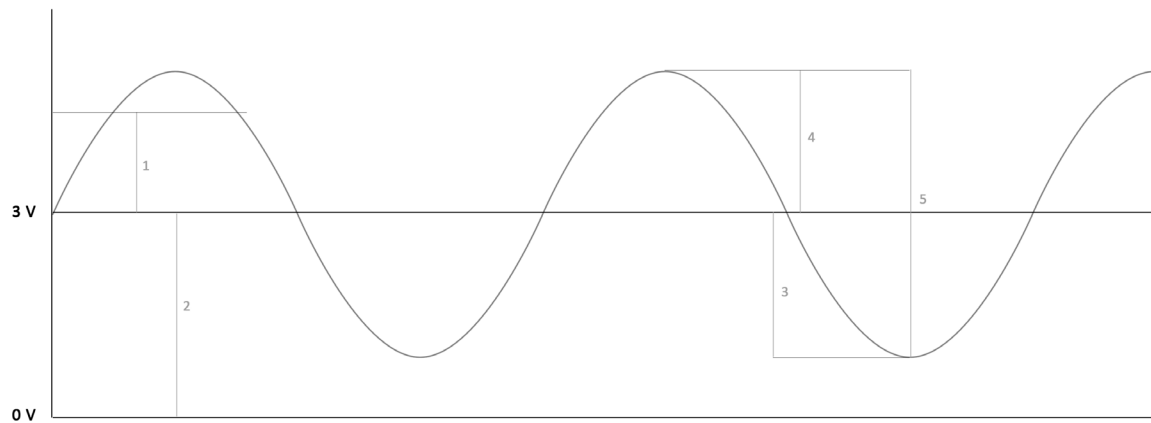
Table III: parameters that can be measured using the ScopeMeter 123



wave no. 1 = 1 Hz  
 wave no. 2 = 2 Hz



$\theta$  = phase difference  
 1 = pulse duration  
 1/2 = event duration



1 = VAC  
 2 = VDC  
 3 = peak min  
 4 = peak max  
 5 = peak to peak  
 4/1 = Crest Factor

## E | Keypad analysis

### *Function keys*

The four blue keys just below the display do not have one specific function. They are related to the menu items in the menu area on the display. This relation is underlined by the vertical inscribed lines above each key. The four keys are used in order to navigate through the menus, although they can only control the menu item on the screen right above the key. Although their function varies, they have a graphical label; F1, F2, F3 and F4. This label is used in the manual for textual explanation.

### *Arrow keys*

The four arrow keys are also blue and also have different functions depending on the menu or function that is active. Because the arrows are used to navigate through the menus, they have the same color as the four blue keys just below the display. When all menus are closed and the trigger and cursor function are inactive, which is the case after turning on the ScopeMeter, the arrow keys can be used to move signal A to the left, right, up or down. Signal B can be moved to the left, right, up or down after selecting 'move B' on the screen. The arrow keys are also used to move the cursors or the trigger after selecting the cursor or trigger function.

### *Keypad area A and B*

Two areas can be distinguished at the left and right side of the area with the arrow keys. The left area is related to signal A and the right area is related to signal B. This is indicated by an inscribed line around each area and an inscribed letter; A or B.

### *Measurements button*

The measurement options menu can be opened with the two yellow keys, situated left and right of the arrow keys. The left yellow key opens the measurement options menu for signal A and the right yellow key opens the measurement options menu for signal B. A difference can be noticed between the texts on the two yellow keys. The ohm symbol ( $\Omega$ ) and capacity symbol ( $\rightarrow$ ) are left out of the label of the measurement options button of signal B, because it is impossible to measure those parameters on signal B. The button closed the measurement options menu when the measurement options menu is opened.

### *Amplitude button*

The amplitude of signal A or signal B can be changed by using the light gray vertical oriented keys below the yellow keys on each side. Pressing the top part of these keys results in a larger deflection of the waveform in vertical direction. Pressing the bottom part of these keys, results in a smaller deflection of the waveform in vertical direction. The texts on both sides of the key refer to the actual effect on the screen. 'mV' stands for millivolt and 'V' stands for volt, where millivolt is less than volt. When the top part of the key is pressed, the voltage per divisions on the screen decrease. This means that more divisions are needed in vertical direction to represent the same deflection.

### *Time base button*

The time base of the waveform area can be changed by using the light gray horizontal oriented key right below the arrow keys. Because both waveforms (of signal A and B) are situated in the same waveform area with one time base, only one key is needed to adjust the time base instead of two keys. Pressing the left part



Figure II: keypad of the ScopeMeter 123

of the key, results in a smaller waveform representation (compression of waveform in horizontal direction). Pressing the right part of the key, results in a wider waveform representation (decompression of waveform in horizontal direction). The texts on both sides of the key refer to the actual effect on the screen. 's' stands for seconds and 'ns' stands for nanoseconds, where nanoseconds is less than seconds. When the left part of the key is pressed, the seconds per divisions on the screen increase. This means that fewer divisions are needed in horizontal direction to represent the same wavelength.

#### *Hold | Run button*

The left button of the second row from the bottom is the 'hold and run' key and has a purple color. The button enables the user to toggle between the hold and run function. A horizontal stroke is placed between the words hold and run to communicate the toggle function. Pressing the button once results in holding the measurements. Pressing the button again results in stop holding the measurements or in start running the measurements again. Hold can be interpreted as 'hold on', where run can be interpreted as 'hold off'.

#### *Scope Menu button*

The middle button of the second row from the bottom is the 'scope menu' key. The key opens the 'scope inputs' menu and gives access to the 'scope options' menu, the 'probes' menu and the 'trigger' menu. The 'scope menu' button is black colored. The button closes the 'scope inputs' menu when this menu is opened.

#### *Auto button*

The right button of the second row from the bottom is the 'auto' key and has a turquoise color. The button enables the user to toggle between the auto and manual modus. Pressing the button once results in automatic triggering and with that stabilizing the waveform. Pressing the button again results in turning off the automatic triggering function. This modus is called the 'manual' modus because the waveform must be stabilized manually. Auto can be interpreted as 'auto on', where manual can be interpreted as 'auto off'. Although the 'auto' button enables the user to toggle between the auto and manual modus, the label of the button is just 'auto' and does not give an indication of a toggle function.

#### *Power button*

The left button on the bottom line is the 'power' key. The button is green colored and is labeled with the typical power symbol. Pressing the button when the device is off, results in turning the device on. Pressing the button when the device is on, results in turning the device off.

#### *User options button*

The second button from the left on the bottom line is the 'user options' key and is black colored. The key opens the 'user options' menu and gives access to the version and calibration information. The button closes the 'user options' menu when this menu is opened.

#### *Save | Print button*

The third button from the left on the bottom line is the 'save and print' key. This key opens the 'save and print' menu and is black colored. The button gives access to save measurements or settings, recall measurements or settings, delete saved measurements or settings, and print measurements, settings or the current screen. Next to this, the function gives access to the printer setup menu. The button closes the 'save and print' menu when this menu is opened.

#### *Brightness button*

The right button on the bottom line is the brightness key. The button has a black color and is labeled with a light symbol. The key opens the brightness menu where light and contrast of the display can be adjusted. The button closes the brightness menu when this menu is opened.

# F | Requirements

## Baseline requirement

The I-set function is applicated	
The display can represent colored and high resolution pictures	
The user interface lines up with the display required capacities; colored and with an high resolution	
The product appearance clearly communicates its capacity and price	
The product can be controlled with gloves and in a dirty environment	
The product is portable	
The product is manageable	

## The user interface is effective

0.04

## The user interface is efficient

0.26

The arrangement of the keys is in line with the frequency of use of the functions and menus	
The arrangement of the measurement options is in line with the frequency of use of the options	
The visual feedback of the information in the screen area is clear	
The visual feedback of the information in the screen area is univocal	
The visual feedback of the information in the screen area is conveniently arranged	
The visual feedback of the information on the keys is clear	
The visual feedback of the information on the keys is univocal	
The visual feedback of the information on the keypad is conveniently arranged	
The visual feedback of the information in the menu is clear	
The visual feedback of the information in the menu is univocal	
The visual feedback of the information in the menu is conveniently arranged	

## The user interface is engaging

0.04

The product looks more advanced than a multimeter	
---	--

## The user interface is error tolerant

0.13

The design prevents the critical use scenario of empty batteries to occur	
The interface allows an explicit and clear way out of all kinds of menus	

**The user interface is easy to learn**

**0.40**

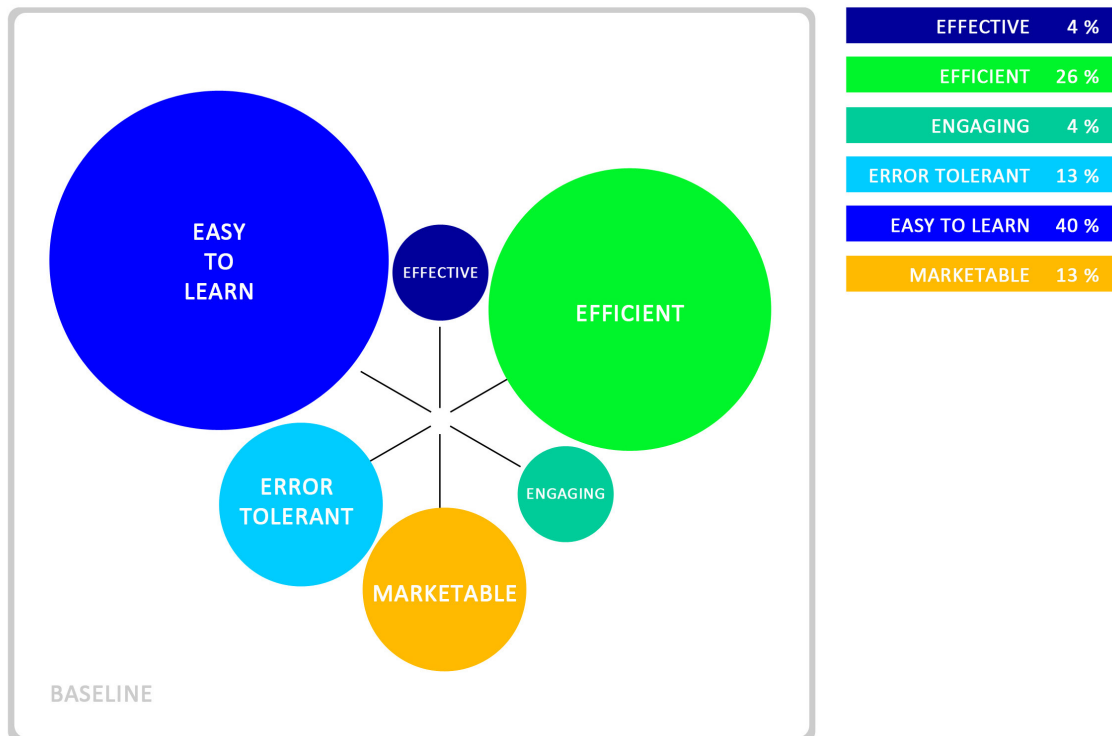
The metaphors used to clarify the menu structure and navigation are consistent with real-world conventions	
The interface allows an explicit and clear way out of all kinds of menus	
The place of functions and menus within the interface is consistent	
The user interface is consistent with the conventions applied on the user interface of a multimeter	
The visual feedback of the information in the screen area is clear	
The visual feedback of the information in the screen area is univocal	
The visual feedback of the information in the screen area is conveniently arranged	
The visual feedback of the information on the keys is clear	
The visual feedback of the information on the keys is univocal	
The visual feedback of the information on the keys is conveniently arranged	
The visual feedback of the information in the menu is clear	
The visual feedback of the information in the menu is univocal	
The visual feedback of the information in the menu is conveniently arranged	

**The user interface is marketable**

**0.13**

The user interface clearly communicates the products strengths and capacities	
---	--

Table IV: requirements with weighting factor



# G | Ideation keypad design





















# H | Pre-questionnaire usability test

1. Gender

- Male
- Female

2. Age

 year

3. Education

None

4. Current profession

None

5. Current employer

None

6. Werkervaring

 years

7. Do you use a multimeter, professionally or in leisure time?

- Yes, professionally
- Yes, in leisure time
- Yes, professionally and in leisure time
- No

8. How often do you use a multimeter on average?

- Not applicable
- Less than 2 times a year
- 2 – 6 times a year
- Once a month
- Once a week
- A few times a week
- Every day
- Other:

9. What type of multimeter do you mainly use ?

- Not applicable
- Digital multimeter
- Analogue multimeter
- Unknown

10. What brand and type multimeter do you mainly use ?

Not applicable

Brand:



Other:

Unknown

Type:










Unknown

11. When did you use a multimeter for the last time?

Not applicable

More than 1 year ago

1 year ago

Half a year ago

4 – 2 months ago

1 month ago

2 weeks ago

Last week

Yesterday

Today

Other:

12. Do you use a handheld oscilloscope, professionally or in leisure time ?

- Yes, professionally
- Yes, in leisure time
- Yes, professionally and in leisure time
- No, but I do use bench oscilloscopes
- No, I do not use oscilloscopes

13. How often do you use the handheld oscilloscope on average ?

- Not applicable
- Less than 2 times a year
- 2 – 6 times a year
- Once a month
- Once a week
- A few times a week
- Every day

Other:

14. What type of handheld oscilloscope do you mainly use ?

- Not applicable
- 2-channel
- 4-channel
- Other:
- Unknown

15. Which brand an type handheld oscilloscope do you mainly use ?

Not applicable

Brand:



Other:

Unknown

Unknown

Type:










16. When did you use a handheld oscilloscope for the last time ?

Not applicable

More than 1 year ago

1 year ago

Half a year ago

4 – 2 months ago

1 month ago

2 week ago

Last week

Yesterday

Today

Other:

17. Have you ever used a Fluke Scopemeter 123, 124, or 125 ?

Yes

No

Unknown

18. How often do you use the Fluke ScopeMeter 123, 124, or 125 on average?

- Not applicable
- Less than 2 times a year
- 2 – 6 times a year
- Once a month
- Once a week
- A few times a week
- Every day

Other:

19. When did you use the Fluke ScopeMeter 123, 124, or 125 for the last time ?

- Not applicable
- More than 1 year ago
- 1 year ago
- Half a year ago
- 4 – 2 months ago
- 1 month ago
- 2 weeks ago
- Last week
- Yesterday
- Today

Other:

# I | Task list usability test

## 1 signal

1. Turn on the ScopeMeter.

1 signal is visible at the screen: signal A.

2. Change the time base of the ScopeMeter to enlarge the amount of pulses visible on the screen.
3. Change the time base to the previous setting.  
Currently, the voltage in alternating current (  $V_{\sim}$  ) is measured.
4. Change the settings to measure the frequency of signal A.
5. Turn the ScopeMeter off and on.

Think about measuring a signal which you cannot stabilize using the trigger function. You suspect the cause to be the frequency of the signal, which is very low. Subsequently you change the time base in order to get a clear representation of the signal. However, this does not work. Another option is to change the settings of the ScopeMeter to let the signal roll through the screen.

6. Change the settings to let the signal roll through the screen.

## 2 signals

7. Turn on the ScopeMeter.

Two signals are visible: signal A and signal B.

Currently, the voltage in alternating current (  $V_{\sim}$  ) is measured of both signals.

8. Change the settings to measure the frequency of signal B.

## 1 signal

1. Turn on the ScopeMeter.

1 signal is visible at the screen: signal A.

2. Change the time base of the ScopeMeter to enlarge the amount of pulses visible on the screen.
3. Change the time base to the previous setting.  
Currently, the voltage in alternating current (  $V_{\sim}$  ) is measured.
4. Change the settings to measure the voltage between the highest and the lowest value of the signal or, in other words, the peak-to-peak value.
5. Turn the ScopeMeter off and on.

6. Change the settings to let the signal roll through the screen.

## 2 signals

7. Turn on the ScopeMeter.

Two signals are visible: signal A and signal B.

Currently, the voltage in alternating current (  $V_{\sim}$  ) is measured of both signals.

8. Change the settings to measure the pulse duration of signal B.



## K | Visualization task performance



Figure XIII: task zoom in –original concept (above) and redesign (below)



Figure XIV: task measure peak-to-peak value – original concept



Figure XV: task measure peak-to-peak value – redesign



Figure XVI: task set roll mode – original concept



Figure XVII: task set roll mode – redesign

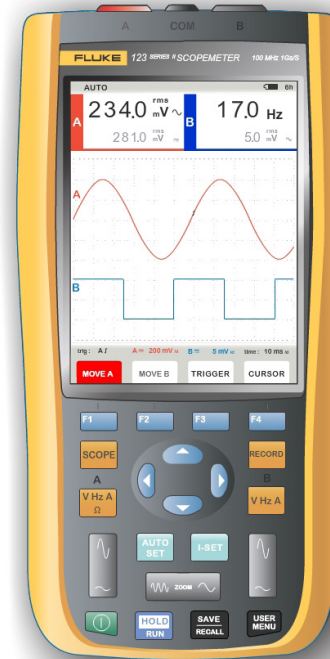
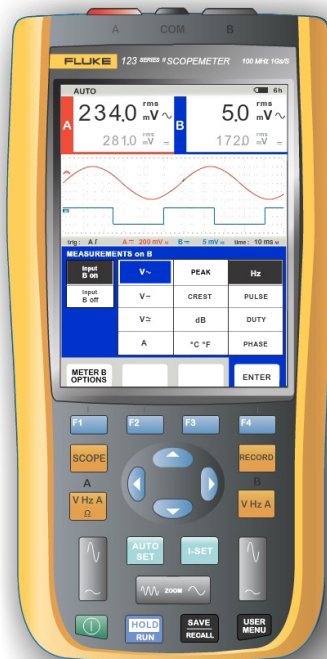
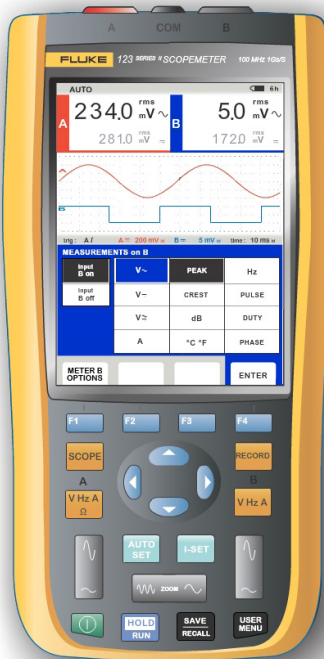
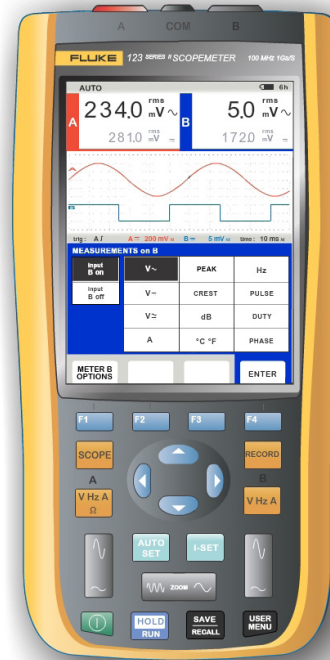
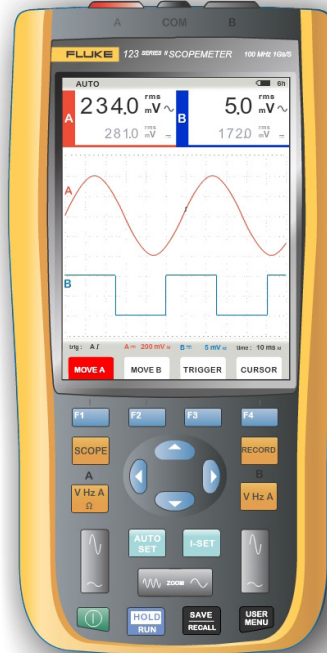


Figure XVIII: task measure frequency on B – original concept



Figure XIX: task measure frequency on B – redesign

# L | Meetings with Peter Deverson

## 1<sup>st</sup> meeting | July 4, 2012 <sup>[33]</sup>

<b>Date</b>	July 4, 2012
<b>Location</b>	Fluke Corporation in Almelo
<b>Attendant</b>	Peter Deverson Rosanne Andriessen Christian Suurmeijer

### Users

The user can be described as those with the blue jackets, or 'blue collar worker'. In general they had their education at intermediate technical school. They do not read the manual of the product and learn by trial and error. They explore the product by using it.

In general the user can be seen as the 'third-party'. If the technical department of a company cannot find the problem, they ask an external company to search for the problem. This external company is called 'the third-party'. If this third-party cannot find the problem, the manufacturer of the machine or device is called in to solve the problem.

### Product

The ScopeMeter 123 is an expensive product, especially considering the other tools the user uses.

The product must be easy to use. Users must do their job fast. With that, there is no time during the job to discover how to use the product. The selling point of the product is its easy use; it automatically searches for the right plot and shows a stable waveform after connecting. Not surprisingly Fluke owns the slogan 'connect-and-view'.

### Usage

According to Deverson, only 30% of the users have their 'own' product, which means they do not have to share their tool with fellow workers. 70% of the users share the product, because of the costs.

The average use of the product is estimated at once in the three weeks. Though some users only use the product once in a few months.

Most of the time the user wears working gloves. Therefore a touch screen is not recommended and the buttons must be placed with sufficient space around.

In most of the cases, the product is used in several environments. Therefore the product must be easy to carry. In addition, the product is used like a hammer. The ScopeMeter is carried in a tool box and used in a dirty setting most of the time.

### New generation

The goal is to design a product that fulfills its task by the push of a single button.

The display of the new generation of the ScopeMeter will be longer, with a higher resolution and colored.

One important improvement will be the functionality to automatically show the desired information regarding the signal characteristics. Nowadays there is sufficient information available to know which information is desired to show on the screen for each waveform. Another improvement will be the addition of the CURSOR key.

The intention is to smoothly integrate the new functions.

### Focus

It is not possible to optimize the total user interface within three months. Peter Deverson advices to focus on:

- application of the new function;
- application of the new display;
- application of the CURSOR button;
- minimization of actions that must be taken before (user) goal is reached.

## 2<sup>nd</sup> meeting | July 6, 2012 <sup>[34]</sup>

<b>Date</b>	July 6, 2012
<b>Location</b>	Fluke Corporation in Almelo
<b>Attendant</b>	Peter Deverson Rosanne Andriessen Christian Suurmeijer

### Physical ENTER button

The Fluke ScopeMeter 190 series has a physical ENTER button, but the 120 series does not. The main reason that there is no physical ENTER button on the ScopeMeter 120 series is that there is not enough space.

In addition:

There is some discussion about the word ENTER. Maybe the word SELECT is a better representation of the function of the button.

Regarding the ENTER button, there is inconsistency between the 190-serie and the 120-serie. At first sight you would say that such an inconsistency (between the interfaces of two products in the same product range) is not desired. In this case it is no problem because the two products reach for a different target group. Users of the 190-serie do not use products of the 120-serie.

### Feedback when charging

No feedback is given when the product is turned off and connected for charging. This way the user does not know if his or her action was successful. When the product is turned on, the feedback on this action is given by a 'battery' symbol changing into a 'plug' symbol. Mobile phones give this feedback by turning the lights on for a moment. This way the user is told that the device is receiving energy and that his action was successful.

In addition:

The battery symbol in the interface of the ScopeMeter 123 is located in the middle of the lower part of the interface, which is not a standard place. The user may easily miss the symbol and with that the battery conditions. In the interface of a ScopeMeter of the 190-serie, provided with a newer display and user interface, the symbol is located in the right upper corner. This location is much more expected by the user because of experiences with other user interfaces.

The battery symbol changes into a plug when charging in the interface of the ScopeMeter 123. In the 190-serie this symbol changes into a loading battery symbol when charging.

### Function of the standard

There are two important reasons why the application of a standard is desired.. The first reason is that the standard can function as hanger, for instance on a door. The second reason is that the user is limited in his movements when measuring. He needs to hold the probes at the right

place, so the display must be readable from that position. From a standing (vertical) position this is rather realized than from a lying (horizontal) position of the display.

### **Time adjustment**

The user of the ScopeMeter 123 can adjust the time. Within this functionality hours, minutes and seconds can be changed. Especially the last one seems useless. The reason for this is that it is very standard to give the user the possibility to adjust seconds next to hours and minutes.

In addition:

Knowing the exact moment of a specific measurement is sometimes essential in the communication of measurement results to other parties.

### **BACK function**

There can be noticed a difference in going back with BACK on the screen and by pushing the (physical) menu button a second time. The intention is that with BACK in the screen you can close a submenu and go back to the main menu, and that a main menu always must be closed by pushing the (physical) menu button a second time. This is not a very consistent use of going back in general.

### **POWER DOWN**

The title 'power down' option in the 'user options'-menu can give the user the intention that the product will 'power down' by pushing the button. An option for instance is to call it 'standby' or 'power save'.

### **Menu navigation**

It is not possible to directly select the last option in a menu by moving up from the first option and the other way round. This possibility is probably not applied because there is a maximum of five options under each in a menu, which is not much. Nevertheless it can be a good addition in a new user interface.

### **Measurement functions**

The functions  $V_{AC}$ ,  $V_{DC}$ , Hz and Peak - from the 'measurement options' menu - are most frequently used. The option dB is rarely used.

Hz is not positioned optimal in the 'input measurements'-menu, regarding the fact that it is one of the most frequently used functions. In the current interface, Hz is placed in the third row, on the ninth place in the menu.

In addition:

The ScopeMeters from the 120-serie do not have a function to make a frequency spectrum. This function is applied in the products that are used by (the white collar workers).

### **CURSOR key**

In the new generation, a CURSOR-button will be added to the physical interface. This will be done because the cursor function is frequently used. With the AUTO button, standard measurements are done. But to gather specific information, on specific points of the signal or between two specific points, the point or areas must be selected by the user with a cursor of cursors. In the current user interface, the cursor function must first be selected from a menu, before the user can use the cursor, which is not desired, especially because the selections of a specific point or area with the cursor(s) already cost more time than a general action.

### **PRINT | SAVE function**

The function to directly print measurement results will be removed. These days everyone has a computer and wants to save the results on the computer and not print them directly.

The save function on the other hand is still an important and frequently used function. In addition to saving on an external device like a computer, the user can save an image or save settings to recall during another measurement. The implementation of a separate physical SAVE- and RECALL-button is not desired and therefore not necessary. The save function is more important and more frequently used than the recall function.

#### **User-product interaction time**

The user-product interaction time varies a lot. Sometimes the problem is solved in 15 minutes, sometimes it takes the whole day. On average you can say the user-product interaction time is half an hour.

In addition:

The lifetime of a product lies between the 7 and 10 years.

#### **Time- and performance pressure**

Generally there is high time pressure with regard to the usage of the product. In most cases a whole production lies down because of the defect machine.

#### **Requirements Fluke**

According to Peter Deverson the most important requirements on the design of the new generation ScopeMeter 123 are:

1. Reliance on good product performance. The product must work on every moment the user needs it. There is no time to fix the product. Therefore the product need to be mechanical and electrical robust.
2. Reliance on valid measurements. Therefore the product need to give continue right and valid measurements, so the user can fully rely on the outcome. In terms of requirements there can be said that the measurement results must be valid.
3. Long-term product performance. The product must perform the whole day, without charging it.

To meet the last requirement in the current product, the battery must be fully charged before use. Although the battery can be charged during usage, this is not desired. In most of the usage environments (production plants), no normal alternating current (like 230 V) is available, which makes charging impossible. In addition, only 50% of the users take the product in its original suitcase. That means that 50% of the users take the product in their own toolbox and are likely to forget their battery charger.

### **3<sup>th</sup> meeting | July 13, 2012 <sup>[35]</sup>**

<b>Date</b>	July 13, 2012
<b>Location</b>	Fluke Corporation in Almelo
<b>Attendant</b>	Peter Deverson Rosanne Andriessen

#### **Market information**

The market information gathered by Fluke, is from registered users. Because only the top half of the users do register, this market information can only give an (first) impression on the items that were asked for. The information must be interpreted as qualitative, not as quantitative. If the outcome of the research says that a specific percentage of the respondents did give a certain answer, this must not be interpreted as representative for all users. You must not rely on the specific outcomes. They must be used to get an impression or a better understanding or feeling of the situation.

### **Differences between Europe and USA**

There is no difference between the ScopeMeters sold in Europe and the ones sold in the USA.

In addition:

Customers in the USA typically overbuy. This behavior is based on insurance. Products of the ScopeMeter 190 series are more advantaged and have more possibilities. Not surprisingly in the USA more 190's are sold than 120's.

In Europe, on the other hand, more 120's than 190's are sold. Europeans do buy more specific on their needs than Americans. In Japan this is even more the case. Japanese buy very precisely what they need.

### **Display dimensions & design evolution**

According to the waveform presentation, a wide display is desired. Although the application of a wider screen is a desired, it is more desired to keep the current product proportions; long and small. This design (long and small) communicates to the customer what they can expect regarding the product capacities and its price. The product must look more basic than the oscilloscopes from the 190-serie. Therefore it has the dimensions of a Fluke multimeter. Another important reason for keeping the current proportions is that the customer must recognize the new generation as a new version of the old. To clarify this statement, Peter Deverson compares the by Fluke desired development to the design evolution of the Porsche 911. Looking at the evolution over the years, it can be noticed the design has changed, but the number of 'basic elements' remains the same. The modern version can still be recognized as the Porsche 911 of 50 years ago. This is what Fluke wants in the development of the ScopeMeter 120 series. People must recognize it as the 'old' trustable ScopeMeter is has been for the last 15 years. It has to be classic and modern in the same time. Fluke wants a design evolution, not a revolution.

### **Critical use cases**

If you ask any user for complains about the current product, 75% will definitely complain about the battery. It is by far the most critical point of the current ScopeMeter.

Another point that will be mentioned as critical point is the display performance. It is not that the display fails, but that the users expect a more modern display.

### **Minimize backlight to save energy**

With the application of the new display (LCD with backlight) lowering the backlight to save energy will be hardly effective. With that there will be applied a new battery which enables longer battery operation without charging. All in all, the option to adjust the backlight must be put deeper in the menu and the physical button for changing backlight and contrast can be left out.

In addition:

With the application of a new battery the option to refresh the battery can be removed. The option was needed to keep the capacity of the old (nickel-metal hydride) batteries, because they have a so called memory effect.

### **Waveform comparison**

To compare waveforms with each other, they can be placed over each other. The waveforms can be moved by selecting MOVE on the interface after which the signals can be moved up or down by using the arrow keys. There is no direct way to place the waveforms over each other, but according to Peter Deverson this is rarely done and not desired by the user.

### **HOLD function**

The hold function originates from the beginning of the oscilloscopes, where users did not

know how to use the oscilloscope (which automatically stabilizes a signal). To get a stable readable waveform, they used hold to freeze the display.

If the AUTO function is used right, hold is not needed in normal cases. But if a user adjusts several settings and then gets an unstable waveform, the hold function is desired. This is because all settings will be reset by using the AUTO function.

A more specific case is when the function TrendPlot is used. Then the hold function is needed to freeze the screen. To obtain a specific numerical readout, a frozen measurement is needed.

Furthermore, every product has a HOLD function. It is very much desired by the user so the product needs it as a standard key.

#### 4<sup>th</sup> meeting | July 23, 2012 <sup>[36]</sup>

<b>Date</b>	July 23, 2012
<b>Location</b>	Fluke Corporation in Almelo
<b>Attendant</b>	Peter Deverson Rosanne Andriessen Christian Suurmeijer

#### **AUTO function**

Within the AUTO functionality, the following 'signal characteristics' are automatically set:

- amplitude;
- time base;
- trigger level;
- trigger slope;
- trigger hold off.

Setting these characteristics gives a stable waveform. The word 'auto' appears on the display, to communicate that the AUTO-function is on.

If the user adjusts the amplitude or time base, after first using the AUTO function, the word 'auto' in the display disappears. This is because only a part of the characteristics are automatically displayed. Nevertheless, the auto-trigger functionality is still on.

If, after first using the AUTO function, the AUTO button is pressed again, the word 'auto' in the display disappears, and is replaced by the word 'manual'. On this point, all auto-functionalities are set off. The display will stay stable because the old settings are used. If the user adjusts one of the settings, the waveform will probably become unstable.

#### **AUTO vs. ISET**

In the next generation of the Fluke ScopeMeter 120 series, a new function called 'I-set' will be applied. With this function not only the signal characteristics like the amplitude, time base, trigger level, trigger slope and trigger hold off are automatically set, but also the 'measurement input' will be set. This means that the device will, given the received signal, determine which result is probably wanted to be displayed in the numeric read-out area. According to Peter Deverson, a lot of research is done and sufficient information is gathered to realize this functionality. This ISET function will be added to the interface and will not replace the AUTO functionality.

**Display previous measurement setting**

In the reading area, at the top of the display, most of the time two different numeric measurement results are displayed. The top one of these two gives the measurement result according to the current measurement settings. The measurement result displayed below, gives the result according to the previous measurement setting. So the idea is that the current measurement result slides down when the 'measurement input' changes. This gives the possibility of a read-out of two different measurements, such as the amplitude and the frequency, at the same time.

## M | Meeting with Bertus Kottier [37]

**Date** July 24, 2012  
**Location** Brusche Elektrotechnik  
**Attendant** Bertus Kottier  
Rosanne Andriessen  
Mark Grob

### **Purpose**

Gain insight into the users and usage of the ScopeMeter 123 within Brusche Elektrotechnik.

## **Brusche Elektrotechnik**

**Trading name** Brusche Elektrotechnik  
**Address** Sniederhof 13  
7603 BZ Almelo  
The Netherlands

*Brusche Electrical Engineering is at the basis of total electrical systems in many buildings, industrial complexes and other projects in various market segments. (...) At the moment there are approximately 70 employees at Brusche Electrical Engineering. (...) The activities are subdivided into three main areas:*

- *Electrical Engineering*
- *Industrial Automation*
- *Service & Maintenance*

### **Service & Maintenance**

If a fault occurs, Brusche Elektrotechnik provides a *prompt and adequate service. If desired, 24 hours a day, 7 days a week. After a fault has occurred, (...) technical specialists will be on site within the agreed response time. The corrective maintenance activities consist of both standard electrical activity as well as specialization in Industrial Automation.*

*The activities in the area of service and maintenance include:*

- (...)
- Corrective maintenance of machinery, production & processing installations (24h/7d)

## **Visit results**

### **Bertus Kottier**

Bertus Kottier is Senior Engineer at Brusche Elektrotechnik. He is, as he says, the second man within the area Industrial Automation. In his position, Bertus Kottier is, in the main, responsible for project management and planning, but next to this he deals with engineering, financials and more. Regarding problem solving with the ScopeMeter, Kottier gives the electrical engineers a short explanation of how to use the ScopeMeter before they need to use it. In some cases he goes along with the electrical engineers to assist in troubleshooting.

The explanation generally takes about half an hour. Together, Kottier and the engineer go over the main functions of the device, the expected cause of the problem and which kind of signals can be expected.

### **Users**

Within Brusche Elektrotechnik, the ScopeMeter 123 is used by the electrical engineers class A, as Kottier called it. These engineers are characterized by their experience. At least five years

of experience is desired but within Brusche Elektrotechnik most troubleshooting engineers have about twenty years of experience. Just graduated or student engineers may not solve a problem because experience and sufficient knowledge is required. In general the users are trained as electrical engineer and had their education at intermediate technical school (Dutch: Middelbare Technische School (MTS) or today's Middelbaar Beroepsonderwijs (MBO)). All the engineers at Brusche Elektrotechnik hold a permanent appointment. According to Kottier it is important to keep knowledge (know-how) in-house.

The user can be characterized as practically and solution oriented. Engineering is in their field of interest. According to Kottier, they like to create a well working installation or system and want to deliver quality. Diversity is, next to the practically and solution oriented part, what makes the user like their work as electrical engineer. The problems are solved on different locations and every problem has its own solution.

Typical for the electrical engineer is that he explores by trial and error and reads the manual only if necessary.

### **Usage**

Within Brusche Elektrotechnik, the ScopeMeter 123 is rarely used. Only in certain problem solving cases a device that can show a signal over time is desired and a multimeter is deficient. According to Kottier, the ScopeMeter is only used about three times a year and by five to six engineers. With that, the ScopeMeter is only used at clients and hardly ever used at Brusche Elektrotechnik.

Brusche Elektrotechnik owns one ScopeMeter 123, with the result that the device must be shared. This, however, does not cause any problems.

Because the ScopeMeter is rarely used, it feels a little uncomfortable every time the device is used.

All engineers start their working day at 7:30 am. After having a cup of coffee, work is divided among the engineers. Depending on the problem description communicated by the client, there will be decided who will go and which tools are needed. It depends on the description whether the ScopeMeter 123 is needed or not. A digital multimeter, current clamp and wire cutter are, unlike the ScopeMeter, common tools. Every engineer has his own multimeter. Within the company, Fluke multimeters are used.

If problems must be solved outside the regular working day, the technical service is called in. Once in a while each engineer works on call for one week.

Before the engineer will start measuring the installation to find the problem, the client is asked about the problem. According to Kottier not infrequently, the client is undeserved sure that certain things cannot be the cause of the fault. Therefore the engineer thinks for himself first, using his horse sense. In the process to find the cause of the problem, clear-thinking and analyzing of the measurement results take more time than measuring itself. In general, problem solving is not a 'five minute job'. It takes approximately two hours to solve the problem.

Subsequently to measuring and analyzing, the engineer fixes the problem. If the cause is a failing part, this part will be replaced. If a part is not immediately available, the engineer tries to find a temporary solution. In most of the cases a broken machine costs the client a lot of money.

## N | Meeting with Maarten van Alphen [38]

**Date** August 23, 2012  
**Location** Benchmark Electronics  
**Attendant** Maarten van Alphen  
Rosanne Andriessen

### $V_{AC}$ and $V_{DC}$

Measuring Voltage in Alternating Current ( $V_{AC}$ ) gives the potential energy of the signal created by the alternating movement of the signal. If a signal has no alternating movements, the  $V_{AC}$  value will be 0 volts. In some cases this is very decent, but in the case of mains supply an alternating current is consciously applied. In fact, measuring the  $V_{AC}$  gives the Root Mean Square (RMS) value of a signal. If the signal is a purely sinus, the peak value is about 1.4 times higher than the RMS value.

Measuring the Voltage in Direct Current ( $V_{DC}$ ) gives the potential energy without the VAC taken into account. It gives the potential energy compared to the ground value.

### Manually triggering and Single Shot

When the expectation is that a peak value occurring only once in a while is the cause of a defect, this peak value needs to be 'caught'. This needs to be done with the Single Shot functionality.

### Hold vs. Touch Hold

Touch hold only holds if a change of a signal is noticed. The user can first press Touch hold, then connect the ScopeMeter to the circuit after which the ScopeMeter automatically holds the signal if the signal is received. The hold function holds directly, without 'waiting' for connection. The touch hold function is especially desired in the case the user has no hands left to push a button or if the user is removed from the ScopeMeter during the measurements.

### Frequency of use measurement options

Voltage, or tension measurements, like  $V_{AC}$ ,  $V_{DC}$ ,  $V_{AC+DC}$ , peak min, peak max, and peak-to-peak, are frequently used and with that important measurement options.

Continuity measurements are, according to Maarten van Alphen, very important and very frequently used in the field of troubleshooting. Lots of problems have a mechanical origin, and then a continuity test can give the answer whether a current is flowing or not.

Also the diode test and resistance measurements are very frequently used; these measurements can be seen as a continuity tests, but more specific.

Next to the voltage and resistance or continuity, frequency is also a frequently used measurement option.

Although ampere and temperature measurements can be useful in the field of troubleshooting, they are less frequently used. The main reason for this is that extra equipment is needed for these measurements. With that, ampere measurements are difficult, can be more dangerous and require an interruption of the circuit. In addition, new technologies enable very easy temperature measurements using infrared technologies.

Crest Factor, capacity, pulse duration, and event duration are, according to van Alphen, rarely used. He calls these measurements 'exotic', because they require reasonable knowledge, more than the average user is trained for.

Phase measurements are, as van Alphen called it, 'two star exotic' if you value the 'exotic' measurements as 'one star exotic' measurement. This measurement option can be seen as very rarely used.

This estimation gives the following rating of measurements options:

**very important**

- continuity test;
- diode test;
- resistance measurement;

**very important**

- $V_{AC}$  measurement;
- $V_{DC}$  measurement;
- $V_{AC+DC}$  measurement;
- peak min measurement;
- peak max measurement
- peak-to-peak measurement;
- frequency measurement;

**less frequently used | difficult to measure**

- ampere measurement;
- temperature measurement;

**rarely used | 'one star exotic'**

- Crest Factor measurement;
- capacity measurement;
- pulse duration measurement;
- event duration measurement;

**very rarely used | 'two star exotic'**

- phase measurement;