POLITECNICO DI MILANO

Master degree in Design & Engineering

E - Knee

Wearable concept with integrated
electro stimulation system
for the muscles therapy

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“ ... nostre sono “le due esprienza della vita adulta” di cui parlava Pavese, il successo e l’insuccesso, uccidere la balena bianca o sfasciare la nave; non ci si deve arrendere alla materia incomprensibile, non ci si deve sedere. Siamo qui per questo ,per sbagliare e correggerci, per incassare colpi e renderli.”

Primo Levi,Il sistema periodico

Index

ABSTRACT

Italiano

E-Knee è un dispositivo wearable con sistema di elettro stimolazione integrata per il recupero del tono muscolare della gamba.
E-knee è stato progettato per accompagnare il paziente e guidarlo durante l'intero percorso di riabilitazione.
Troppo spesso i pazienti si affidano alle terapie passive come manipolazioni di fisioterapisti e trattamenti di elettrostimolazione, non dando all'attività fisica la giusta importanza nel percorso di riablitazione post intervento.
Un approccio sbagliato, spesso dettato da pigrizia e superficialità nella considerazione del proprio stato di salute, porta i pazienti ad un recupero più lento e non ottimale.
E-knee ha uno scopo educativo poichè, grazie alla subordinazione della terapia con elettro stimolazione rispoetto all'attiva fisica, riesce a guidare il paziente in un percorso strutturato in maniera ideale dove le fasi di attività fisica attiva e passiva sono riconsiderati nel loro giusto ordine e importanza.

English

E-Knee is a wearable device with integrated electro-stimulation system for recovering leg's muscular tone.
E-knee is designed to follow and guide the patient throughout the entire rehabilitation path.
Too often, patients rely on passive therapies made by physiotherapists and electrostimulation, not giving the right significance to physical activity during the post replacement process.
A misguided approach, often dictated by laziness and superficiality in the evaluation of their own health, leads patients to a slower and less great recovery.
E-knee has an educational purpose because, thanks to the subordination of electro-stimulation therapy to physical activity, manages to guide the patient in an ideally and structured path where the phases of active physical activity and passive stimulation are reconsidered in their proper order and importance.

INTRODUCTION

The idea of this project was born by my interest in physical activity and my passion for fitness.
During the analysis, also thanks to my trainer experience, I have identified some aspects in this area that could figure out like unexpressed desires and can improve the people approach people to fitness.
Physical activity should lead to a physical condition improvement and psycho-physical health of a peron, if done wrongly and with superficiality can lead to poor results and it may cause injury in more serious cases.
The problem is even more serious if a person uses physical exercise to recover their health from accidents or illnesses: in these cases no athletic performance or an aesthetic result is compromised, but the health of the person and their quality of life.
For this reason, I decided to design a product that could help patients doing physical activity in the right way and time.
Pursuing the concepts of motivation, control and flexibility, the analysis continued with a research into wearable design world and in parallel with research into the orthoses sector and passive rehabilitation treatments.
Also thanks to interviews and meetings with orthopedics and patients at the Borghi Brebbia foundation (Varese), I could guess that patients often relied solely on passive therapies and electrostimulation, neglecting physical activity.
So I tried to combine these two aspects, identifying the relationship between the patient's physical energy consumption and the electrostatic energy consumption of the electrostimulator, I've found the key relationship around which to design.
This insight led me to study and consider the use of piezoelectric materials that, thanks to their properties, will in the future be protagonists in supporting wearable technology.
In defining the aesthetic features of the E-knee concept, I decided to move away from the classical archetype of bio medical devices, thanks to the style choices I wanted to create something able to recall the sports and running world, highlighting once again the importance of fitness.

1. Fitness overview

1.1 What is fitness?

The term fitness, that now a days can be considered an international word, comes from the english adjective "fit" and describe the good physical state got with training, sport activities and healty lifestyle.
When talking about fitness often tends to consider, in addition to physical skills, a set of psycho-physical features that if present in an individual make it a good shape, not only by physical poit of view but also by mental shape.
In 1978 at Alma-Ata in Russia, during the International Conference on Primary Assistance, he said, " ... *health is a state of complete physical, mental and social well-being and not just absence of illness or infirmity, is a right fundamental human and achieving the highest possible level of health is an extremely important social result throughout*

the world, the realization of which requires the contribution of many other economic and social sectors in addition to health care ..... "

Thanks to these words it is easy to understand how fitness time has assumed different perceptions based on specific features over time.

The tendency to consider fitness linked to the psychological well-being of an individual has inevitably led in recent years to a new definition of the "phenomenon" to which the name Wellness was attributed.

The term wellness is therefore an extension of the concept of fitness: it refers to a lifestyle that puts the well being of the person at the center of attention by proposing as well as to moderate sports activities, regeneration and mental training practices, healty nutrition for the purpose of promoting a state of well-being and psycho-physical balance.

Balance and moderation are keywords that distinguish the wellness approach to physical activity: every activity must be devoid of the stressful or traumatic aspects that often involve sports disciplines, so it normally has no contraindication.

fig. 1

It is no coincidence that the term wellness has spread to the modern world, this philosophy seems to be a remedy to the awareness that current society exposes people to physical and psychological stress states that are the source of many diseases. Wellness aims to propose virtuous behaviors in motor activities, nutrition and "maintenance" of your emotional state. Regarding the physical condition, wellness includes:

- Physical activities according to the age and general condition of the subject
- The muscles tone development and strength without overloading organs and stress the body
- Exercises for improving general flexibility and balance improvement practices.
- Relaxation exercises

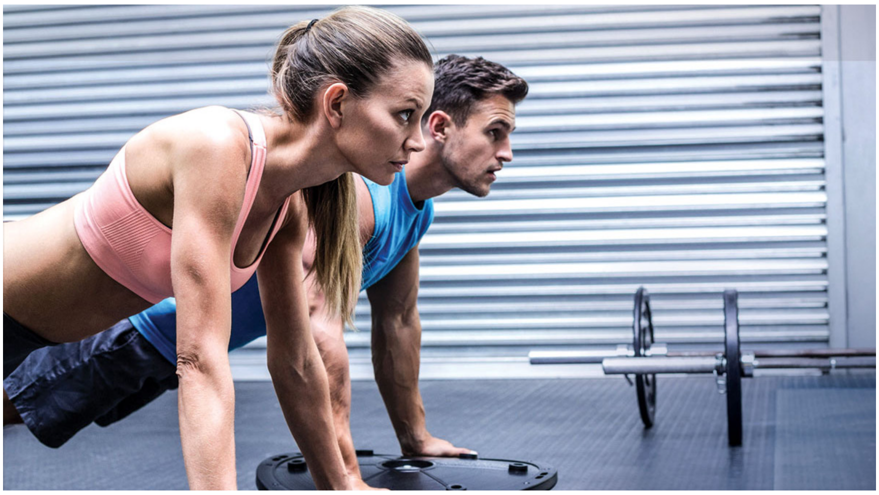

fig. 2

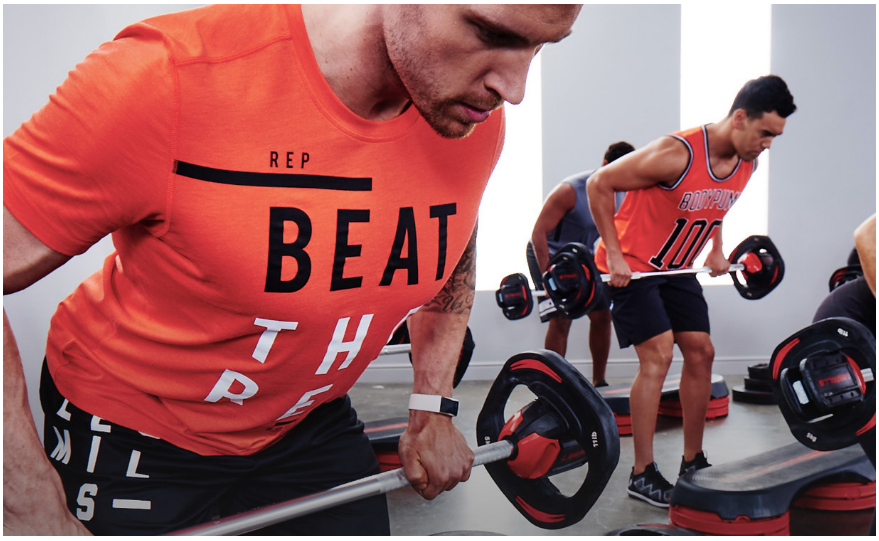

fig. 3

Example of a group workout when a person has to follow the rest of the group .

By closing the parenthesis on wellness, which was desirable to make it clear in an evolving context, from now on we will talk about fitness, discipline that considers all the conditional and coordinative capacities that if well developed and trained, bring the subject to one Was more and more well-being.
The features you are talking about are:

- Power
- Speed
- Resistance
- Coordination
- Joint mobility
- Equilibrium

All the elements we have listed are equally important if you want to achieve a good level of health, avoiding the onset of multiple pathologies.
From the outset it should be pointed out that fitness has various facets, can be practiced on various levels and with different purposes.
Anyone can practice a healthy and balanced physical activity, from the kid to the elderly person, generating remarkable benefits from all points of view. So let's start from the idea of doing fitness, it's to consistently practice a series of exercises and have a healthy and balanced life expectancy.
As fitness is based on physical conditioning exercises, over time it has spread to various contexts ranging from sports (basic athletic training is essential to compete at high levels) to post-rehabilitation work.
The application of fitness to the sport is in some cases considered a degeneration, because the obsessive search for increased athletes' performance does not lead to a well-being but to stress: you must not confuse it with the good ones The maximum development of muscle mass and therefore does body building and not fitness!

1.2 Goals

At first speaking about the conditions that make a fitness person or not, we have listed a series of anatomic and physiological modifications that we are now analyzing in a more exhaustive way. A motivation to practice healthy and continuous physical activity is given by the will to fight the problem of being inactive.

The fact that our ancestors, of which we still have memories at the genetic level, are born athletes should make us reflect on how much physical activity is proper to human nature and necessary to maintain a good state of health. Walking, running, climbing, launching, swiming and many other activities for years and years have been common all days, until progress with all the comfort it has brought has made man become a being sedentary, with all the health problems that this implies.

Though it is undeniable that the average life now a days is higher than 100 or 200 years ago (but also of the Paleolithic period!), it must be said that this is due to modern medicine that was able to defeat and overcome a lot of illnesses.

Pathologies such as obesity, cardiovascular disease, blood pressure, cholesterol, and muscle hypotonia are the consequences associated with high levels of stress, the fruits of progress and sedentaryism, and they are among the major causes of deaths in industrialized countries.

Among the purposes there is the aesthetic goal, that is the "remodeling" of your body according to the canons that today's society imposes through specific exercises that allow weight loss, toning and muscle mass increase.

This, unlike the previous one, in some cases leads to a distorted view of fitness by the person who tends to push his body beyond the limits to achieve ever more pronounced results.

The extreme degeneration of this concept is represented by disciplines such as weight lifting and bodybuilding, practices in which the concept of physical well being is

fig. 4

D I F F E R E N T   G O A L S

fig. 5

D I F F E R E N T   A P P R O A C H E S

fig. 6

This is a clear exaple of body-builder approach. The goals is to gain muscles and reduce the body fat as much as possible, even compromising the general healt.

sacrificed on the altar of "performance at any cost", which also through harmful practices such as doping that often leads to weariness of joints and internal organs.
Since fitness leads to physical conditioning, and therefore to increased muscle performance, another goal is to use this discipline in various sports training.
Thanks to exercises based on concepts of bio-mechanics and bio-chemistry you can train muscle in a specific way, in order to increase its performance in a targeted way.
Making many examples: think of a modern basketball or volleyball player and compare him with a player at the same competitive level of 50 years ago.
The athletes' physical differences are palpable, as well as the power and explosiveness of athletic gestures that often make the most spectacular sporting events.
For example, a defender who wants to increase his effectiveness on the header's detachment will certainly not miss his days jumping in the air of penalty of a soccer field! More likely, however, is a scientific approach that will form a training table that, thanks to the use of isotonic tools and / or equipment, will allow the athlete to train the muscle capacity (mainly quadricipite) Of blow and explosion with specific techniques.
Such a training is often the only possible solution especially when the athlete can not practice his sport all year long for seasonal reasons or unmanageable variables: a skier can not join all year long on the ski slopes , As a surfer often fails to find the right waves.
In the macro-areas of fitness, the post-operative rehabilitation and treatment of pathologies (mainly linked to postural aspects such as paramorphisms) are also included.
In this area, knowledge of bio-mechanics is essential to be targeted so that it allows for stretching / shortening muscle to correct an incorrect posture or to strengthen some muscle districts with the purpose, for example, of supporting damaged joints.

fig. 7

Passive training during a rehabil-itation process

fig. 8

Lindsey Vonn: stabilization exer-cises to train coordination during skiing

1.3 Fitness classes analysis

So far it has been explained what is fitness, its main functions and what kind of users it is aimed at.
In this chapter, however, the gym environment will be examined. In particular, the figures that are part of this sector will be analyzed. Furthermore their role, goals, problems and desires (even unexpressed) will be analyzed in order to find and define one or more areas on which the design process could follow.

1.3.1 Clients /Users

Gym enthusiasts are not part of a single category of sportsmen, but they differ in many ways so much that perhaps the only thing they have in common is that they attend a gym. Because of this marked diversity each user will seek to achieve different results according to their goals, will have different needs and needs as well as the problems or difficulties they may have.
As mentioned earlier (Chapter 1), it is possible to practice fitness at all ages and to all the various physical conditions, so even for people who go to the gym we can select some categories, each of which has special needs and attitudes.

Sedentary
In this category we group all those subjects who for reasons of work or other causes, make a static life, devoting little or nothing of their time to sports. When they start practicing physical activity, in this case fitness, they are beginners in the industry and as such have the advantage of having the best start-ups from training as they move from a non-fitness to a fitness Fitness condition and being on average their low starting point, they immediately improve. The disadvantages are due to the fact that they still do not know how to move well and may experience traumas and that immediate benefits, once they have arrived,

are not followed in the short term by so many physical results, which leads to the abandonment of the activity. The goal achieved is to smash inactive people, to get them to become constant in moving.

fig. 9

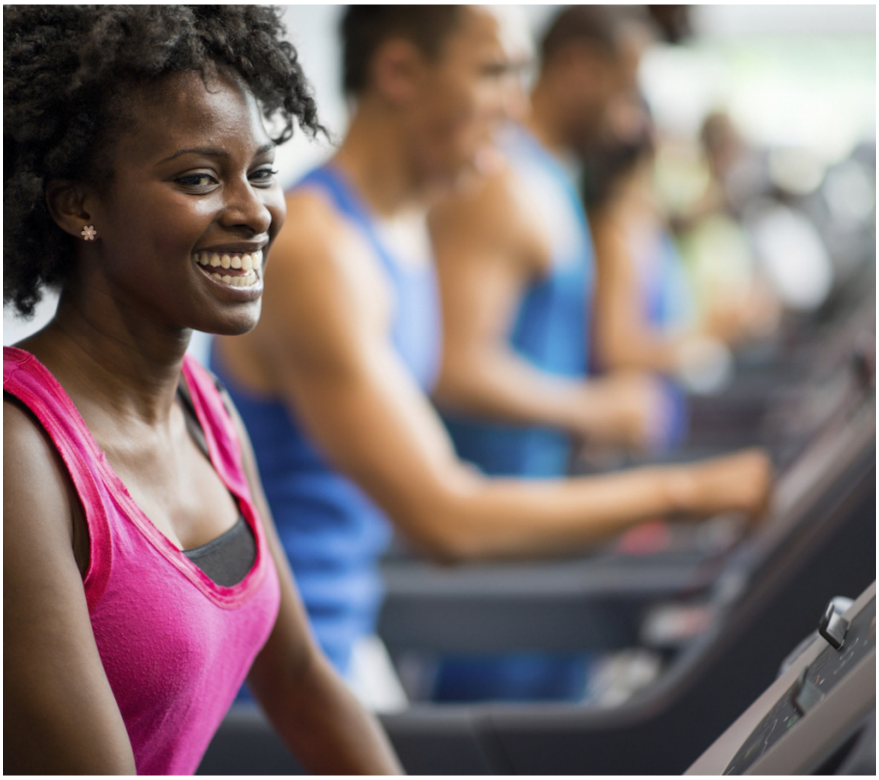

fig. 10

Athletes of other sports

They are athletes who have an active and positive relationship with sports.They realize that the gym offers great opportunities to train those muscle groups in standard conditions that are then specifically used in the typical athletic gestures of the sporting disciplines of origin, to balance the posture and muscular imbalances that certain asymmetric sports create.They have greater neuromuscular coordination and awareness of their limits during training.

Bodybuilders

They are primarily interested in muscle hypertrophy. Motivation is very sharp, marked. There is a choice to choose hard and tiring work to achieve the purpose. This availability also affects the modification of life, nutritional and sometimes pharmacological habits.

Unfortunately, this availability makes them vulnerable to the whole set of seemingly scientific seductions, but commercially, which are pushing for excessive medicalization. The reference is aimed at prolonged and unnecessary visits protocols. More and more frequent hematochemical controls on unusable data (amino acids, hormone doses). To the ever more refined measurements of body composition. Computerized measurement of the vitamin requirement. To the computerized processing of the diet, of the amino acid requirements.

When prescribing the kit of tablets, flours, powders, and tablets that are added to each other during the day, they are more like a terminal patient's therapy than the normal feeding of an athlete who spoils health. The only thing that does not fit in this discipline is precisely the market pressure through specialized information bodies that is transforming an extremely interesting sports practice into a kind of therapeutic protocol for sports sufferers. Body building does not need this fake medicine but only a rationalization operation. Correct, non-damaging exercises, tailored to the possibilities and motivations of subjects that can be recommended for healthy and less medicalized living habits.

fig. 11

Yohan Blake, 100mt and 200mt runner

Injured people

They use the gym for mainly rehabilitative purposes. This aspect is even more delicate than the previous ones with regard to the instructor's true professionalism. Here too, as in the case of a physician, it is not a substitute for another profession, in this case that of physiotherapist, but it is necessary to know those basic criteria that enable the problem and the limits of their intervention to be framed. Strengthening a muscle following a trauma requires in-depth knowledge; It's not enough to know that some exercise train some muscle to advise who needs to recover. The characteristics of the injury may render useless or detrimental to certain enhancement exercises. However, the coach must avoid trying to make a diagnosis and prescribe physiotherapy. It is advisable to request specific information from the competent personnel: doctors and physiotherapists.

fig. 12

Senior

They are generally assimilable to sedentary but with physical and psychological peculiarities. First of all, it is common experience that there are eighty years in perfect physical fitness and at the same time fifty years with low functional autonomy that depend on various therapies (this is the difference between ages and biological age).
To understand the limits of these different subjects, it is advisable to direct contact with a medical figure rather than simply presenting the certificate.
With age, there is a progressive reduction in the movement capabilities of the individual joints and, above all, of the control of posture and movement. Muscle strength also decreases but the elder usually needs less. Aerobic activity, while still benefiting greatly, will often have to be controlled to avoid cardiovascular risk.
In front of older people you can not apply standard training schemes but the custom table becomes necessary. Better yet, it would be to create high school gymnasiums with specifically dedicated instructors.

Junior

Young people can only exercise fitness if they are given specific fees, which are correct posture, moderate loads, correct exercise execution, and multilateral stimulation. We talk about young people who are growing up and who are subject to sudden changes both physically and psychologically, so they are potentially problematic if they engage in exaggerated workouts. The best methods for junior are circuit training, because they are varied, fun and with the purpose of stimulating all the systems in our body.

fig. 13

fig. 14

Fitness machines for children by Panatta Sport

1.3.2 Trainers

The role of the trainer

The role of the trainer is diversified. There are several types of professional figures in the fitness world, each offering a precise service, different skills and responsibilities.
The figure of the trainer over the years has evolved in line with what has been the evolution of fitness centers that, even in relation to the economic situation of the current period, have changed the format of the offer. The instructor's figure is subdivided into two sub-categories: the room instructor and the personal trainer (or athletic trainer). The room instructor is generally called to interact with all customers in the weight room, must be able to control the situation and intervene if it is needed to correct incorrect exercises. The personal trainer generally does not have to take into account these aspects because he trains a person at a time, but he must address all his / her attentions and provide all his / her technical (but also human) skills to the achievement of the client's goals. Although there are not a few differences between the two figures mentioned above, there are some aspects that each trainer should take into account, the tasks and duties he must fulfill in order to provide an attentive and professional service.
You can not think of dealing with the profession of instructor with approximate knowledge, with only the baggage of the personal workout experience. Generally this is an agonistic experience that gives a cut too univocal to the instructor's work. Often the instructor comes from the category of agonists or advanced athletes. If it is not able to diversify and offer a variety of different responses to the requests of other categories of visitors it will always be an incomplete instructor. The instructor must not reproduce himself, he must adapt to the needs and motivations of gym attendants and therefore he must first know them. An injured athlete who has to retire in time for the start of the season has surely an enthusiasm and goals other than those of the overweight forty years who wants to lose a

few pounds before the summer. The instructor must then identify the goals of these people to try to satisfy a psychological-motivational profile. Motivation plays a key role in an activity like the one where fitness, unlike other sports, lacks the challenge and competition component.
If a customer loses their motivation, they will almost certainly begin to train incorrectly and uncomfortably, leaving them not to renew the subscription will be short, resulting in economical damage to the gym and the trainer (in the case of personal service). The instructor is therefore interested in understanding the motivations that drive a subject to the gym, its function is to reinforce and satisfy them.

fig. 15

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Often, those who come to the gym for the first time do not have the ideas clearer than what they want and what they can find. The instructor must give the first correct information on both the merits and the limits of the activity in the gym. The most widespread motivation is the desire to stay in shape, fitness. Often in this there is a desire to control the weight; Sometimes slimming motivation is the most explicit and prevalent one. On these topics the instructor should frame the subjects by informing them that the gym alone is not enough to lose weight, but a proper dietary regime needs to be established. In short, you train at the gym, but it slows down mostly at the table. Associated with the desire to stay fit at times, the aspiration to improve their aesthetics appears to be. The practice of gymnasium can hardly produce results that go beyond the change in the relationship between the muscle cloak and the fatty coat.
Obviously, you also need to know the tools available at the gym, machines and exercises to work out a work plan. The instructor has the task of stimulating the motivation of the members by transmitting their knowledge and experience. In this we can not afford to go wrong on the basics, for example by demonstrating ignorance about the anatomy of the locomotor system, the basic physiology, and the various possibilities of proper training: we lose credibility in the eyes of the subject.

The gym would become a room where renting space and machines to the members for a few months and the instructor's figure would be superfluous, for absurd enough would be a hostess service.
Another mistake is to hide their cultural flaws by spreading novelties (in the sense of nutrition, training, etc.) without evaluating them with a critical spirit. In this case, the trainer loses his professional role and becomes a commercial exhibitor: without a solid basic preparation he finds himself the exclusive of today's novelty, which is already the memory of tomorrow or frenetic pursuit of chimeras Of the market, in an often improper economic development.
Schematicly the trainer's professionality is divided into three elements:

- Know
- Know to be
- Know-how

Know
Principles and effects of motor activity. Anatomy, biomechanics, physiology (and not just these) must be the cultural basis of those who work on the locomotive apparatus of the neighbor. It is also necessary to recognize the inherent difficulty of the proposed exercises and to understand the difficulties faced by people with such activities. Translated in terms of training methodology, this means that the instructor needs to know, in addition to techniques for muscle enhancement, for "mass" and for "definition" also techniques for aerobic use of machines, stretching techniques, Muscle heating, etc. Continuous critical re-evaluation of their knowledge will then enable them to keep up-to-date and always be able to offer a level professional quality.

Know how to be
The instructor must be able to communicate with people in a diversified way so that they can convey their knowledge and experience. For this purpose it is important to know how to handle different communication modes (see

below) depending on the environments and subjects we interact with. The effectiveness of the instructors' role can not therefore be excluded from strong motivation in relation to themselves, to others and to the activities proposed.

Know-how

You must understand the difference between theory and practice and possess them both: knowing an exercise, the affected muscle districts, knowing how to do it properly and know how to communicate. Moreover, the practical ability of the instructor should not be confined to the correct execution of a certain exercise that the visitor must subsequently imitate best. This practical experience is transferred to people by setting them up and correcting them with words and hands effectively, even this is "know how to do".

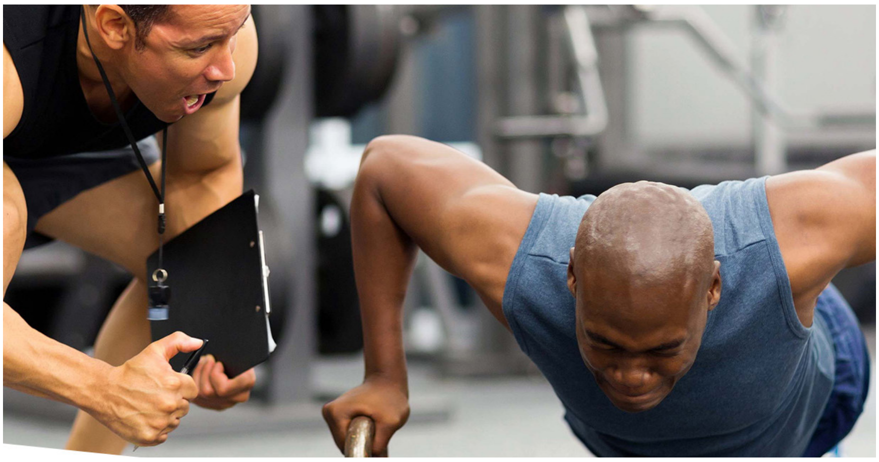


fig. 16 / fig. 17

Comparison between two different way to motivate the client: a good trainer know when to change approach to get out the best from different kind of person.

In summary, the instructor's job is a combination of knowledge and practical experience, and both of these qualities are to be transferred to the visitor's person. For this to happen, communication is of the utmost importance. There are different ways of communication. A first distinction can be made between verbal and nonverbal communication. The latter takes on a prevalent importance in interpersonal relationships and consists of gestures, mimicry, gaze, clothing, the tone of voice that is adopted while communicating with others. Nonverbal communication gives us the meter of involvement of the person you are talking to and also the person receiving the message (difference between hearing and listening).
Verbal communication in the gym recognizes different languages and different modes. We still remember that the process of communication starts from identifying the goals of the frequentator, that is, his motivation, to try to stimulate this motivation by emphasizing it in order to convey experience. You can locate three different languages that are currently used:

Common Language: This is the language that we speak fluently and which is used to communicate with most athletes, that is, common people who do not have a specific training culture. It is the "pull", "spring", "push", "raise", somewhat approximate but easy to understand.

Technical language: it serves to be able to properly dialogue between instructors, ie professionals. The basic assumption is that there is a uniformity of the terms adopted. Tools, machines, and exercises have their own names that the student will learn to know and that the instructor may not know. It serves to build training tables and to read and understand professional training articles and materials. The basic exercise for deltoids, which in Italian can play as "lifting the weight of the side", becomes a technical "side lift with dumbbells".

Medical Language: That is the technical language, often unobtrusive for non-practitioners, just about medical definitions. The instructor's cultural baggage is highly matched by subjects of traditional medical expertise such as anatomy, physiology and others. Without field invasions and skills, knowledge of some common definitions is needed to talk and team together with your doctor or to better understand a report or prescription. For example, the movement of side elevations in the anatomy language becomes a "abduction of the upper limbs against resistance".

Possible problems

Regardless of professionalism and skills, the trainer may have some issues and issues that could reduce the effectiveness of the service or advice provided to the client. Let's observe the work of a room trainer. Many gyms nowadays do not always adjust the weight-based service in the weight room, but in the name of a decrease in costs they often opt for one figure in a weight room with a very large number of people, Moreover, it often happens that the trainer service is only included in some hours of the day where there is a greater turnout. Let's imagine a room trainer employed at a "peak" time, it's easy to guess as he will not always be able to best follow any requests that come from people who often have different profiles and experience. The practical impossibility of explaining best practice to a neophyte, not correcting an improper (and potentially damaging) movement during an exercise or the inability to enforce the general order are all negative aspects that make the service worse. These aspects are heavy on the clientele, on the trainer and on the gym that, even for its own fault, can not guarantee a service at the highest level and causes discontent in some customers. The personal trainer in this sense has less difficulty since the variables with which he is forced to crash are considerably smaller and more predictable, since he works and follows only one person at a time. Despite this "advantage"

for a room trainer, the work of the personal trainer is rather complex as it does not just set up a personalized training program and follow the customer during the training session but additionally it often accompanies a food program That the customer will have to follow for the achievement of their goals.
The role of the personal trainer is alongside that of the athletic trainer: this figure often operates "at a distance" and is often ideal for people who already have some experience but who want to rely on a professional to achieve even better results . For this type of user, for which the personal trainer "classic" would be unnecessary and onerous, distance counseling is ideal for having professional guidance at sustainable costs.
In this case the distance and the periodicity of the meetings between the athlete and the preparer play a decisive role: the preparer does not have the means to monitor the performance of the athlete's exercises during the training, he is unable to evaluate his lifestyle and respect Of the charted food table. This problem also arises when the athlete is severe with himself and sincerely in reporting to his trainer his actions as mistakes are often unintentional or unannounced as such (eg wrong executions of exercises or misunderstandings in protocols).

1.3.3 Entrepreneur / Manager

The role and the goals

The gym manager is the professional figure who manages one or more gyms (or sports facilities), guaranteeing its operation, technological adequacy and compliance with current regulations. In carrying out its activity, depending on the type of structure, it relies on consultants who cooperate in the performance of specific functions (accounting, advertising, etc.) and staff including both personnel with technical and sporting skills who act as Direct contact with the audience, both people who carry administrative and administrative roles. The manager / entrepreneur of a gym should have and develop technical and cross-cutting skills to best perform his work, have a successful structure and offer an appreciable service. Technical skills include knowledge of regulations in various areas (hygiene, health, structure security, etc.) and knowledge of "sporting matter", that is, the knowledge of the sports disciplines that the service is to offer. Cross-competences include knowledge of marketing, communicative and administrative capacity, decision-making skills.

As in any business sector, even a fitness center operator must always monitor the quality of his or her product or service, and even before that, he / she must decide the type of service according to the target audience to whom he / she wants to target. In this sense, a gym manager should have aptitudinal and personal qualities such as motivation, propensity for innovation and entrepreneurial spirit. These qualities are fundamental to keep up with the times, upgrade if necessary and therefore offer a timely and profitable service.

Possible issues

The little heterogeneity typical of users who attend a gym leads to very different demands. These often unexpressed user requests are hardly intercepted by the operator who, while having a direct relationship with the instructors and the subordinates, does not always find the weaknesses of the structure to work on and progress. One of the biggest dilemmas of an entrepreneur who wants to open a sports facility is the type of activity to be opened and the resulting service that will be offered: there are gyms that include a multitude of activities (courses, weight room, martial arts, wellness center etc. .), Gym-centered gymnasium, gyms with dedicated areas for functional trainings or specialized crossfit gyms.

These are just a few examples of the benefits that a fitness center can take, each of these types of services definitely offers very different services that can satisfy a large pool of users or a narrow niche of people, has different costs and consequently very different prices (from A few hundred euro / year, to a large extent exceeding 4 digits).

What is even more complicated is being able to innovate, in fact the trends change and often the service delivered is no longer current and appreciated nowadays. In this sense a good example may be the crossfit discipline that in recent years has seen an impressive increase. Many gyms have integrated their service by devoting time and space to crossfire courses by investing resources for competent instructors and suitable equipment, while specialized centers where crossfit is the only discipline practiced.

1.4 Where fitness can be practise

Fitness is an extremely versatile discipline that, with a little imagination, allows you to practice physical training anywhere.
Obviously, depending on where the training is going to take place, the person will be able to use tools of various genres and sizes and adapt to the available spaces: although it is correct to say that for fitness it would suffice for a floor in one Empty room, it is also true that equipment and spaces will certainly affect workout and fitable exercises.
As with the chapters on users and purposes, in this case, to have a clearer idea, we will identify some macro areas where fitness is usually practiced.

Gym: no doubt the gym is the most suitable place for fitness and any muscle conditioning activity. Gyms are specially designed to accommodate the largest number of customers and not only offer equipment and machinery, but often incorporate a training service for less experienced people and provide courses of a variety of genres. The indoor gyms are therefore divided into rooms for group activities (courses, spinning, yoga, etc.), gym room with isotonic and cardio equipment, functional training rooms and other "contour" services, which most concern wellness as a sauna And whirlpool. Of course the services listed above are not always present in all gyms (except for the weight room); This depends on the type of gym, the cost of the subscription, the spaces and a number of factors often linked to company logic.

Sport centers: there are often a gym in the sport centers of teams of various sports where you can perform muscle strengthening and recovery activities. Though it is a gym in all its effects, the fact that it is part of a sporting environment differentiates it because in this context there are few marketing considerations and the user

Sport centers: there are often a gym in the sport centers of teams of various sports where you can perform muscle strengthening and recovery activities. Though it is a gym in all its effects, the fact that it is part of a sporting environment differentiates it because in this context there are few marketing considerations and the user (in this very specific context). In fact, these gyms are provided with only the equipment and tools needed for specific athletic training, and since there are not always large spaces available, high-level sports centers are definitely an exception, you prefer to opt for tools and compact machinery that Allow you to perform a wide range of exercises.

fig. 18

Open air: Exercise can be practiced free of charge by simply using your body weight. Exercising in the open air, if climate permits, is an excellent solution for all those who are not inscribed in a gym or who exercise fitness exercises occasionally. It is not uncommon to see in the parks people who, in addition to running, perform free body exercises for muscle strengthening by using steps and other urban elements as support for exercises. In the most popular public parks you can also find dedicated dedicated areas that offer free tools for those who want to train. Obviously, in this case, the structures must be standard, resist atmospheric agents and prevent possible vandalism. For these reasons, there are extremely rough and uneven gears, but very solid and functional.

Home: fitness at home is in some respects similar to the way and approach to doing so in the open air because with a little fancy you can use decorative objects as auxiliary facilities to carry out several exercises. Thanks to the explosion of the fitness phenomenon over the last few years, we often come across television services or news on the web that advise us how to move home using over-the-top solutions such as water bottles or broomsticks. With a small investment you can buy a set of adjustable dumbbells, some ankle and elastic straps that will allow us to vary the stimulus and training intensity. In addition to these small tools, it is possible to buy real machinery, such as bike, carpet and isotonic machinery, as far as isotonic machinery is concerned, it is a good solution to buy multi-stations, that is, compact structures that synthesize the Functions of various tools in a single product thus enabling you to train your entire body. The home-based product range ranges from economical and easy-to-find solutions to the market (the most famous example is dechatlon domyos line) to more expensive and refined solutions that often offer, in addition to performance, design research Which makes these machines

fig. 19

Open air gym

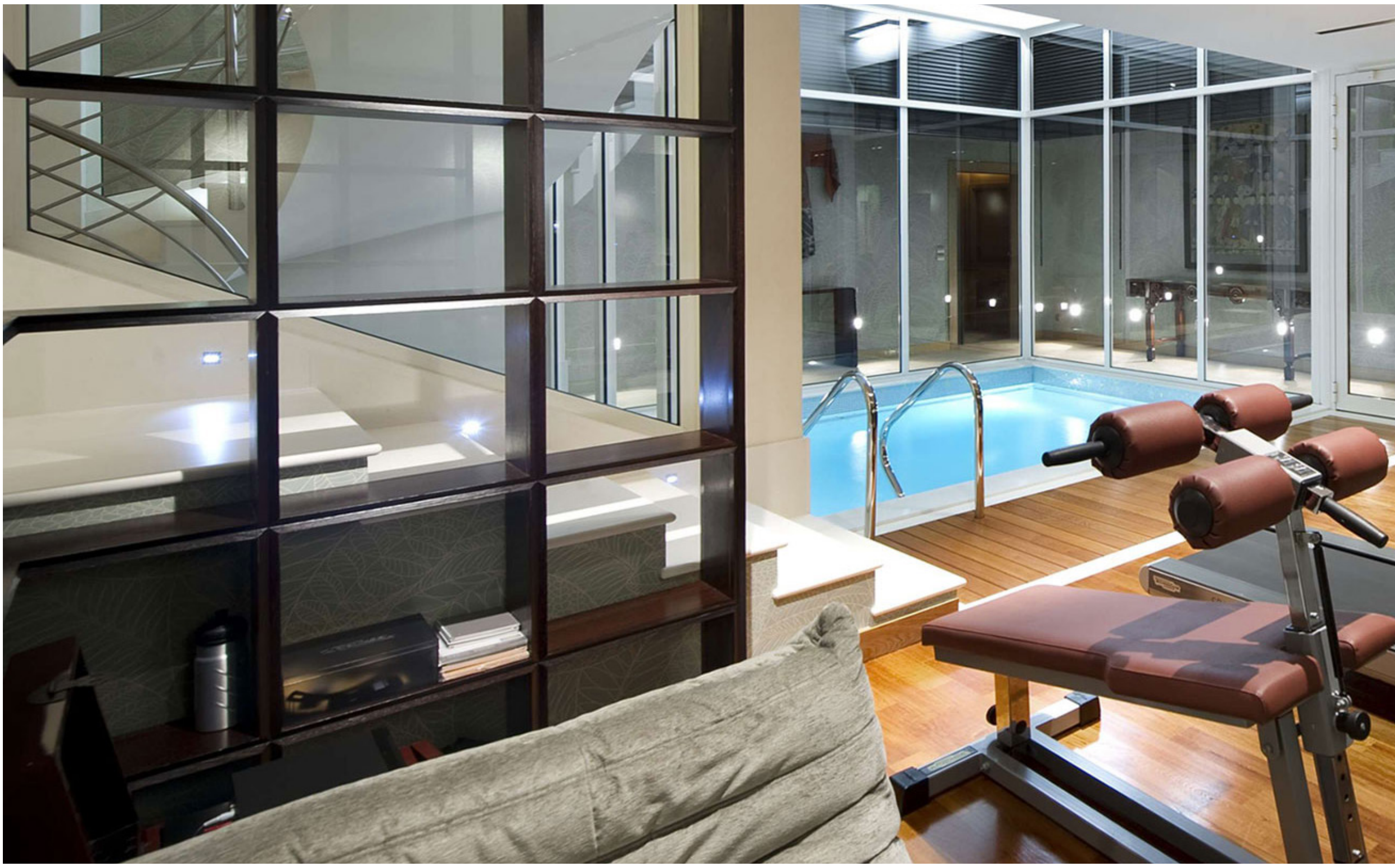


fig. 20

Home luxury gym

1.5 Sport tools overview

With the term sports tool, you define a device used during physical activity that allows you to (or improve) a training gesture, for example by using an overload.
The equipment can be both fixed and adjustable and is intended to improve the experience or the result of an exercise.
Depending on the training mode and purpose, there are several types of tools, we will look at the following to provide a concise but exhaustive overview of this type of product by dividing them into categories and subcategories.
The first macro distinction contrasts the "free body" tools from the machines.
The differences between these two categories include aspects such as complexity, size and size (often greater in machinery), the advantages / disadvantages of one category on the other, and finally the costs.
Although in some cases you prefer a category rather than the other depending on the purpose of the training and the user, it is necessary to specify right away that both solutions are suitable for developing the physical on multiple fronts such as strength, strength, speed , Coordination and joint mobility.

1.5.1 Free body exercise tools

This category includes all the tools that allow the body to move space as naturally as possible without excessive constraints.
The tools are widespread in various disciplines because they allow for strength training, flexibility, motor coordination and muscle extension.
Training with such tools requires more coordinated capability and a more consolidated technique because it is able to move without any constraint controlling trajectory and fluidity.

This is often to be considered a Advantage as it allows to engage in movement more stabilizing muscles, sometimes it becomes a limit if the user is particularly inexperienced and takes the risk of performing gestures and incorrect movements.
Another advantage of free body tools is the ability to adapt to the skeletal structure of all users without any special problems even for those who are not included in the classic 95 percentile.
Being essentially simple objects that implement residence to a natural body movement, these products are often simple from the point of view of mechanical and component solutions, without any integration of screens, controllers, or pulleys systems; this generally implies a lower cost and Smaller footprints compared to machinery.

1.5.1.1 Tools for strenght

This category includes the tools that enable muscle strengthening exercises for strength and hypertrophy by using weights assembled to tubular supports of various types.
Basically, this subcategory is made of steel barbells (shaped or straight) loaded with loads consisting of cast iron disks of various sizes and weights.
In addition to the barbells there are dumbbells: they perform the same function as the rockers but allow to perform mono-artwork, and generally have a default load except for some home-based solutions that include modular dumbbells.
The use of rocker arms and handlebars is almost always related to other support elements that allow them to be stored when not in use: the rack is used to accommodate weights, columns for stacking disks and rack to support the rocker when unused.
Free weight training also includes the use of adjustable benches that support the body and allow many exercises and variables to perform.

fig. 21

Bench press

fig. 22

Single barbell curl

1.5.1.2 Functional training tools

Before going into describing the products of this sub category, you should briefly explain what you mean when it comes to functional training.

First functional to what ?! If we ask this question and we reason broadly, it will be unavoidable to think that there is no single answer: a functional workout for a marathon will never be for a boxer or for a coach who will need different methodologies and tools respectively .

The English term Functional training does not translate into functional training, but it would be more appropriate to call it "Global Functional Gymnastics" that best describes the purpose of this type of workout.

Functional Training is a philosophy that aims to create a broad spectrum training that, in addition to the classic physical strength characteristics, also has the task of soliciting the development of balance and agility.

Functional work seems to be the source of some studies and research in the field of rehabilitation in the USA and Australia in the early 1990s under the name of Functional Theory. According to some training experts, functional training has a rejuvenating origin and is rooted in the concept of "attention to real-life movements".

Precisely this trend of functional training to train proprioception through the emulation of real-life movements has led to tools that are often very similar to archetype to various objects.

This category includes strings, chains, swiss balls, flow bags, Trx®, Kettlebells, footrests and elastics.

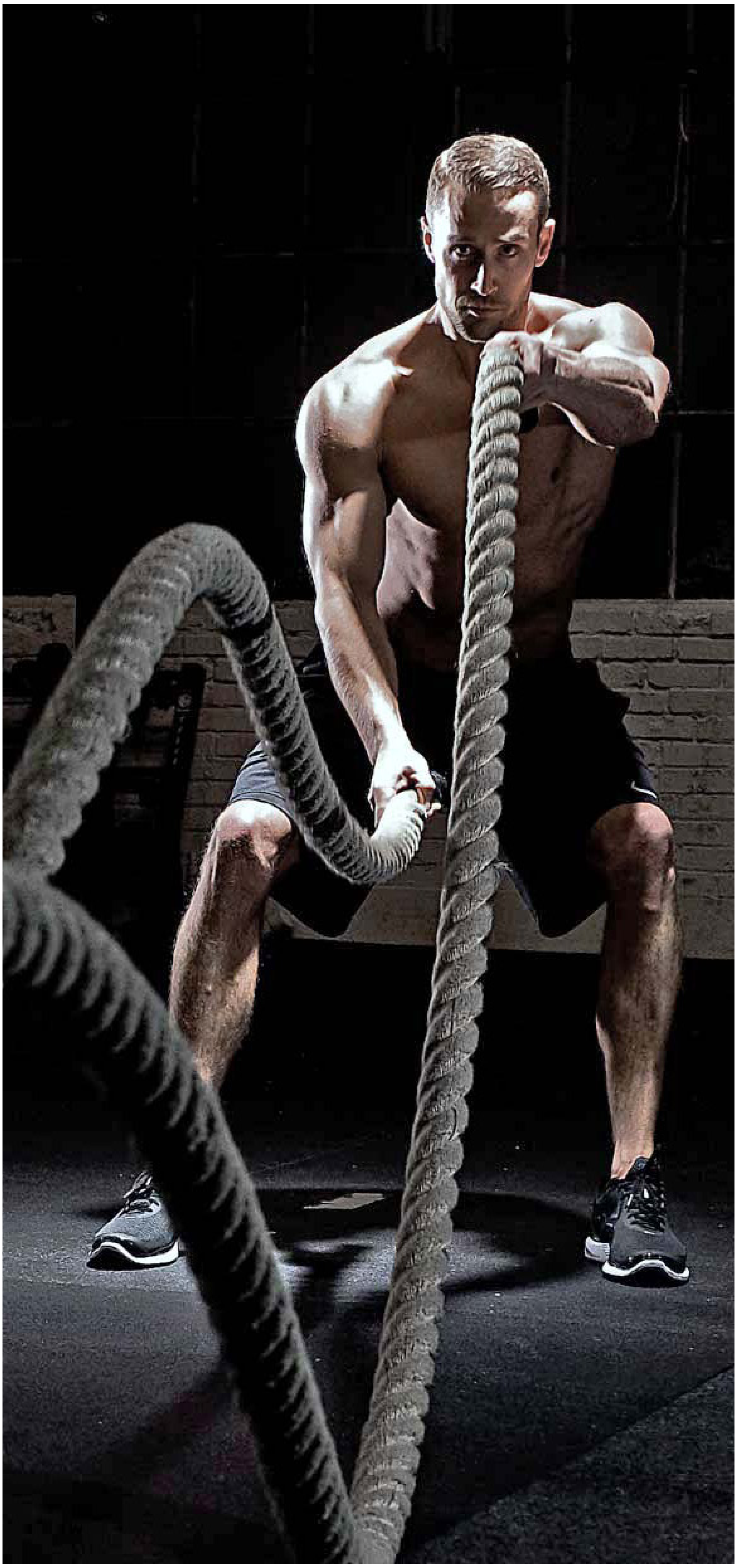


fig. 22

Functional exercise

fig. 23

Functional exercise

1.5.2 Machines

Fitness equipment is a product that allows you to train by performing controlled and predefined gestures to the user through the use of several more or less simple technologies.
The use of guided gym machines tends to undo the unstable component in every exercise to free body, favoring the muscular exhaustion of the specific trained area.
This feature makes the exercise run by the user in total safety, a benefit that often makes newbies prefer the use of machines for body workouts.
On the other hand, being free-spirited, often preferred by the most experienced people, allows to train the proprioception that can be defined as the expression of the body's control in space with the use of high capacity stabilizing and adaptive to the stresses imposed by the exercise context.
Having a mastered proprioception and good motion control implies the involvement of the gesture, as well as the target muscle target, also the stabilizing muscles, the muscles that intervene during movement to stabilize posture and joints.
The machines can be divided into three subgroups based on the purpose: cardio machinery, isotonic machinery and stretch machines.

1.5.2.1 Cardio machines

In this category there are machines developed for aerobic training that usually have the purpose of increasing pulmonary efficacy (VO2max) and slimming.
The most common cardio machines are treadmills, elliptical exercise, cyclists and stair climbing.
Although there are some versions that work simply through the user's movement, most products use electricity to operate and offer options and accessory features.
Thanks to internal technology, these machines are able to calculate caloric expenditure based on the user's char-

- acteristics (age and weight), offer various pre-set training methods and monitor heartbeats. In addition to these "classic" features, in recent years, getting more and more foot cardio machines that offer optionals as the ability to interact with touch screens on which to connect to the internet ...

fig. 24

Innovative tapis roulant by Technogym

fig. 25

Cardio machine : glidex

1.5.2.2 Isotonic machines

This category includes all the machines that, through the use of variable overloads, allow the user to develop hypertrophy and muscle strength.
Overload can be obtained by exploiting different technologies and solutions, making it possible to further subdivide into this category:
Plate Overload Machines: These machines exploit a cable and pulleys system that is connected to a stack of plates. The user can then easily choose and change the weight to be used simply by moving a plate / rod to fit into the hole selected. A defect in these machines is that the weight selected does not really correspond to the overload that the body raises but is purely indicative and difficult to calculate.
Free-to-machine machines are isotonic machines that are "loaded" by the user with the same disks used for billers. Unlike plate machines, this type does not include wires or pulleys, but the movement and trajectory of the training gesture is obtained with mechanical systems of pins and hinges. The advantage of these machines is to raise the actual weight that the person has loaded, in contrast the weight should be changed (gone or lowered) by the user more gently than the plate machines.
Kinesis Machinery: This particular category has been overwhelmingly established in recent years, also thanks to the diffusion of functional training. These machines have the purpose of creating a bridge between the ease of use of the machines and the training of features such as the balance and propriosity typical of functional training. This type uses the same principle of machines that use plate overloads but, instead of giving the user a fixed and predetermined handle, place the handle directly on the cable.

fig. 26

Leg press freeweight by Technogym

fig. 27

Marco Belinnelli (NBA player) during a workout with the shoulder press freeweight

1.5.2.3 Stretching machines

These machines allow the user to perform stretching exercises safely, monitoring muscle extension and thus preventing exaggerated tensions that could damage the muscle.
Machines in this case are also often assistants with a monitor that provides a visual feedback system to the user and, thanks to the use of sensors and internal software, you can also record your performance and evaluate progressive improvements over time .

fig. 28

Stretching machine by Technogym

1.6 Electrostimulators and passive training

So far, we have been talking about physical training and physical activity, and we have tried to explain the fitness world in a concise way: a complete picture of the various types of training has been provided highlighting the peculiarities of each category, listing the aims that May drive a person to physical activity, locate the most common places and catalog the machines / tools according to their specific characteristics.
Throughout this analysis we have been training and muscle characteristics such as strength, strength, elongation capacity, and so on.
Well any physical exercise activity starts from a muscular contraction: without going into scientific explanations, muscle contraction comes from an electrical impulse that the brain sends to the bone marrow that transmits it to the servomotor, which causes the muscle contraction resulting in conversion Of chemical energy in mechanical energy.
Obviously during an athletic gesture, as in any movement of daily life, we are volunteering to contract or stretch the muscles.
In light of these brief considerations, the workout that has been written up to now could be reclassified as active training and would be counteracted by passive training obtained by electrostimulation of muscle tissue.
improving explosive strength, speed or resistance by specific programs and all without the risk of sports injuries.
Not only that, but in the event of injury, it allows us to continue training the muscles not damaged by the injury at home.
The big workloads we can use by training with the ENM result in virtually no psychological stress, also improves microcirculation and facilitates relaxation.
Ultimately, it should be pointed out that the most effective way to use an electrostimulator is to combine

(and not replace it!) With exercise.
Thanks to the electrostimulator we can recruit more fibers in less time, which we could not do with classical training, which is indispensable for another reason, or because it allows us to transfer the strength and the physical qual ties acquired at the ‘ Skill and technical gesture.

1.7 Environmental sustainability trend

Today, as ever, society is increasingly paying attention to the protection of the environment and the targeted and sustainable use of energy. All manufacturing sectors, both goods and services, seek to overcome the ecological impact by always studying new methods that will enable ever more stringent environmental standards to be met.
This very important resource for life itself is produced in huge quantities in the fitness centers is produced a huge amount of energy, but unfortunately it is dissipated in mere mechanical work: just think how a small dinamo on a bicycle can illuminate the road In the night it is easy to understand that all the movement created by those who train at the gym is a resource that is still not being exploited to the maximum today.
But the fitness world is also adapting to the eco-sustainability of its infrastructure, and important responses are already coming to think of a growing “green” fitness. All over the world, there are always new gyms that use equipment, mostly cardiovascular devices, which allow them to self-feed, illuminating the display of the same, but to retain some of this energy that can be used later on by the rest of the structure. Half an hour of training on such a modified elite produces about 50 watts per hour, enough to turn on a fluorescent light bulb for 2 hours and a half, or to charge a cellphone 6 times. The British town of Hullha even installed a small open-air fitness center in the Shaw Park

public park, which, with the energy produced by the movement of the various machinery, can illuminate the surrounding area. In fact, whenever a local resident uses one of the available cardiovascular tools, the energy consumed to burn calories is converted to electricity.

Unfortunately, current technologies allow you to capture the energy produced by the aerobic training equipment, leaving unmanaged gestures of weight training or skipping in a step or total body lesson. But the future hope is to be able to make this whole mountain of energy accessible.
Among the first projects of the eco-sustainable gym stand out Green Heart, inaugurated in Hill Shaw Park, near London.
Usually, workout rooms, located in gardens or outside areas, carry signs with "Not allowed for children under 14 years". In the "Green Heart" the devices are designed to be used by anyone in the utmost safety. Adults and children can enjoy the sport without risk.
The gym, therefore, is free from traps, sharp edges, the danger of slipping, so to list some of its peculiarities. As a result, even elderly people or people with disabilities (eg paraplegics) are able to train in the Green Heart in a simple and effective way.
On the market some companies are following this trend by offering cardio machines that can develop reusable energy.
As a first example we cite WeWatt, a Belgian company that produces interesting cardio fitness equipment integrated in tables and seats that, thanks to the conversion of mechanical power to electric current, are able to recharge PCs or tablets. These solutions are indicated for public places or offices, they integrate effectively in all environments but are certainly not meant for professional use in the gym.
The second example is Technogym, the world's leading fitness product company in the world, which has created a line (Artis) of cardio machines that are able to fuel and feed the environment in which they are inserted.

fig. 29 / fig. 30

Green Heart, inaugurated in Hill Shaw Park, near London.

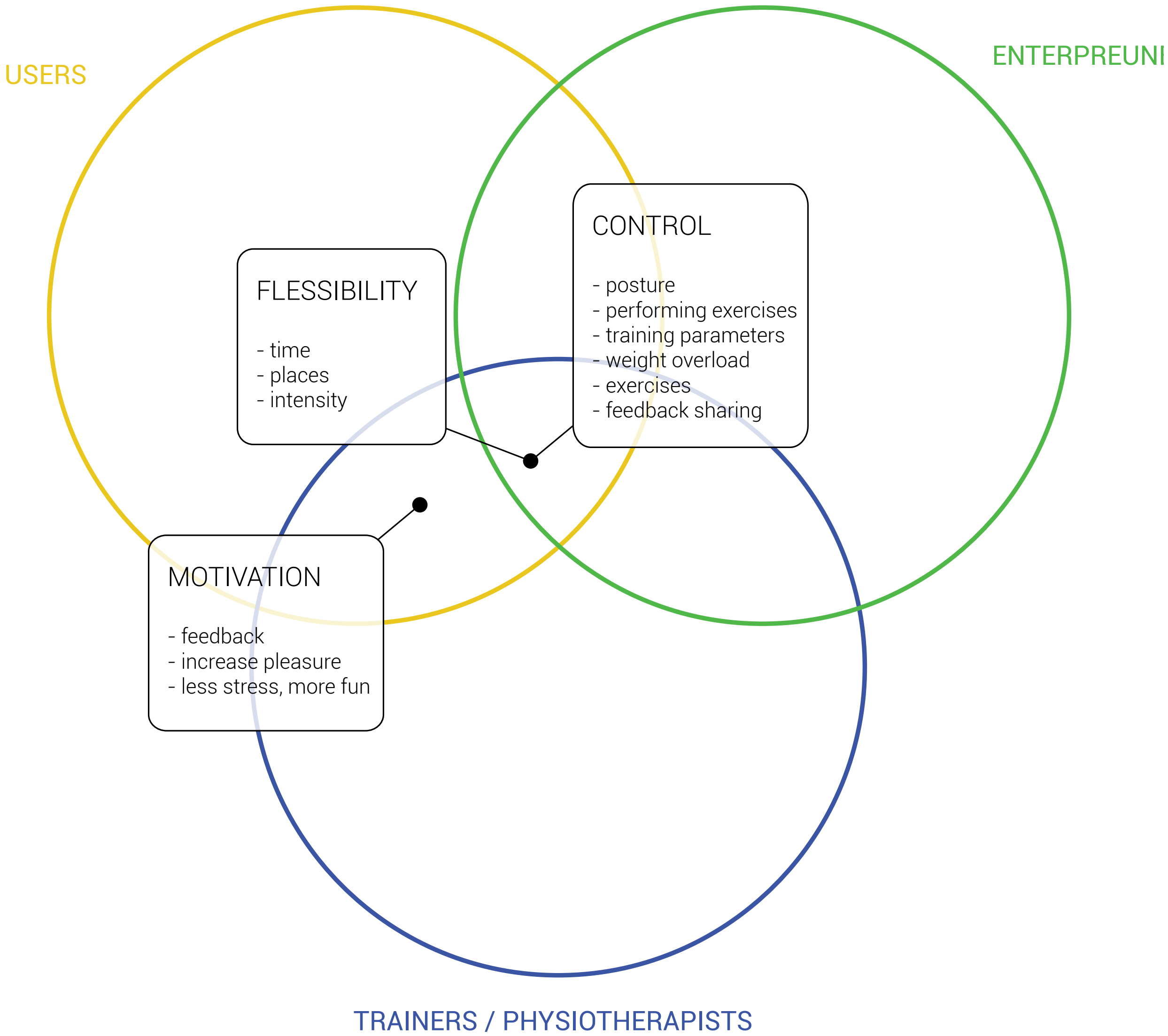
fig. 31

Concept allow the user to re-charg devices cycling

1.8 First step conclusions and considerations

This first analysis step , where the fitness and physical activity sector was analyzed in all its sides, was important because it allowed me to understand what are the fundamental aspects that drive a person to do physical activity, the importance of physical activity, possible problems and unwanted wishes of users.
After that I wanted to get out from this analysis some arguments/words in order to begin to trace the direction of my design path.
Control, Flexibility, Motivation: these are the three conceptual areas that I have identified, they have a strong connection each others and represent an important starting point for planning my project.
When we take in consideration physical activity and movement, control is undoubtedly an important value for improving performance, analyzing data, increasing benefits, and reducing risks.
Controlling any kind of thing means knowing behaviors and feedback, this puts us in the position to be able to act in the best way to achieve any goal and correct the action if needed.
This concept is important for people who exercise physical activity, for personal trainers, and for those medical figures such as physiotherapists.
The control produces feedbacks, fundamentals both in relation to the concept of prevention (personal health and medicine) and the motivational aspect.
Feedback in turn can make the user understand the progress in the short term, thus increasing the motivation and gratification.
The motivation is for sure an important element that improves performance, consistency, and makes goals easier to achieve.

Finally, flexibility, in this case synonymous with personalization, takes on value as a result of control and the ability to decide what is best for each person.
After analyzing the relationships between these three concepts, I have assessed which categories (Chapter 1.3) these concepts could bring greater benefits and being more useful.
From this association I found particularly interesting and inspiring the idea to design for that user chategory who uses physical acivities to recover joint and muscular function after injury, to correct a posture or a pathology.
For this category of users, flexibility and motivation play a key role in the pathway leading to the improvement of physical condition, control is a key factor not only for patients but also for professional figures (physicists, doctors and trainers) that set the rehabilitation program.
For these reasons, I considered it appropriate to continue my research project with an in-depth study on electrostimulation and the world of wearable design.
The world of electrostimulation plays a central role in the rehabilitation sector, wearable design is closely linked to the person's control and to various emotional and motivational aspects.



Scheme 1

Schematization of first analysis phase

2. Electrostimulation

2.1 Electrostimulation introduction

So far, it has been about training and physical activity in general and has been trying to get rid of the fitness world in a synthetic way: a complete picture of the various training types was provided by highlighting the peculiarities of each category, we listed the purposes that can push a person to exercise physical activity, locate the most common places and catalog the machines / tools according to their specific features.
Throughout this analysis, training and muscle characteristics have been considered, such as strength, strength, elongation capacity, and so on.
Obviously during an athletic gesture, as in any movement of daily life, we are volunteering to contract or stretch the muscles.
In light of these brief considerations, the workout that has been written up to now could be reclassified as active training and would be counteracted by passive training obtained by electrostimulation of the muscle tissue.
At this point, it is spontaneous to ask, **"What is electrostimulation?"**
Electrostimulation is a medical technique that, by the use of electrical impulses acting on the motors of the muscles (motoneurons) or on the nerve endings (TENS pulses), causes a muscular contraction similar to the voluntary one. Electrostimulation is thus based on the natural principle that low-frequency motion current is activated by some organs and parts of the human body such as the heart, brain, muscles and nerves. These organs create a physiological stimulus that stimulates the drive unit from the path to contraction. This current passes through the body in the form of electrical impulses.

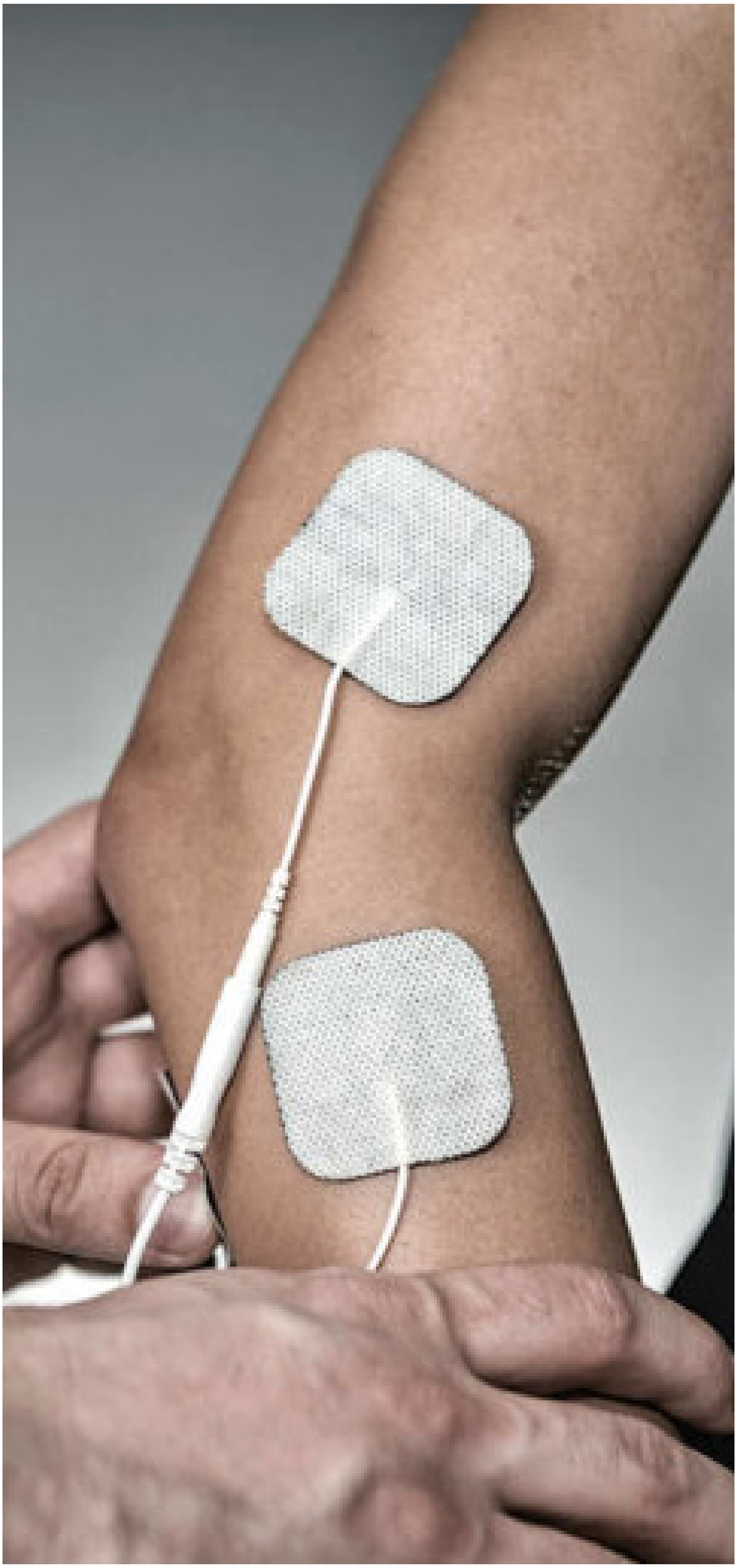


fig. 32

Electrodes application before an electro stimulation teraphy

The electrostimulator is essentially a current generator with square wave pulses, but whose electrical parameters can be programmed with tabs that are simply inserted into the device. Electrostimulation is made with electrodes to be applied on the muscle, the purpose of the various and sophisticated programs is to produce stimuli that give rise to physiological contractions. Medical applications include various types of pain therapy, physical medicine, rehabilitation, sports medicine, rheumatology, reflexotherapy, etc. Although electrostimulation has been born and has developed in the medical field, currently the possibility of modifying the pulse parameters has allowed this technology to spread rapidly in several areas.

The **main fields of application** are:

1. medical field - for antalgic and anti-inflammatory therapy and for post-injury functional rehabilitation;

2. aesthetic field - for localized slimming and lymphatic drainage;

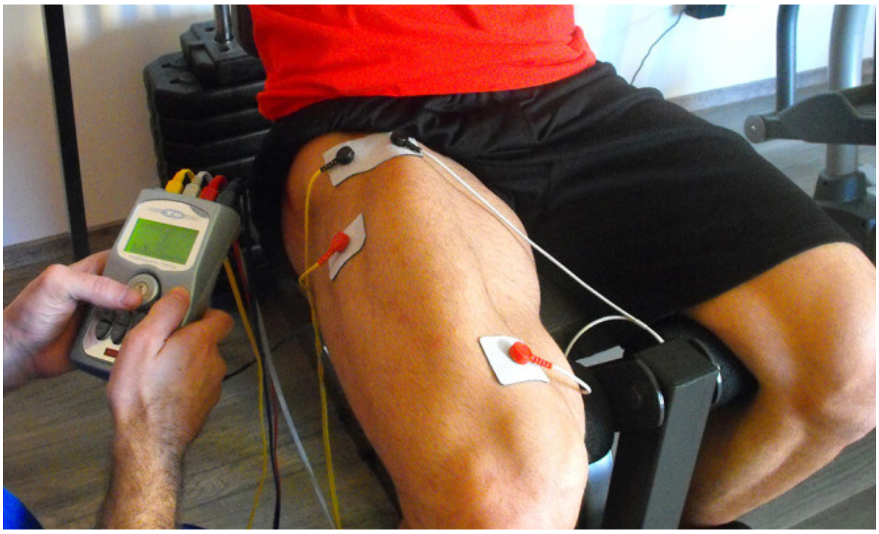
3. Sports field - for muscle strengthening and recovery.

Depending on the type of current supplied to the body, different effects are obtained, each of which is clearly linked to the application fields listed below:
• Analgic current - pain relief: blocking the nerve impulses that involve the pain sensation;
• Aesthetic - slimming effect: lipolysis and drainage of retained liquids;
• Sports running - relaxing and toning effect: increased circulation and heating of the affected area; Muscle contractions of varying intensity. The electrostimulation used on healthy people does not have any particular contraindications, it is to be modulated according to the level of subject training. Wrong evaluations in this regard could lead to fatigue and exaggerated muscular pains and stresses to the body.

fig. 33

fig. 34

Combination between active muscles contraction and passive muscles contraction (with electro-stimulation)



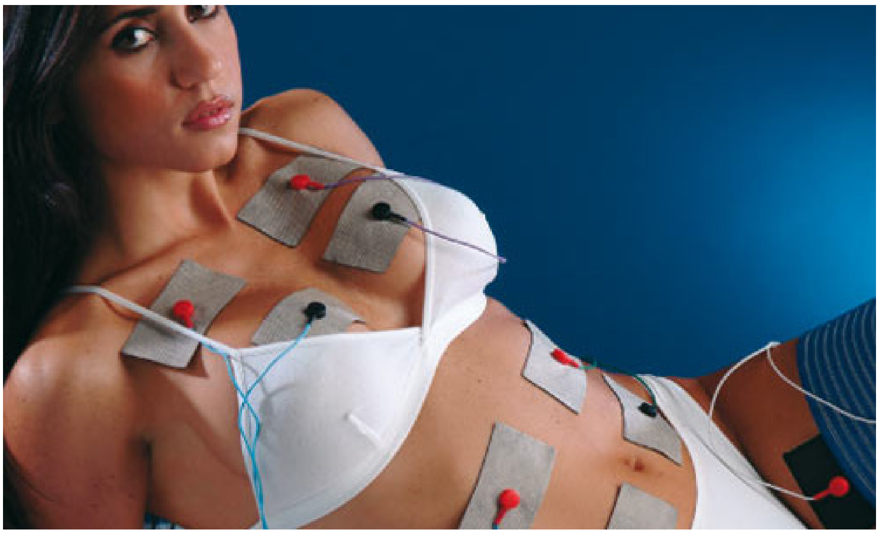


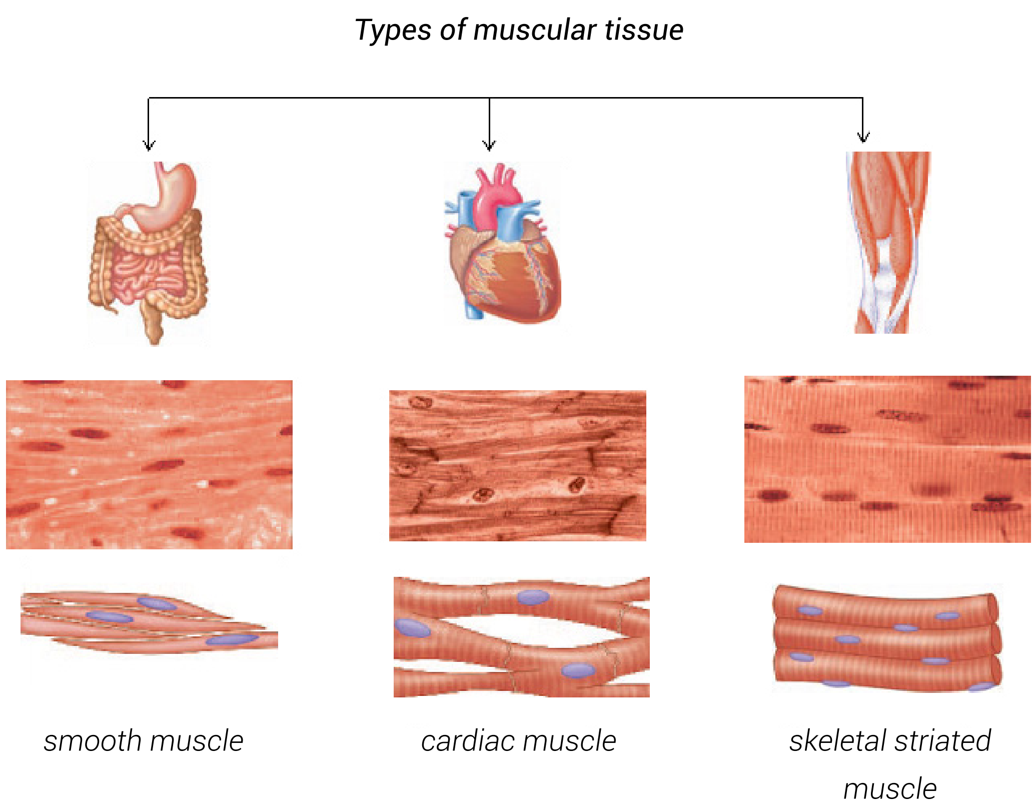
fig. 35

electro-stimulation used to drainage

2.2 Muscles contraction overviw

2.2.1 Types of muscles: histological structure

The muscular tissue differs from the other tissues (nervous, bone, connective) for an obvious feature: contractility, that is, muscle tissue is able to contract, or shorten its length. Before we see how it shrinks and for what mechanisms, we talk about its structure. We have three types of muscular tissue, different both histologically and functionally: skeletal striated muscle tissue, smooth muscle tissue and cardiac muscle tissue. The main functional difference between the first and the other two is that while the former is governed by the will, the other two are independent of the will.



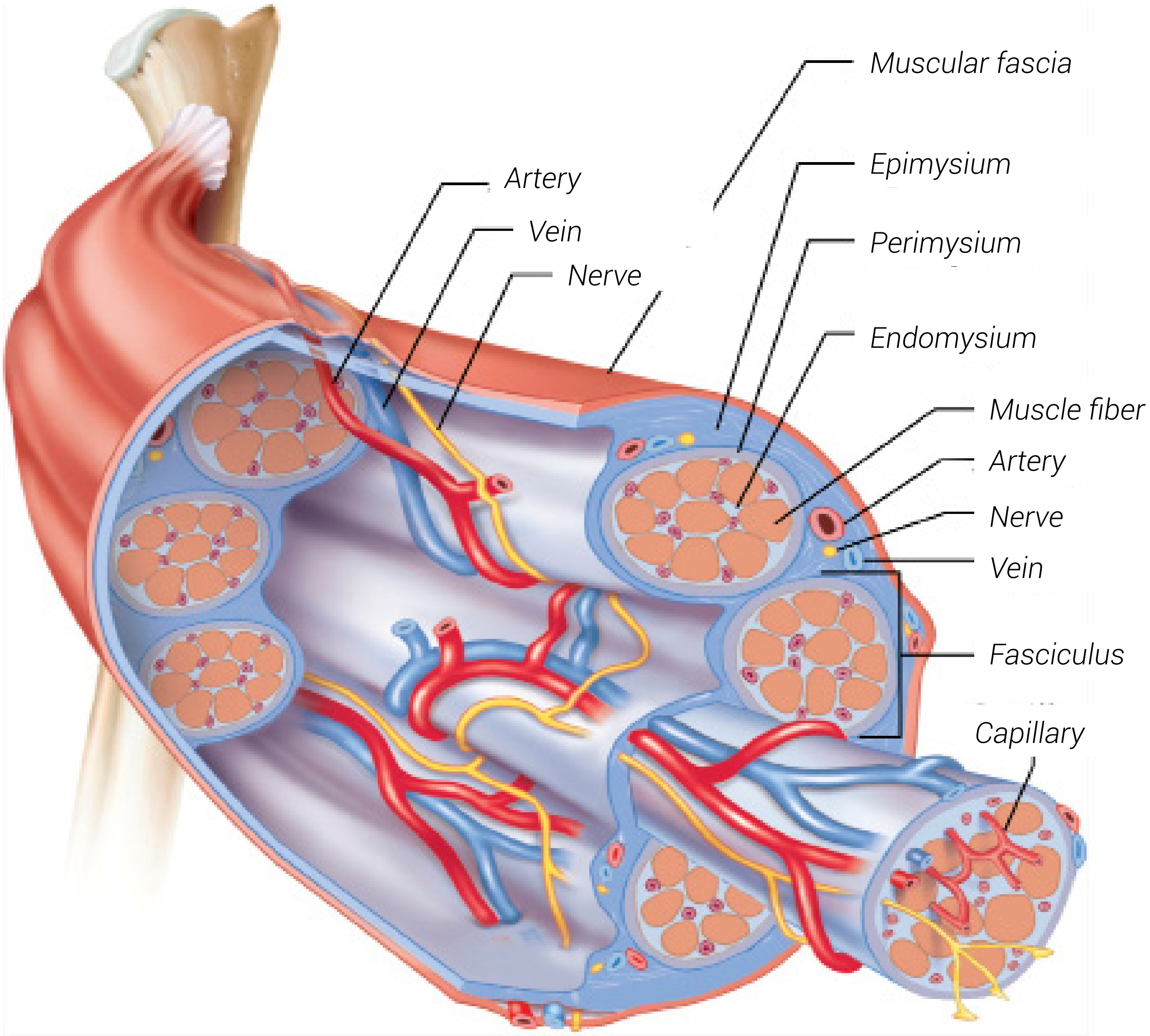
Scheme 2

The involuntary (smooth) muscle is the inner walls of our organs; We find it in the wall of the blood vessels, in the wall of the body organs (stomach, intestines, ...), within the ocular globe and in the hair eruptors muscles. Its main function is to push materials inside and out of the body. Smooth muscles do not stick to skeletal structures; They have very slow, but prolonged and more efficient contractions (require less ATP than the energy molecule of our body) and are not subject to fatigue.

The heart muscle is responsible for the continuous and rhythmic contractility of the heart; Has functional and structural features that are intermediate to the other two types of muscle tissue. Smooth muscle and heart muscle are not voluntarily controlled. Most human body muscles belong to the category of striated or voluntary muscles, with about 200 muscles for each body side (about 400 in total). Skeletal muscles are the goal of EMS (Electrical Muscle Stimulation).

Volunteer muscle (striatum) includes skeletal muscles and organ muscles such as eyeball and tongue. It allows the movement and maintenance of the posture and contributes to determining the shape and shape of the body. It responds with great speed to nervous impulses, swiftly and intensely. Volunteer muscle can not stay contracted with high intensity for a long time because it tends to ease. As a rule, striated muscles are linked to the skeleton by means of tendons.

The striated muscle is made up of cells, as well as all the other structures and apparatus of the organism; The cell is the smallest unit capable of autonomous life. In the human body there are billions of cells and almost all have a central part called the nucleus, surrounded by a gelatinous substance called the cytoplasm. Cells that make up muscle are called muscle fibers: they are elongated elements, arranged longitudinally to the muscle axis and clustered.


Muscular fascia
Epimysium
Perimysium
Endomysium
Muscle fiber
Artery
Nerve
Vein
Fasciculus
Capillary
Artery
Vein
Nerve

Scheme 3

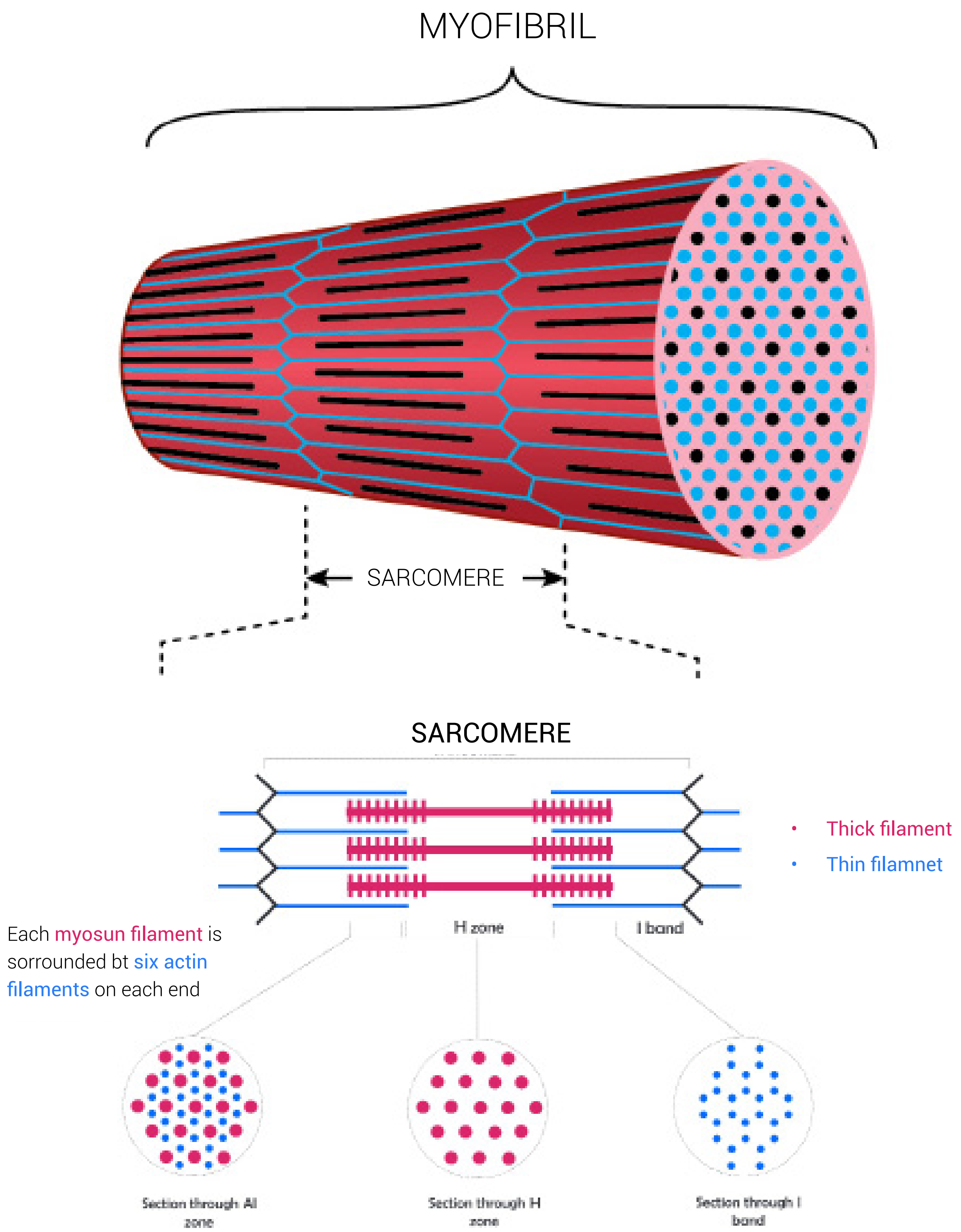
The **main features of striated muscle** fiber are three:

1) It is very large, its length can reach a few centimeters, the diameter is 10-100 micron (1 micron = 1/1000 mm). The other cells of the body are, with some exceptions, microscopic dimensions.

2) It has many nuclei (almost all cells have only one) and for this reason is defined as a "polynucleated sincence".

3) It has a transversal strip, with alternating dark bands and light bands. Muscle fibers present in its cytoplasm elongated formations, arranged longitudinally to the axis of the fiber and hence also to that of the muscle, called myofibrils, we can regard them as elongated cords placed within the cell. Myofibrils are also cross-streaked and they are the ones responsible for streaking the whole fiber.

Let's take a myofibril and let's study it: it has some dark bands, called **bands A**, and the clear bands I, in the middle of the band I there is a dark line called **Z-line**. The space between a line Z and the other is said **sarcomero**, which represents the contractile element and the smallest functional unit of the muscle; In practice, fiber shortens because it shortens its sarcomar.
Myofibril is made from filaments, some large filaments of myosin, other thin filaments of actin. The big ones cling to the thin ones so that band A is formed by the big filament (that is why it is darker), band I is instead formed from that part of the thin filament that is not embedded in the heavy filament (being formed by the thin filament is clearer).


MYOFIBRIL
SARCOMERE
SARCOMERE
Thick filament
Thin filamnet
H zone
I band
Each myosun filament is sorrounded bt six actin filaments on each end
Section through AI zone
Section through H zone
Section through I band

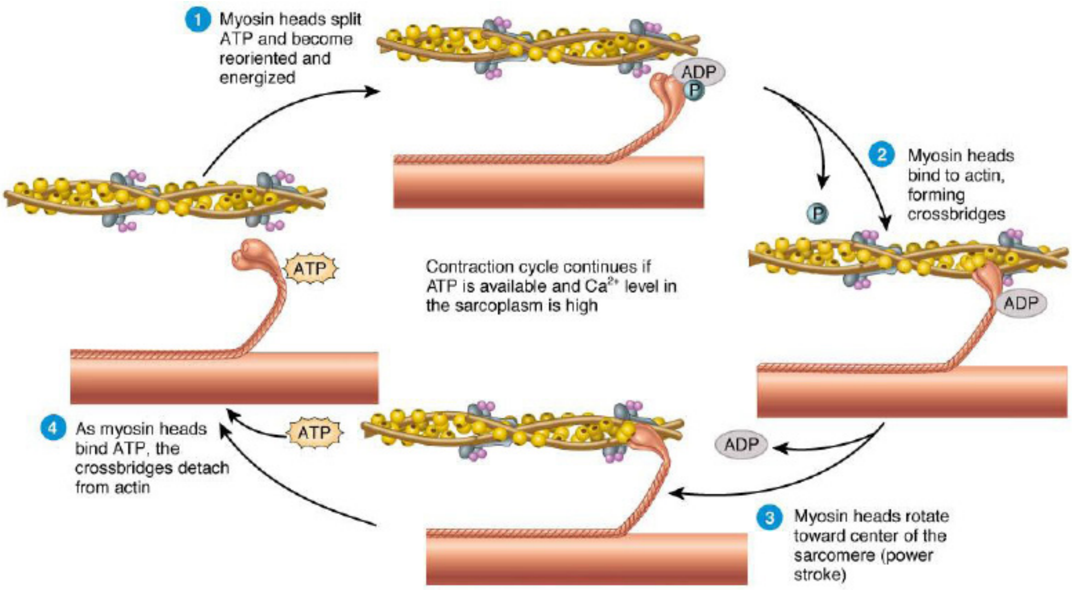
Scheme 4

2.2.3 Mechanism of muscle contraction

Skeletal muscle exercises its functions through the contraction mechanism. When muscle contraction occurs, the movement of the joints is produced and, consequently, the movement of the skeleton.

Microscopic post of view

In the contraction the light filaments flow through the heavy filaments, so that the bands I decrease in length; So the sarcomero, that is, the distance between a Z band and the other, decreases in length, so the contraction occurs not because the filaments have shortened but because they slid down decreased the length of the sarcomero. Decreasing the length of the sarcomer decreases the length of myofibrils, so since myofibrils make up the fiber, it decreases the length of the fiber, consequently the muscle, which is made of fibers, shrinks.



Scheme 5

Obviously, for these filaments to flow, energy is needed and this is given by a substance: ATP (adenosine triphosphate), which constitutes the "energy coin" of the organism. ATP is formed by the oxidation of foods: the energy they feed is passed to the ATP, which then transfers the filaments to flow. For the contraction to occur there is also another element, the Ca ++ (Calcium) ion. The muscle cell holds large amounts of it inside it and makes it available to the sarcomero when contraction occurs (The same type of mechanism is activated when the muscle contraction is produced by the electrostimulator).

Macroscopic point of view

We have just seen the sarcomero is the contractile muscles' element , we now examine all the muscle and study it from a physiological point of view, but macroscopically. As already mentioned in the introduction to electrostimulation, so that a muscle can contract, an electrical stimulus needs to come: this stimulus comes from the motor nerve, starting from the spinal cord (as is the case naturally); Or it can come from a motor nerve resecuted and stimulated electrically, or directly stimulating the muscle electrically. Let's imagine taking a muscle: an end tied to a fixed point, the other extreme weighing it to a weight; At this point we stimulate it electrically; The muscle will contract, that is, it will be shortened by lifting the weight; Such contraction is called isotonic contraction. If we tie the muscle with both heads to two rigid supports, when we stimulate the muscle it will increase tension without shortening: this is called isometric contraction. Isotonic contraction generates mechanical **work (work = force x displacement)**; In the isometric contraction the mechanical work is zero, because: work = force x displacement = 0 (displacement is null).
If we stimulate the muscle with a high frequency (ie a number of pulses per second), it will develop a very high strength and remain contracted to the maximum: muscle in this condition is said to be tetanus, so tetanic contraction means massive and continuous contraction.

A muscle can contract little or much at will; This is possible through two mechanisms:

1) When a little muscle is contracted, only some fibers contract; Increasing the contraction intensity, other fibers are added.

2) A fiber can be contracted with less or greater strength depending on the frequency of discharge, that is, the number of electrical pulses that reach the muscles in the time unit.

By modulating these two variables, the central nervous system controls how strong the muscle is to contract. When it controls a strong contraction, almost all muscle fibers are shortened not only, but all will become lighter: when a weak contraction commands, only a few fibers shrink and with less force.
We now face another important aspect of muscle physiology: muscle tone. Muscle tone can be defined as a continuous state of light contraction of the muscles, which is independent of the will.
What factor causes this contraction state? Before birth the muscles have the same length of bones, then, with the development, the bones stretch more than the muscles, so that the latter are stretched. When a muscle is stretched, for a spinal reflex (myotatic reflex) it contracts, so the continuous stretching to which muscle is subjected results in a continuous state of light but persistent contraction. The cause is a reflection and since the main feature of reflexes is non-volunteering, the tone is not governed by will. Tone is a phenomenon based on a nervous reflex basis, so it is governed by the nerve that the central nervous system goes to the muscle: if the nerve is cut off the muscle becomes flaccid, losing completely the tone.
The contraction strength of a muscle depends on its cross section and is 4-6 kg / cm2. But the principle is generally valid, there is no direct relationship of direct proportionality: in an athlete, a muscle slightly smaller than that of

another athlete may be stronger. A muscle increases its volume if it is trained with increasing resistances (it is the principle on which weight training is based); It should be noted that the volume of each muscle fiber increases, while the number of muscle fibers remains constant: this phenomenon is called muscle hypertrophy, not to be confused with the hyperplasia that is the increase in the number of muscle fibers.

2.2.4 Different types of muscle fibers classification

Skeletal muscles are made up of a set of muscle fibers that have different shapes in relation to the mechanical functions that are called to perform.

Type I

This type of fiber is also called ST fibers (slow-shrink fibers) or SO fibers. The motoneuron that injects it is tonic and with low running speed. They are red-colored fibers (the staining is due to the presence of the myoglobin molecule) which have a slow contraction rate and a predominantly oxidative energy metabolism (oxygen consumption).

Type I muscle fiber is very hard-wearing because it is responsible for all kinds of activities of a tonic nature, slow and linked to the maintenance of posture. These fibers are surrounded by a dense network of capillaries that allows the optimal performance of aerobic metabolism in a prolonged activity and characterized by modest strength expressions.Type I fibers are of great importance in all endurance sports: running, cycling, swimming, cross country skiing, etc.

Type IIa

These kind of fibers are also called FTa fibers (FG fibers) or FOG fibers (fast fibers to oxidative-glycolytic metabolism). These fibers are to be considered as intermediates

between type I fibers and type IIb fibers; Are innervated by a phasic type motoneurone characterized by a higher conduction speed of the tonic motoneurone.
Due to their characteristics, they can specialize in addressing more aerobic or anaerobic metabolic properties.
Type IIa fibers are therefore able to exert rapid contractions and characterized by a discrete force development, but also sustained over time due to their relative fatigue resistance.

Type IIb

Often known as fast glycolytic fibers they are white in colour due to a low level of myoglobin and also contain few mitochondria. They produce ATP at a slow rate by anaerobic metabolism and break it down very quicky. This results in short, fast bursts of power and rapid fatigue. As mentioned above, this type of fiber can be turned into type IIa fibers by resistance training. This is a positive change due to the increased fatigue resistance of type IIa fibers. These fibers are found in large quantities in the muscles of the arms.

Muscle fiber type	Contraction	Contraction frequencies
Type I	Slow I	0 - 50 Hz
Type IIa	Fast II	50 - 70 Hz
Type IIb	rapid IIb	80 - 120 Hz

Tab. 1

2.3 The electrical stimulation

2.3.1 Cronassy and rebase: important parameters

The graph showing the relationship between the intensity of a stimulus (I) and its duration (t) is not linear, as evidenced by the studies performed by Lapique. Observing fig. 1, which reports the relationship between intensity and duration of an electrical stimulus induced to excite a target tissue, is apparent as an increase in duration of the stimulus corresponds to a decrease in its intensity.
The importance of Lapique's discovery is to understand that in order to obtain a qualitative electrical stimulation, it is not enough to randomly choose a parameter and derive the other accordingly. This is because organic tissues have intrinsic characteristics that they tend to add to a repeated stimulus and consequently raise the value of their excitation threshold. The stimulus must therefore be such that it can be effective despite this "tissue adaptation" phenomenon.
The two parameters identified by Lapique, necessary to remedy the problem, are: reobase and cronassy.

REOBASE: is the minimum intensity value to excite the fabric regardless of its duration.

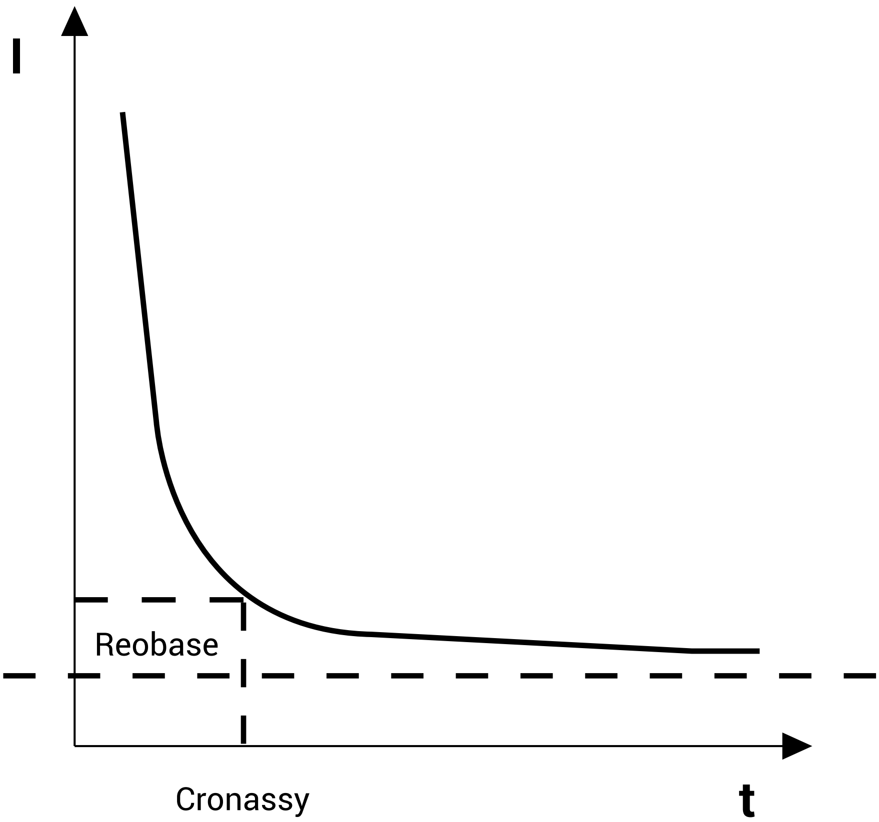
CRONASSY: It is the duration of the stimulus (with double reboot intensity) needed to excite the target tissue.

Once the chronache has been detected, it is automatically able to produce an appropriate stimulus to excite the target muscle region properly without incurring the arrangement phenomenon that would diminish the effect of excitation. In this way it is also possible to avoid any skin or muscle problems due to prolonged electrical stimulation.
During the study and determination of the electrostimulation programs, it is indispensable to take into account the

chronachia, which varies according to the muscle group that you intend to solicit.

Body part	Cronassy
Thigh	400 µs
Leg	350 µs
Back	300 µs
Chest	250 µs
Arm	150 µs
Forearm	200 µs

Tab. 2



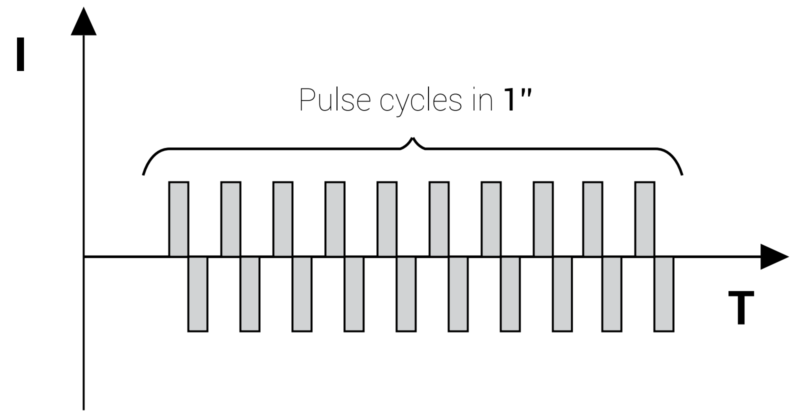
Scheme 6

2.3.2 The pulse parameters

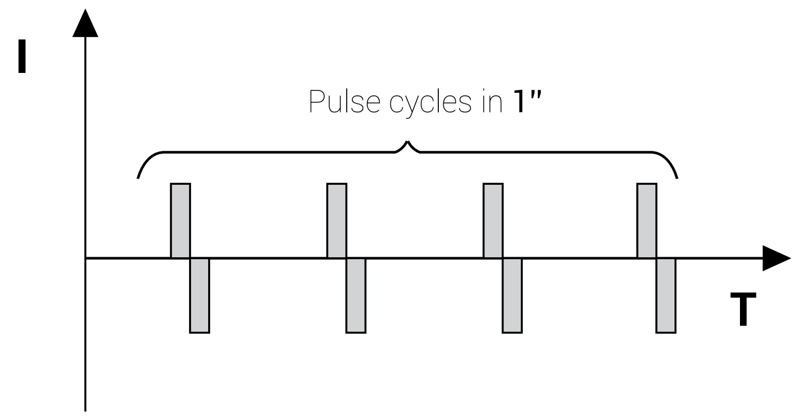
Recent studies have made it clear that muscle contracts in different ways depending on the type of stimulation received and the parameters that characterize it: intensity, frequency, pulse amplitude, duration and recovery time. The parameters that characterize an electric impulse are:

-Frequency
- Amplitude
- Intensity

Frequency indicates how many pulse cycles are present in a second and is expressed in Hertz. This value affects the type of fibers that will be stimulated: the higher the frequency the more stimulation will be to the "fast" fibers. At low frequencies, the "slow" fibers are stimulated.



Scheme 7

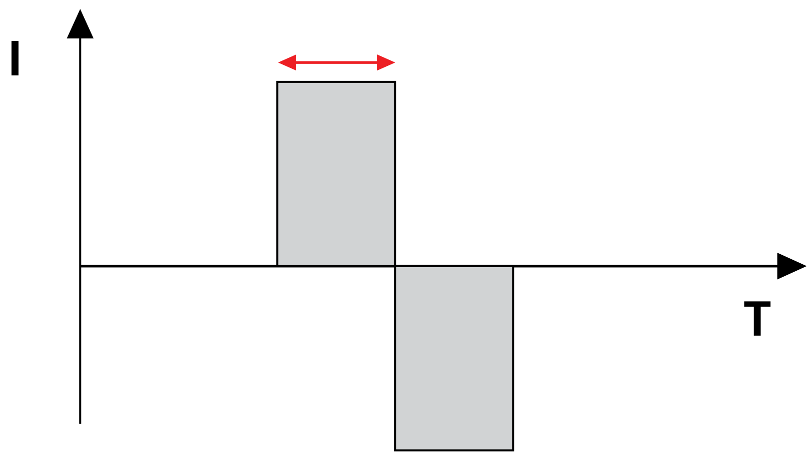


Scheme 8

Frequencies	Fiber type (work)
10 - 50 Hz	Slow fibers - **resistamce**
50 - 70 Hz	Intermediate fibers
70 - 100 Hz	Fast fibers - **strength**
100 - 120 Hz	Rapid fiber

Tab. 3

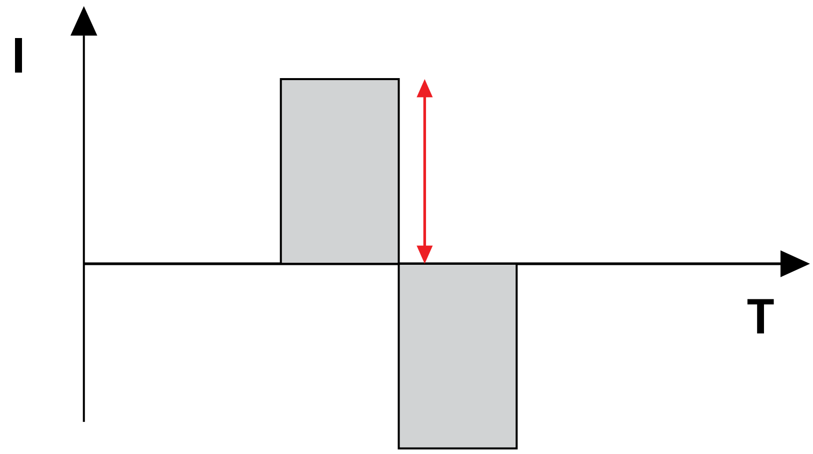
Amplitude is the pulse duration value. It is measured in microseconds and represents the chronase value of the motor nerve that injects the muscle to be treated.



Scheme 9

The intensity is the user-adjustable electrical current value and is measured in mA (microampers). The number of recruited fibers increases in proportion to the increase in intensity.
The value of the current intensity needed to achieve a particular contraction is entirely personal, depending on the position of the electrodes, the adipose layer, the sweating, the presence of hairs on the area to be treated, etc

For these reasons, the same power intensity can provide different feelings from person to person, from day to day, from right to left. During the same work session, in order to overcome the accommodation phenomenon, you will need to gradually increase the intensity to get the same contraction.



Scheme 10

2.3.3 Stimulation intensity

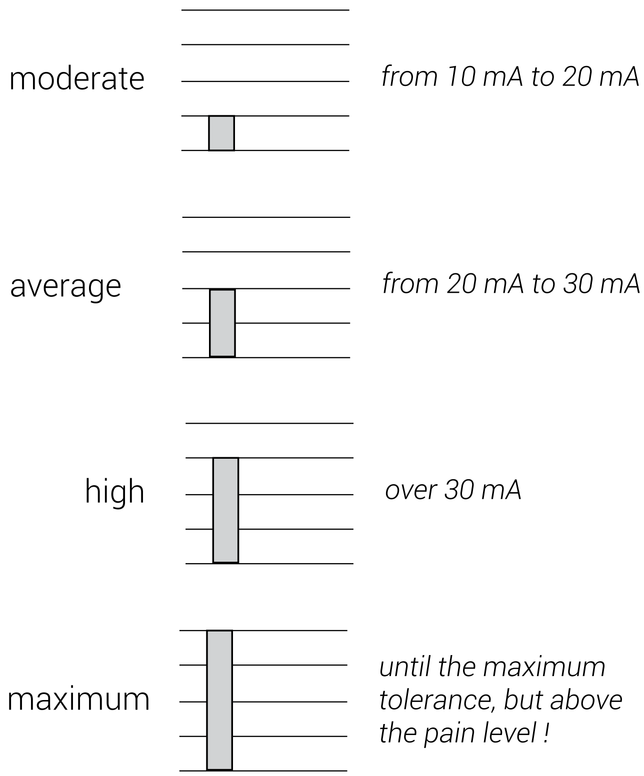
The current intensity used in the various phases is proposed with an indicative value but needs to be tailored to suit individual needs.

- **Moderate:** Muscle is not fatigued even in prolonged treatments, contraction is absolutely bearable and pleasing. First level in the intensity chart.

- **Intermediate:** muscle contracts visibly but does not cause joint movement. Second level in the intensity chart.

- **High:** muscle contracts in a sensitive manner. Muscle contraction would cause the extension or flexion of the limb if it were not blocked. Third level in the intensity chart.

- **Maximum:** muscle contracts in maximum. I work very hard to run only after several applications.

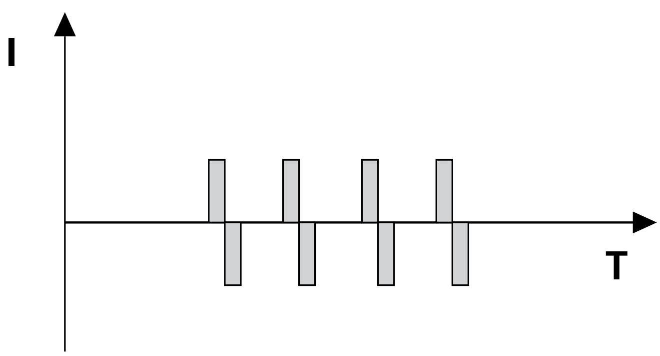


Scheme 11

2.3.4 Pacing Types

Electrostimulators have different stimulation modes: continuous, alternating, frequency modulation, amplitude modulation

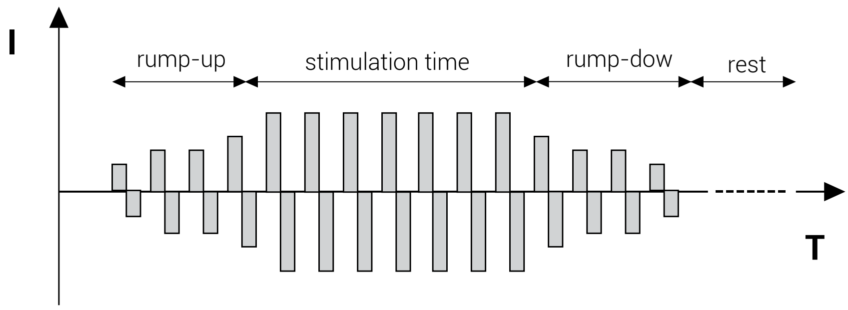
- **Continuous stimulation** :Consists in continuous stimulation without recovery time for the duration of the phase.



Scheme 12

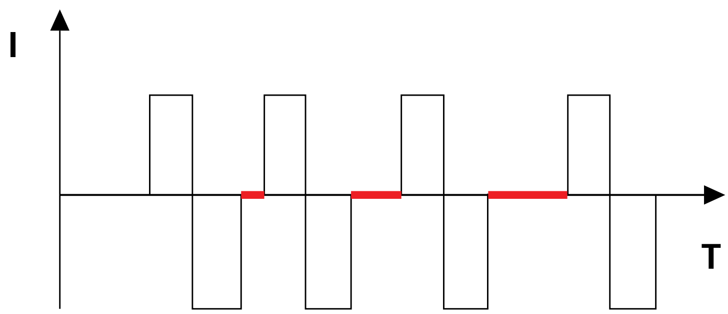
This type of stimulation is typically used to perform low-frequency heating and low-frequency treatment (with TENS currents) or for analgesics.

- **Intermittent stimulation:** during this type of stimulation there is the alternation between a working and a rest period (active and passive); There may be, for example, 6 seconds of contraction and 10 of recovery, then restarts for 6 seconds and so on throughout the phase. During rest time, there is also the possibility of raising the current intensity to perform an active regenerative recovery.



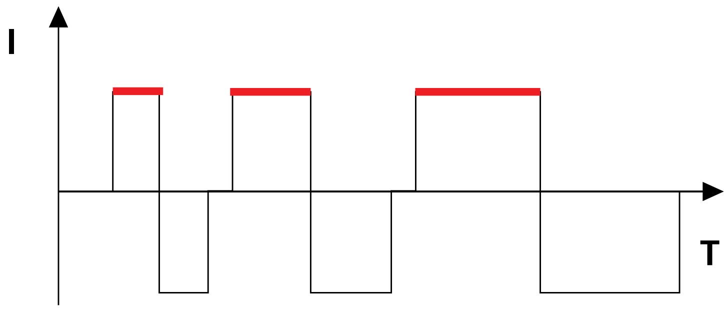
Scheme 13

- **Frequency sodulation stimulation:** this type of stimulation is characterized by the fact that during the work phase the stimulus frequency varies from predefined values to involve the largest number of muscle fibers. They are used both for aesthetic treatments and for specific programs, such as explosive power programs.



Scheme 14

- **Amplitude modulation stimulation**: in this type of stimulation, the frequency remains constant, while the pulse amplitude varies progressively between predetermined values. It is mainly indicated for aesthetic and fitness treatments.



Scheme 15

2.4 Pratical applications

2.4.1 Use in sports

The use of electrostimulation in the sports field is very versatile and suitable for various purposes: it is useful for the muscular development of some districts less stressed than others, for active recovery after very hard workouts or simply to give a different stimulus than the classic programs .
Electrostimulation allows for greater muscular isolation and allows this technique to use for the selective stimulation of deficient muscles that want to be better trained. Electrostimulation by using electrodes allows the generation of electric fields that stimulate the muscle with extreme precision that no exercise even using the best isotonic machines on the market can get: it is possible to create such electric fields to contract specific muscle groups.

fig. 36

Combination between active muscles contraction and passive muscles contraction (with wireless electro-stimulator by Compex)

2.4.2 Use in aesthetics

Treatment with electrostimulation in aesthetics can be divided into two major areas:

- **specific programs against blemishes:** improvement of capillary microcirculation, fluid drainage, increased metabolism and cellular activity, reduction and mobilization of fatty deposits (eg Cellulite, water retention, localized slurry, ...);

- **toning or firming programs:** suitable for those who want to relax and toning up your muscles and tissues.
For long-lasting results, it must be associated, as soon as possible, with motor activity.

Among the endless applications in aesthetics we briefly summarize some of the most important goals.

- Slimming / Lipolysis Localized
- Anti-Cellulite Treatment
- Lymphatic Drainage
- Firming / Toning

Localized weight loss It is well known that when a dieter loses fat more quickly in areas where he is already leaner. For example, a low-slim woman who wants to lose weight because she has wide hips, if she begins to follow a low-calorie diet she will lose more breast and almost nothing in her hips. To overcome this disadvantage, it is appropriate to resort to the so-called "localized slimming" To that slimming process that, through increased muscle activity, facilitates the mobilization of fat from adipose tissue in areas close to the muscles activated.

fig. 37

Beauty treatment with electro stimulation

2.4.3 Rehabilitation applications

After a forced immobilization for a musculoskeletal trauma, it is very important to recover the tone and muscle trophism. Electrostimulation allows to quickly recover muscle tone and drain liquids accumulated due to immobility. It should be remembered, however, that electrostimulation should not completely replace the reheat sessions with a physiotherapist who may associate with proprioceptive and mobility exercises. The presence of osteosynthesis material, such as screws, plaques, etc. Does not constitute a contraindication to the use of the electrostimulator, precisely because the latter is designed to avoid damaging such devices. The advantage of electrostimulation is that it can often be started first with respect to active gymnastics as it does not require movement of joints, does not cause loads on structures and / or tendons, does not require proprioceptive capabilities to the user.

fig. 38

TENS transcutaneous electrical stimulation (TENS) is widely used to relieve much muscular or joint pain but also of endogenous nature as it has no side effects other than conventional pharmacotherapy; Is therefore considered to be an important alternative care. TENS consists in the selective stimulation of the large fibers of the peripheral nerves; This favors the closure of the "entry gate" for nociceptive impulses and increases the release of endorphinic substances, thus significantly reducing the intensity of several painful cadres.
The decrease in pain following the application of TENS currents is related to these factors:
to. Gate control theory (gate theory) b. Endorfinac secretion. Different sedative effects in relation to frequency.

Theory of the gate

If you block the electrical signals that bring the pain information to the brain, it also nullifies the perception. If their intensity is sufficient, their priority becomes so prevalent on the signs of pain. Once the priority is obtained, the "gate" for the sensory signals is open and the pain is closed, thus preventing the passage of these signals to the brain.
Endorphin secretion
When a nervous signal proceeds from the area of pain to the brain propagates through a chain of jointly connected mutually said synapses. The synapse can be seen as the space between the end of a nerve and the beginning of the next. When an electrical signal reaches the end of a nerve, producing such neurotransmitter substances crossing the synapse will trigger the onset of the next nerve. This process is repeated throughout the path required to bring the signal to the brain. The drugs (in the form of opioids) involved in reducing pain have the task of creeping into the synapse space and preventing the propagation of neurotransmitters. This way you get a chemical block of the pain signals. Endorphins are naturally occurring opioids from the body to fight the pain and can act in both the marrow and brain, resulting in powerful analgesics.

Tens are able to increase the natural production of endorphins and, consequently, they act by decreasing the perception of pain.

The MENS Microcurrent

The use of microcurrent in the electrostimulation is growing. In the USA and in many other countries (including Japan and Canada), MENS has for many years been one of the most commonly used currents in therapeutic physiotherapy (differing from the Tens, which, as is well known, only contain indications against ache). Unlike conventional electrostimulation therapies, which use milliampere (mA) intensity streams, the microcurrent uses a low intensity current (microamps μA). This light current is below the human perception threshold and is therefore not being warned by the patient.

MENS therapy offers the patient considerable benefits:
- security
- comfort
- decreased acute and chronic pain
- Quick tissue recovery and rapid healing of wounds, scars and bone fractures
- Production of collagen fibers, which promote the elasticity of skin
- total absence of side effects and complications.

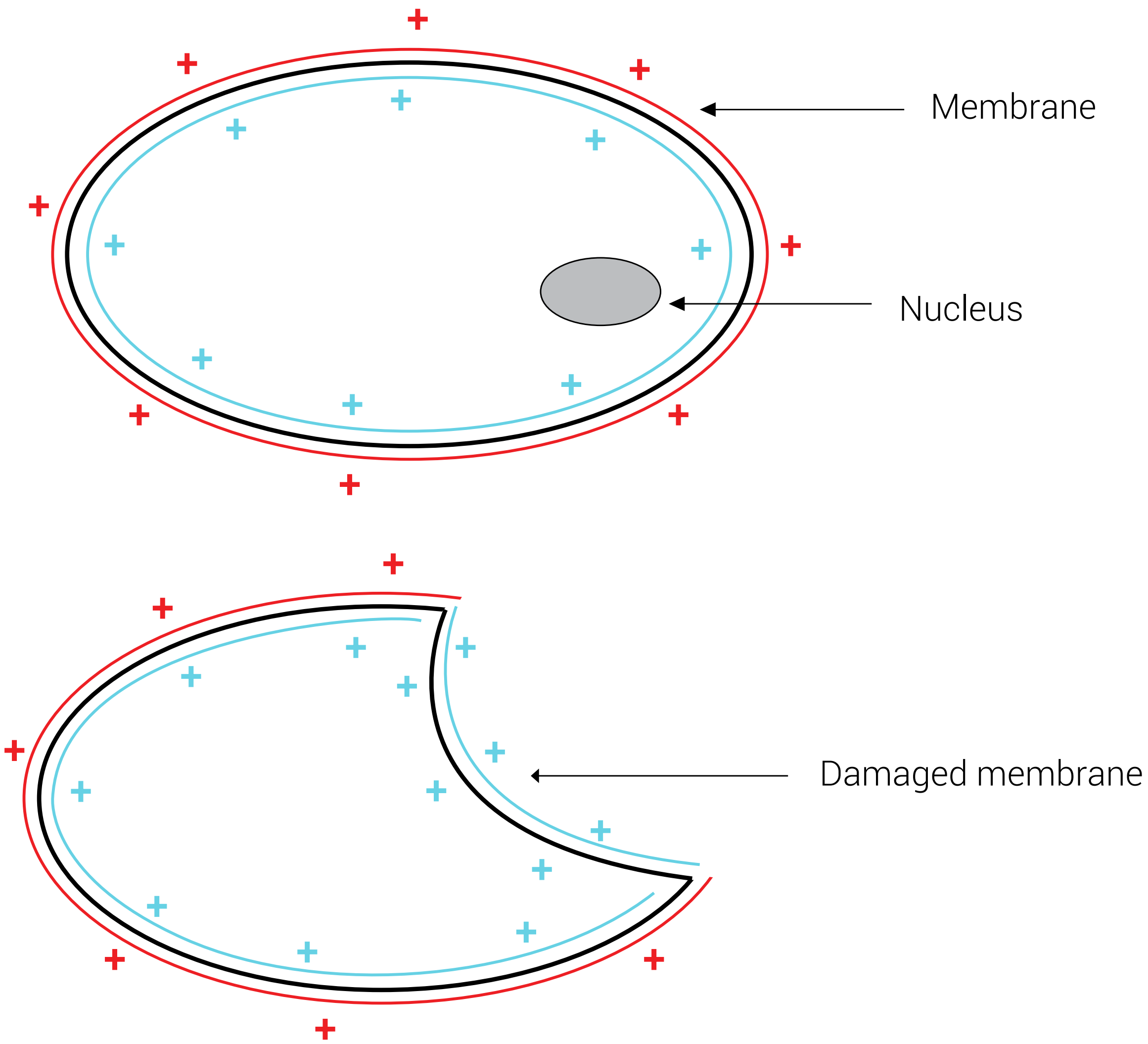
Neuromuscular electrostimulation with microcurrent (MENS) was approximately 20 years ago. Lynn Wallace treated more than 600 MENS patients and examined their therapeutic effects on pain caused by problems with the feet, lower limbs, femur, lumbar area, shoulders, elbows, and neck, and thus discovered its important Healing effects. According to Wallace, an initial 15/20 minute treatment resulted in pain relief in more than 95% of patients. Pain reduction was approximately 55% after the first treatment, 61% after the second and 77% after the third; Pain disappeared completely in 82% of patients after less than

10 treatments (four median treatments).
The MENS feature of being not perceptible by the patient offers an infinite possibility of studies and research. Lerner and Kirsch conducted experiments on 40 patients with chronic lumbar pain. These patients were randomly divided into two groups, one was treated with MENS microcurrents and the other with placebo, using a MENS electrostimulator, which did not cause any electrostimulation. Therapy was repeated three times a week for eight weeks. The results showed a reduction in pain at an average of 75% of patients treated with MENS therapy and only 6% in those with placebo. Other studies have found that MENS therapy favors healing of wounds and ulcers. Gault and Gatens reported the positive effect that MENS had in 106 patients with ischemic ulcers in the skin. Their studies showed that the MENS therapy group with an intensity of 200 μA to 800 μA had a recovery approximately two times higher than an untreated control group. Some doctors have also reported that healing of bone fractures is greatly facilitated by low-intensity stimulation. The above results show that MENS therapy is therefore remarkably effective in treating acute and chronic pain, promotes regeneration of damaged tissues, heals wounds, scars and bone fractures. (Gault WR, Gatens PF Jr: Use of low intensity direct current in management of ischemic skin ulcers Phys Ther 56 ~ 265, 1976.)

Functional mechanism of the "Injury current" MENS currents and MENS functions

It has been known for more than a century that the cell membrane has a potential energy of about -50 mV. This energy is known as a membrane resting potential. The outer surface has a positive charge while the internal one has a negative charge [Fig.3]. When a cell is damaged the potential of the wound part becomes negative and the electric current flows into the wounded area.
This phenomenon was accurately measured by Matteucci (1938) and Bois Reymond (1843);

This current is commonly known as “injury current” today. The injury current is generated not only when individual cells are damaged but also when tissues are lost.
The injury current intensity ranges from 10 μA to 30 μA as demonstrated during the experiments; In other words the current injury is a microcurrent. Current injury promotes the recovery of damaged cells and tissues in the living organism. It is believed that stimulation with this type of current can generate ATP, synthesize proteins, and favor the reconstruction of damaged tissues.
It can be assumed that an artificially generated microcurrent can supplement and further stimulate the natural functions of the injury current.



Scheme 16

The Phases and Duration of Mens Therapy

MENS therapy generally comprises two phases. Phase 1 primarily aims to lessen pain while Stage 2 to solve the trauma and repair the damaged tissue. While Phase 1 allows rapid pain relief, Phase 2 promotes ATP production and protein synthesis accelerating recovery of tissues and therefore basic healing. These two phases are performed in succession.
The duration of treatment varies between 15 and 30 minutes in phase 1 and between 5 and 10 minutes in phase 2 (5 minutes of default). The number of sessions varies depending on the problem to be dealt with. Generally, it is sufficient to treat a day or every two days. To achieve satisfactory results, the duration of therapy may vary from 10 to 45 days. After achieving satisfactory results, it is recommended that 5 to 10 sessions be continued.

Combined use with TENS

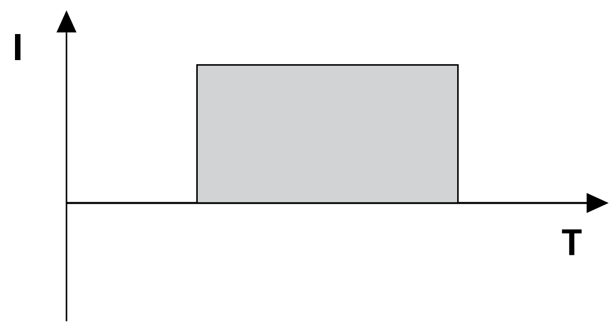
Microcircuits can be combined with TENS electrostimulation. This combination can produce great results in the presence of acute pain or muscular stiffness symptoms.
Ionophoresis
Ionophoresis is a therapeutic technique that utilizes the continuous electrical current that allows the displacement of charged particles through the tissues. If charged particles are medicinal, then DC continues to act as a carrier that allows the introduction and penetration of medicinal substances. It has been shown that by means of continuous current, there may be a migration of ions that according to the polarity law (negative ions migrating in the direction of the positive pole and vice versa) are inserted into the current flow into the body through the ducts Sweat and sebaceous hair and hair canals.
The fields of ionoforese use are all treatments that act positively on musculoskeletal inflammatory states.

Currents for denerved or partially denervated muscles

The stimulation of a denervated muscle differs from that of a healthy muscle because the activation of denervated muscle fibers requires special currents. In the presence of traumatic lesions of the peripheral nerves, the measurement of the chronicles allows to determine whether the denervation is poor, partial or total. As the reinvention process may last sometimes for a few months, the excitomotor treatment aims to maintain trophism and to limit muscle sclerosis to allow the muscle to be as functional as possible at the end of recovery. The efficacy of this type of treatment depends greatly on the correct setting of the stimulation parameters; These must be defined specifically for each patient and must be adapted over time based on the progress achieved. In denerved muscle programs, mainly three types of current are used.

Rectangular current

The rectangular current is characterized by single rectangular pulses, which vary rapidly from the null value to the maximum value of the set intensity. The pulse duration results in a selective contraction of denervated fibers and the average null pulse value (alternating polarity) avoids any skin ionization phenomenon. Rectangular pulses are mainly used on wholly denervated muscles.



Scheme 17

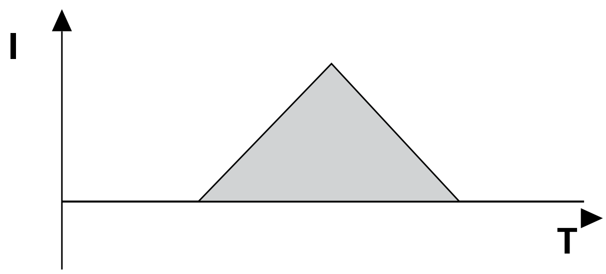
Triangular current

The triangular current reaches the maximum value of the intensity set with a linear rise ramp which, coupled with long-lasting pulses, results in a valid contractile response of denervated fibers (controlled by injured nerves) without, however, stimulating the adjacent normally innervated fibers (healthy). Of course, since this current is excitomo-motor, the triangular pulse, responsible for the contraction of the denerved fibers, will be followed by a pause period in which the current is null. The polarity of the pulses is alternated to avoid the phenomenon of ionization at the level of the skin.

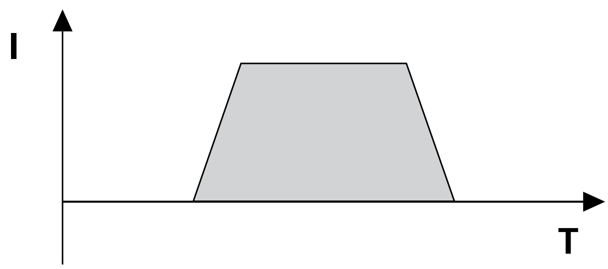
Due to the ability to accommodate nerve fibers to the slow growth of stimulus intensity and the absence of any discomfort to the patient, the triangular current is used to stimulate totally denervated and partially denervated muscles. Selective fiber stimulation takes place without involving those already normalized, which is sometimes detected with the rectangular current due to the rapid rise of the pulse.

Trapezoidal current

Trapezoidal pulses are mainly used on partially denervated muscles.



Scheme 18



Scheme 19

Interferential Current

Interferential Current is an alternating frequency medium frequency (2500 Hz - 4000 Hz - 10000 Hz) frequency sinusoidal current, characterized by high capacity to penetrate the tissues and excellent tolerability for even the most sensitive patients . The antalgic action of bipolar interference, with a modulation frequency of 0 to 200 Hz, is transmitted to the mechanism of gate control (peripheral block of pain transmission), stimulation of the inhibitory mechanism, removal of algogens from the affected region, as with TENS current. By varying the modulation frequency used, one can also exploit an excitomotor effect, which contributes, activating the "muscle pump", to the return of venous flow.

They are called interferences because they form and interfere with tissues at the points where two medium-frequency currents cross.

The interferential current is particularly suitable for deep arm joints (hip, lumbar spine), deep tendinopathies, and muscular hypotrophy of normally innervated and deep muscles. The interferential current is used in physiotherapy for excitomotor and antalgic purposes.

Erythomotor effect: it causes the contraction of normally innervated and deep muscles. Analgesia: causes vasodilatation which, by increasing the local blood flow, removes algae from the tissues. The guidelines for applying the electrodes are identical to those provided for the TENS.

3. Wearable design

3.1 Wearable devices introduction

The terms "wearable technology", "wearable devices" and "wearables" refer to those electronic or computer technologies that are incorporated in clothing and accessories that can be easily worn on the body. Wearable technology is therefore a wearable device capable of carrying out many of the processing activities, such as mobile phones and laptops, smartwatches, microcomputers; In some cases, wearable technology can replace larger portable devices with the smallest ones. Wearable technology tends to be more sophisticated than the so-called hand-held technology (technology held in hand).
Today, the market offers tools and devices with sensors and scanners that had not been present in mobile and portable devices so far, such as biofeedback and physiological function monitoring.
The wearable technology is constantly improving on communication capabilities and will allow more and more access to real-time information. Data entry capabilities are a feature of these devices, as well as local memory, although data storage is now being increasingly dealt with for wearable technology, cloud computing systems. Examples of wearable devices include watches, eyeglasses, smart contact lenses, interactive fabrics and smart fabrics, so-called e-textiles, fitness bands, headsets and helmets for virtual reality, jewelry such as rings, bracelets, and help devices, , Wearable fitness devices.
The wearable technology tends to refer to elements that can be worn and removed with ease, but there are more invasive versions of the wearable concept, as in the case of devices implanted as microchips or even smart tattoos. Ultimately, that wearable devices are used externally or inserted into their body, their purpose as any wearable tech

fig. 39
Google glass

fig. 40

bracelet by Misfit

fig. 41

Apple watch

nology is to create constant, convenient, portable, wearable and mostly give access to electronics and computer while leaving Hands free.
The implications and uses of wearable technology are vast and can affect the health and medical, fitness and sports sectors, aging, disability, education, transport, business, finance, games and music. The goal of wearable technologies in each of these areas will be to integrate seamlessly functional, portable electronics and computers into everyday people's lives. Before their presence in the consumer market, wearable devices were mainly used in the field of military technology and had major implications in health and medicine.
Although wearable technology may potentially have a greater impact on health and fitness, the great influence that wearable technology can have on gaming and entertainment is not to be overlooked. Increased reality and wearable technology can combine to create a much more realistic and engaging real-time environment. The concept is not new, the increased reality through the use of wearable devices has been discussed and sought after since the late '90s; However, prototypes are moving away from cumbersome technology and large glasses or large helmets, giving way to the ever-increasing number of small, lightweight, and more mobile devices. Also, as you can see from the innovative design of new mobile phones and digital cameras currently on the market, wearable devices can become fashionable, practical, functional objects. This approach combining technology with aesthetics is already evident in devices like The Google Glass, which have a sleek, lightweight and discreet design.
Since the possibilities of use in various fields are constantly growing, the impact that wearable technology has on sociological and cultural spheres is not to be overlooked. Already, handheld devices available on the market, such as smartphones, iPods and tablets, have changed their social habits on a global scale, so they do not get tired of seeing crowds with their tense hands intent on taking or taking pictures concerts or events. This photo of the company

was nonexistent only 20 years ago. That said, developers and analysts predict that wearable technology will quickly change technological and cultural landscapes once again, and will also change the nature of mobile phones and many other portable devices.

3.2 BAN: the technology behind the wearable

Before talking about the potential of wearables, their fields of application and their diffusion it is advisable to take a brief look at what are the technological components that run this type of product.
The Body Area Network represents the natural union between connectivity and miniaturization. A Body Area Network (BAN) is formally defined as a ***device system close to a body of people cooperating for the benefit of the user.***
BBC's Jo Twist gave a more informal definition of Body Area Networks in its article titled "When technology becomes personal":
Inanimate objects will begin to interact with us - we will be surrounded - on roads, homes, household appliances, our bodies, and possibly in our heads - from things they "think".
The BAN system is also called BSN (body sensor network), depending on the characteristics it can undergo some changes in the acronym:

MBSN

A Managed Body Sensor Network (MBSN) is defined as a system where a third device decides on the databases collected by one or more BSNs.

ABSN

Autonomic Sensor Networks (ABSNs) and MBSNs share the same goals but realize them in different ways.

While an MBSN will be based on reading sensor information and delivering to a third party for decisions and interventions, ABSN takes a more proactive approach. ABSN (autonomous body sensor network) introduces actuators in addition to the sensors to enable the BSN to make changes to the user body. In addition to the actuators, ABSN contains smarter sensors that have sufficient capacity to perform their tasks independently.

These devices can be placed on the human body in a particular position depending on what you want to monitor.
The main purpose of these networks is to transmit data produced by portable devices outdoors to a wireless local area network (WLAN) or to the Internet. In some cases, wearables can also swap data directly to one another: it is obvious that the world of wearable design and the development of sensor networks travel almost in the same direction, in particular wearable growth has been an important push for With regard to the development of the sensory world.
The field of a BAN is a particular area that could allow medical and constant medical monitoring of medical monitoring over the Internet. A number of clever physiological sensors can be combined into a WBAN Wearable (wireless body area network) that can be used to detect medical conditions. This area is based on the viability of the very small biological sensor plant within the human body. Fixed sensors in the human body collect various physiological variations to observe the state of the patient's health.
The information will be transferred wirelessly to an external processor. The BAN device will immediately send all the information to doctors all over the world. If an emergency is noticed, doctors will instantly update the patient's health status through the PC by sending a special message.

3.2.1 BAN components

A typical BAN (or BSN - Body Sensor Network) kit includes 4 main core modules for operation:

• **Battery Module:** Provides power to the entire node;
• **Transceiver:** Handles the signals and data collected by the sensors to the processor;
• **Processor:** Receives collected data and processes them
• Sensor Module: An electronic part that deals with measuring a specific physical size.

The battery is definitely one of the elements subject to greater dimensional variability, it depends on the technology used and can often represent a design limit as it may prove to be too big in relation to sensor and processor. A second constraint of this element is the usability of the ban, as you have to be careful about energy consumption, so make the nodes (set of sensors) energy efficient as efficiently as possible.
Another variable consists of sensor modules, there are very different types of sensors (they will be analyzed in Chapter XXX) based on what you want to measure. In general, it can be said that in the wearable and BAN domain the absolute prerogative of sensation is to have very small dimensions capable of adapting well to human anatomy without disturbing and creating mobility problems.

A sensor is composed of:

• A **transducer** that converts the measured magnitude into electric impulses;

• A **conditioner** that limits electrical signals within a certain range of values;

• A **signal sampler** that converts them into numeric form.

The ban systems are applied to the body and in the design phase you have to consider some issues like:

• **Target application**: what kind of problem you want to solve by applying sensors to the body;

• **Users:** who will use the application, sick, healthy, sports, etc .;

• **Wearability required:** Depending on the type of activity that the user will perform, the sensors must respond to different investment choices;

• **Costs:** a proper cost-assessment of potential benefits is needed at the design stage to see if it makes sense to develop the idea for commercial purposes (bans and bsn have a high industrial pre-development cost).

3.2.1.1 Batteries

To power these systems, it is necessary to use energy accumulators (batteries) or systems that produce electricity. The existing types of batteries are many, the choice of their use is based on the use made of them and the disadvantages / benefits that each type has. Below is a brief explanation of the most used battery types in the wearable consumer electronics market:

• **Alkaline batteries:** In electrical and electrochemicals, a battery is a device that converts chemical energy into electricity, typically used as a power generator or voltage generator for powering electrical circuits and electrical devices. Although not rechargeable due to principle of operation, are the most common, small, cheap and lightweight. They usually have a voltage of about 1.5V, so to power a device you may need to use more than one.

fig. 42

• **NiMH batteries:** they are rechargeable batteries, used in case of high long-term currents in lightweight and portable mode. Normal NiMH batteries work better with devices that require moderate power currents, such as digital cameras, and consumer electronics. NiMH battery types also include hybrid vehicles such as the Toyota Prius or the Honda Insight / Civic. They have a lower efficiency than their competitors, in addition they have a higher weight and discharge about 30% of the energy Is not returned. They are more expensive and have a voltage of 1.3-1.6V.
• Li-Ion batteries: they are rechargeable batteries with the best electrical and hi-tech features, they are expensive, light and efficient, there is no memory effect. They have a voltage of about 3.6V.

fig. 43

• **Li-Ion batteries:** The rechargeable battery known as lithium-ion battery (sometimes abbreviated Li-Ion) is a common type of battery used in consumer electronics. It is currently one of the most popular types of laptop and cell battery, as well as some electric cars with one of the best weight / power ratios (each unit develops about 3V), no memory effect and a slow charge loss when it is not in use. The main disadvantage of the Lithium ion battery is that it has a progressive degradation even if it is not used: it has a shelf life from the time of manufacture regardless of the number of charge / discharge cycles.

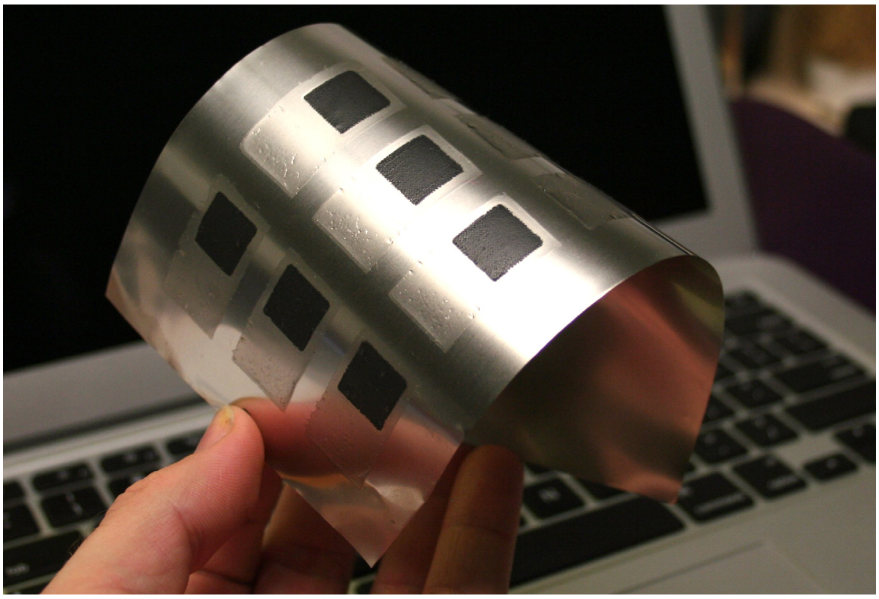
In addition to these solutions, there are other types of batteries which, although less common and widespread, can be very interesting for certain types of applications:

• **Thin film batteries:** Approx. 5 * 5 mm or 9 * 9 mm, Solid State Li-Ion Cells with Built-in Power Circuit to Maintain Charging and Primary Power. They are used to provide energy in short periods and recharge when not in use.

• **Super capacitors:** Machines that can accumulate electricity more than other batteries, have no memory effect, can deliver very high currents and can undergo many recharge cycles without losing performance. Dimensions between 1.5 * 20 mm and 1.9 * 40 mm.

• **Printable batteries:** Non-rechargeable batteries, made with metal stamping silk screening technology, react chemically to produce energy. It has not exceptional performance and the fact that it is not rechargeable limits its uses.

fig. 44



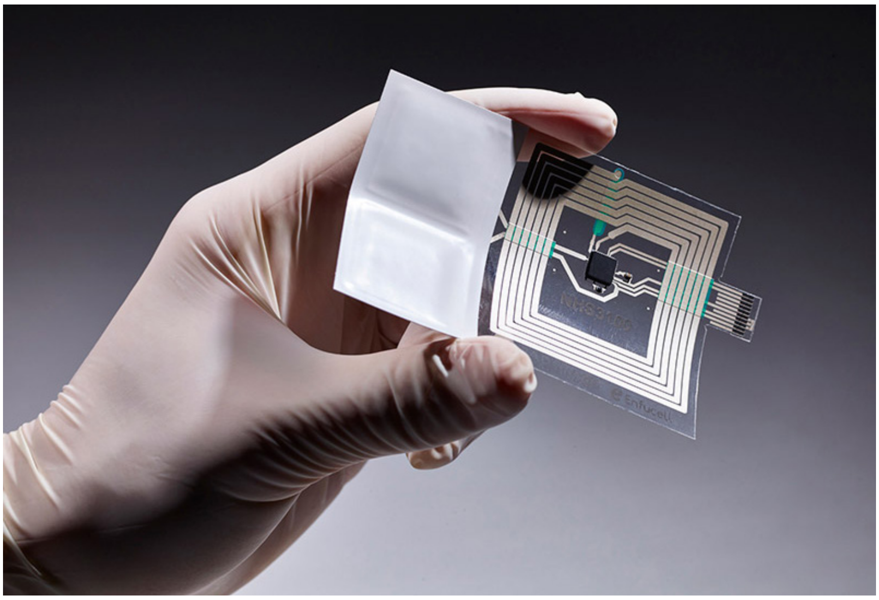


fig. 45

fig. 46

PowerResponder is a line of new hybrid supercapacitors with technology enhancements that aim to replace traditional lithium ion batteries in select applications

fig. 47

F I L M   B A T T E R I E S

A P P L I C A T I O N

fig. 48

3.2.1.2 Sensors

First of all you need to clarify what a sensor is, a possible definition is: A sensor is a device that detects a physical or chemical input signal and converts it to an appropriate output signal.
Sensors can be classified according to:
• Parameter measured (eg pH)
• Application (eg for biomedical use)
• The type of material on which the measurement is based (eg semiconductor)
• The principle of transduction (eg electrochemical sensor)

Chemical sensors
Possible Definition: It is an analytical device that transforms chemical information ranging from the concentration of a specific analyte to the complete analysis of the composition in a useful (generally electrical) signal.

2 main components constitute the sensor:
• a molecular recognition system (receptor, which gives specificity to the measurement)
• a physical-chemical transducer (the real sensor)

Biosensors
It is a chemical sensor in which the recognition system uses a biochemical mechanism
in which the biological recognition element is either integrated or intimately connected (i.e. in direct spatial contact) with the transducer

Therefore, they are NOT biosensors
• Chemical sensors used to monitor biological processes (eg Sensors of
Blood pressure, in-vivo pH sensors)
• Analytical systems that include additional hardware or systems
Sample processing (such as liquid chromatography systems).

If we wanted to circumvent the speech to the sensors applicable to the BAN, we could reclassify the sensors in three groups according to what they detect:

• **Physiological sensors:** measure all personal physiological values, including heart rate, blood pressure, and can also provide an electroencephalogram (EEG);

• **Biocinetic Sensors:** these are sensors that measure movement, and make the system
-aware (aware of the space in which it is located and in which it moves)

• **Ambient sensors:** measure the various ambient values, such as temperature or humidity.

As for the most popular BANs, they are certainly the first type, followed by biocinetic ones, and seldom there can be ambient sensors within such a network.
The main differences between the sensors of a BAN and the sensors of any generic network are that the generic network sensors are often homogeneous, distributed in a very large space and the errors are quite tolerable (there are more sensors that measure a certain phenomenon), While with regard to the BAN, the sensors are placed on the body that is to be monitored, which means that their distribution is much more collected, the sensors are heterogeneous and above all the position of a sensor greatly influences what the measurement will then be Of a certain value.
In the design each type of sensor has certain constraints of both design and wearability.

3.2.1.3 Sensor features

All sensors, regardless of their typology or classification, have parameters that define their capabilities, effectiveness, and precision.

Sensitivity: This is the output variation of the output signal of the sensor as a result of the variation of the input signal *$\Delta S / \Delta c$, or dS / dc.*
For some sensors based on dynamic response, the output signal is not S, but dS / dt so the sensitivity is defined as $\Delta (dS / dt) / \Delta c$.

Calibration: this is a procedure based on the exposure of the sensor to various standard compositions of known composition (the calibration points should include the entire working range of the biosensor).

Range: range between the highest and the lowest output value on the instrument scale. It is measured in decibels

Through bandwidth: Frequency range within which the measuring system can operate below a certain error. It depends on the dynamic response of the sensor.

Linearity: a perfectly linear sensor has a constant sensitivity in the range of concentrations accessible (starting from zero to the maximum concentration available in the metering device). Linearity is not strictly necessary for the measurement utility when it has a sufficiently accurate calibration curve. Some sensors have a semi-logarithmic sensitivity (DS / DlnC).

Selectivity (specificity): refers to the extent to which a method of measurement is capable of determining the concentration of a species in a mixture without interference from other components. The ideal chemical sensor responds only to the concentration variation of a certain analyte without affecting others. This feature primarily depends on the sensing element of the sensor. To reduce the effects of interference you should:
- try to remove the interferences through dilution, chemical conversion membrane filtration
- Correct the measured signals (eg with differential measures)

Limit of detection (LOD): is the smallest analytic concentration detected by the instrument. It should ideally be limited by the resolution of the measuring instrument; it's defined as the output S for which:
$S-S_B \geq 3\sigma_B$

Bottom signal (SB): this is the signal in the absence of the analyte
LOD is limited by sensor and electronics noise and environmental interference

Possible sources of noise: sensor (thermal noise, drift depending on time); Electronics noise, quantization noise in A / D converters
• Environmental interference: electromagnetic fields, pH variations, temperature variations (crosstalks); Interfering molecules, non-specific links (cross sensitivity)

Dependence on temperature affects both chemical reactions and dissolution of species in solution. Therefore measurements are possible if possible under isothermal conditions.

Resolution: This is the smallest increment of measured value detected by the reading instrument scale. It depends on the sensitivity and reading electronics.
Detection limit ≠ resolution

Long-term stability (drift): is determined by changes in sensitivity over time. Sensitivity typically decreases but could also temporarily rise (variations in the sensitive layer). A gradual decrease in the sensitivity may be due to several factors (oxidation of exposed metal surfaces, deposition of solution proteins, in vivo species, in technical terms, is defined as sensory poisoning).

Response time: is defined as the time needed to obtain a certain percentage of the stable value of the measurement, eg. T95 time to reach 95%.

It depends on the physical properties of the sensor (eg size) and how the measurement is performed (eg if the solution is mixed or not). The internal diffusion in the sensing layer also takes some time, not negligible.
Mass shipping
Diffusion: due to concentration gradients
Convection: Due to flow of fluid
Drift: due to electric field

Life time: is limited by weaker element (biorestination).
Shelf life is the stability of the sensor before use (depends on the storage conditions. Operational stability depends on the number and type of samples analyzed

Hysteresis: difference observed on the output obtained at the same concentration value on the curve obtained by increasing concentrations compared to that for decreasing concentrations
Ideally it should be zero, but it comes from the fact that the measurement can determine environmental or sensor variations (pH, buffer capacity, ...)

Biocompatibility: is relevant for sensors used for biomedical applications where acute phase monitoring or in-vivo sensors are required.

3.2.1.4 Connection systems

Connection between multiple devices is a key factor in the Internet of Things (IoT), and this can become a real challenge when working in the industrial environment. The industrial IoT, in fact, requires a reliable connection between many devices, called to operate in hostile environments both physically and electromagnetically.

Wi-Fi

Wi-Fi or WiFi is a technology for wireless local area networking with devices based on IEEE 802.11 standards.

Wi-Fi is the trademark of Wi-Fi Alliance, which limits the use of Wi-Fi Certified term to products that successfully complete interoperability certification testing.
Wi-Fi compatible devices can connect to the Internet via WLAN and a wireless access point. Such an access point (or hotspot) has a range of about 20 feet (66 feet) indoors and a greater range outdoors. Hotspot coverage can be as small as a single room with walls that block radio waves, or as large as many square kilometers achieved by using multiple overlapping access points.
Wi-Fi most commonly uses the 2.4 gigahertz (12 cm) and 5 gigahertz (6 cm) radio bands. Having no physical connections, it is more vulnerable to attack than wired connections, such as Ethernet.
Devices that can use Wi-Fi technology include personal computers, video game consoles, smartphones, digital cameras, tablet computers, digital audio players and modern printers.

Bluetooth

In telecommunications, Bluetooth is a wireless personal area network (WPAN) technical-industrial data transmission technology. Provides a standard, economical and secure method for exchanging information between different devices through a short-range safe radio frequency.
This standard is designed with the primary aim of obtaining low fuel consumption, a short range of action (up to 100 meters coverage for a Class 1 device and up to one meter for Class 3 devices) and a low cost of Production for compatible devices.
In fact, the network created by Bluetooth is defined as a personal area network (PAN), while Wi-FI forms a local area network call.
Each Bluetooth device can simultaneously communicate with 7 other devices, although it is a master-slave connection, only one device at a time can communicate with the master. Each Bluetooth device can be configured to constantly search other devices and to connect to these.

SMART Bluetooth

Smart bluetooth (or Bluetooth Low Energy) is a wireless communication technology.
Its main peculiarity is the ability to communicate by consuming very little energy.
That's why it is the most used technology in portable products such as smartwatches, trackers, or GPS clocks.

What is the difference between Bluetooth and Bluetooth SMART?
Bluetooth SMART is different from "classic" Bluetooth. The latter uses much more energy and allows a more important transfer rate. This is why it is most used in helmets or in hands-on kits.
The coupling mode is just as different.
Bluetooth SMART products do not appear in the list of phones Bluetooth devices but require a specific download application. Coupling will therefore only be made from that application.

ANT +

ANT is a proprietary (but open access) multicast wireless sensor network technology designed and marketed by ANT Wireless (a division of Dynastream Innovations, a wholly owned subsidiary of Garmin [1]). It defines a wireless communication protocol stack that enables hardware operating in the 2.4 GHz ISM band to communicate by establishing standard rules for co-existence, data representation, signaling, authentication, and error detection.
It is conceptually similar to Bluetooth low energy, but is oriented towards usage with sensors.
ANT-powered nodes are capable of acting as slaves or masters within a wireless sensor network simultaneously. This means that the nodes can act as transmitters, receivers, or transceivers to route traffic to other nodes. In addition, each node is able to determine when to transmit based on the activity of its neighbors.

Differences between ANT+ and SMART Bluetooth

Smart bluetooth technology is a protocol of Bluetooth 4.0 technology that has emerged in recent years to counter the absolute predominance of the already established ANT + protocol in the wirless low-power communication world.
But what is the real difference between Bluetooth Smart and Ant +?
Both BT S and ANT + work at 2.4GHz, and both allow low power consumption, for example a cardio bandwidth or pedal count with both technologies being able to work with a standard “button” battery for more one year without needing to be recharged or replaced. Both communication systems also provide interference-free communication.
What are the real differences between the two technologies then?
At the moment the most marked difference between ANT + and BT S is the ability to have devices, multiple connections with receivers, in practice a BT4 cardiac band can be used on only one receiver at a time, while an ANT + cardio band can be used simultaneously on multiple receivers.
This, which may be an insignificant problem for an end user, is not really for those who use, for their own business, multiple receivers, or for a cycling coach and / or spinning instructor, for example, who wants to monitor more athletes at the same time or want to follow a single athlete from his own place.

Li-Fi

Li-Fi is a bidirectional, high-speed and fully networked wireless communication technology similar to Wi-Fi.
Li-Fi is a term introduced for the first time by Harald Haas at a speech to TED Global in 2011 referring to the optician's Wi-Fi optician.
The peculiarity of the Li-Fi is that the frequencies occupied for the communications belong to the spectrum of visible light, which has a number of interesting consequences in comparison with radio transmissions.

• There is no conflict with any radio broadcast in terms of interference due to the occupation of the same spectrum

• The absence of radio interference makes promising use in hospitals and aircraft, where interference poses security problems

• The signal is limited to the optical range, which reduces the security problems caused by the interception

• Large transmitters can be created with far greater energy efficiency than radio stations

Li-Fi is a bidirectional, high-speed and fully networked wireless communication technology similar to Wi-Fi.
In practice, with the new instrument, the information is aggregated electronically and then transmitted in the form of a light signal through an optical cable for hundreds of kilometers without interference and loss of quality. In addition to a huge increase in speed, photon technology promises almost instantaneous communications across the globe.
The disadvantage of optic wireless is to be a point-to-point networking type, or to connect only two perfectly aligned hosts without intermediate obstacles.

fig. 49

Rapresentation of how Li-Fi work

3.3 The features a wearable product must have

Every product on the market can be inscribed in a product category based on the features it has: this rule applies to all products that want to belong to the world of wearable design.
As explained above, wearable items are essentially inspired by clothes or accessories that are enriched with a technological core. The difficulty here is not to get too far from the archetype, finding a way to integrate technology and make it easy for you to use.
Below are some of the key features for an item to be defined as wearable:

Keep It Glanceable

No word has been thrown around in wearable design theory quite as much as "glanceable." We were first introduced to the concept through screen-less fitness trackers, which rely on lights or other simple indicators to explain to the user what's going on. The term is used a little differently in the context of the smartwatch: Glanceability is less about reducing the interface down to its most basic visual feedback and more about figuring out exactly what the user needs to see at any given moment: for example Shazam is a great example of a glanceable wearable app in the way that it only presents you with what you need.
The goal is to show users one thing at a time, that requires a new framework for how those users will move through an application. What do you serve them first? How do you keep them engaged? And just as importantly, how will they communicate with the application?

Don't look now : non visual communication

It's time to stop looking at our screens. Much of the way we interact with wearables will be dependent on other senses: looking,hearing, feeling. Many design thinkers believe the future of getting and inputting information on wearables is a matter of non-visual communication tools. Think: vibrations that tell you which way to turn, voice dictation to compose texts and emails, gestures that activate certain applications. We're already seeing this with things like the Apple Watch's Force Touch, which senses the difference between a tap and a long-press. It's a small but significant design detail that greatly expands the functionality of a tiny screen by ignoring it almost entirely.

fig. 50

Necklace by misfit

Avoid the data avalanche

Since wearables should be simplier than devices like computers or smartphone, they have to communicate just the most important stuff to the user.
The information pushed to you via a wearable should be filtered, and making that happen is an intense design challenge that's mostly reliant on smart AI that understands what any given person actually needs to see. Context is the backbone of almost all other UI principles—once you understand what a user needs, you can design an experience to be lightweight.

Design for Offline

Wearables are gadgets, and gadgets often don't work as planned. They lose connectivity or don't sync up correctly, so a good approach in design is to design for the moments when things go wrong. Since wearable products always use to be connected to share information and data, you should build core functionality into offline mode, but if you can't, then you should at least explain to the user what's happening.
Facebook is a good example: while it's offline, the user not only sees a UI element letting he know that he's offline, but also he still can post while offline.
It both acknowledges the situation and provides clear steps to the user about what features are currently available.

Hands- free

Wearability presupposes that the object is somehow integrated with the body, it must not hinder mobility and require hands-on. This difference is for example between a smartphone and a smartwatch, which is one of the most commonly used wearable products.

Always on and immersive in the eco-system

A wearable object must be able to integrate with the body and adapt to any kind of situation while remaining worn even when it is not in use. It must then try to be the least invasive possible and consequently be in harmony with the user and the surrounding environment.

3.4 Applicable wearable fields

The applications of wearable devices have become very different nowadays. The growth of internet of things products and the development of nanotechnologies are the basis for the growth of wearable devices.
Their design touches the most varied sectors, often there are products that are difficult to insert into a precise category due to their transversality and polyvalence.

3.4.1 Military Sector

Wearables Technologies for Armed Forces include wearable systems such as head displays, wearable tactile devices, ally and enemies location detectors, give the ability to watch live video from multiple locations including drones and 3D map display of battlefields.
The evolution of wearable technology in this sector is also important for monitoring physical condition and injury.
The Armed Forces of the United States of America have for decades been using mini-screens connected to remote computer systems and mounted on soldiers' helmets to provide them with an "increased reality", that is a representation of the territory around them, addition of altimeter data, information about the presence and danger of the enemy, details that are always up to date on the targets to be reached.
Another US based research project, called Warrior Web, aims to create a lightweight uniform under wear and intended for soldiers carrying over 40 kilos of weight on rough terrain. The suit has a network of sensors to monitor and collect data, both organic and location-related to the soldier who wears it.
This suit has already been tested to determine the reduction of injuries and fatigue in soldiers, with satisfactory results. In the same research project, ways are being explored to use the wasted kinetic energy in the course of

the march, for the purpose of charging electronic instruments, such as radios or smartphones.
These are just some of the examples, wearables experiments in this area are constantly growing and developing.

fig. 51 / fig. 52

Warrior Web by armed forces of United states of America

3.4.2 Work

The importance of these technologies applied to the world of work and industry has many benefits in terms of control, productivity, security and more.
The first attempts for their adoption in the manufacturing field are not recent: primordial rugged, hand-armed or supportive handheld experiments date back to the early 2000s. The goal was to leave the operator with both hands free.
After 2010, however, the first uses of Google Glass are recorded as a new futuristic interface between man and machine.

The situation has changed rapidly over the last few years, during which new products have been developed (the place of Google Glass is now occupied by Microsoft's HoloLens), some of which are designed for industrial use, such as the Mover of Epson. But other devices such as 3D viewers for increased reality (HTC Vive and Oculus Rift) and smart-watches can be useful at different times of an industry's life. There are also some interesting experiments made with smart clothing, a kind of second-sensing skin.
But why wearable also affecting the industry? What are the benefits associated with the effective use of wearable devices in manufacturing? A first advantage is the best use of the workforce and its productivity.

fig. 53

Great exaple about the use of wearables in work.
Virtual reality make the worker able to be more efficent and have a fast visualization and feedbacks.

The use of a wearable device can replace workplace presence certification, allow employee location to work (especially useful when managing work teams for time-sensitive tasks) and speed up sending Instructions for the tasks to be performed.
Managers can receive real-time data on the warehouse, executing orders, and have production visibility. Having access to this information contributes to the overall process optimization.
Then there is the management of "alarms" related to failures and problems on machines and plants. Receiving a notification when a machine stops working or when security devices are more common than usual can be valuable information.
The last point is the least immediate, but perhaps the most important, security issue. In fact, wearable are not limited to burning calories or kilometers, but they can also collect information that is particularly useful for preventing accidents at work, measuring breath, heart rate, posture, and detecting whether a person has been exposed to gas toxic.
Connecting the industrial operator to the digital world through wearable sensors can, in short, improve the efficiency and safety of workers directly or indirectly.
Wearable devices are also a precious source of data to integrate with others (perhaps in clouds) to get statistical correlations that can help you take a proactive approach to problem solving, reduce downtime, and prevent accidents.

HoloLens

HoloLens is essentially a holographic computer built into a headset that lets you see, hear, and interact with holograms within an environment such as a living room or an office space. Microsoft has built the headset without the need to be wirelessly connected to a PC, and has used high-definition lenses and spatial sound technology to create that immersive, interactive holographic experience.

Microsoft presented some of the most interesting potential uses. For example HoloLens will be able to let you view and interact with work projects such as assembling 3D models, play games like Minecraft, video chat with hologram versions of Skype contacts, and even watch live content.

HTC Vive

HTC Vive is a virtual reality device designed by Valve in collaboration with HTC and released on April 5, 2016. This device not only allows you to see the virtual world through an optical viewer, but thanks to a new technology called "room scales" Transforms the environment surrounding the user into a 3D space where he can move almost freely. This new technology coupled with precision head tracking and game controls simulating hand movement, transforms the virtual reality of HTC Vive into a particularly immersive experience, allowing the user to interact almost completely with the game world .

fig. 54 / fig. 55

3.4.3 Healtcare

The medical sector is definitely where the wearable technologies have brought more benefits and have developed before.
The first of the advantages to be listed is the ability to monitor a remote H24 patient in a simple and non-invasive way.
Control allows doctors to always clear the situation of patients and to make immediate changes to therapies depending on the feedback of wearable devices.
This possibility connects to the gang of personalized medicine that basically consists in the ability to adapt the drugs to the individual characteristics of each, minimizing the side effects and increasing the benefits.
Control is possible thanks to the use of sensors (in particular biosensors) which give the possibility to record many vital and hormonal parameters.
Technology with the help of medical knowledge has allowed the development of more invasive chips and devices than a normal wearable device, in this category there are devices that are implanted under skin, intelligent contact lenses, and intelligent tattoos.
In addition to devices capable of providing data, there are other types of devices that, instead of providing data, implement the actual actions.
This is the case with the latest generation actuators, capable of administering to the patient certain quantities of any substance with remote control.
The possibility of constant monitoring not only serves for diagnosis but also for the prevention of certain diseases, resulting in a reduction in health costs.

Rapael Smart Glove

The Rapael Smart Glove has an exoskeletal design that assists people who have had strokes, and other patients with neurological and musculoskeletal injuries regain mobility in their hands. Using a Bluetooth sensor, the glove measures the patient's motion through a 30-minute exercise, and creates an exercise schedule based on the patient's needs. The glove includes game software allowing patients to simulate playing ping pong, chopping food and catching a baseball, rewarding points to encourage engagement.

fig. 56 / fig. 57

Rapael smart glove : an exaple showing how the motivation (in this case achived with game) is important durng a rehabilitation process.

K’Track Glucose

Painless and accurate glucose monitoring has been the goal of many health technology companies. The watch-like K’Track Glucose monitor aims to be the solution for people with type 1 and type 2 diabetes by using technology that uses micro needles to collect and analyze fluid right below the skin surface. The needles are less than 0.5 mm. The micro needles are a part of a replaceable cartridge that lasts 30 days, but can take unlimited readings in the time period.
Users push a button on the device to check their glucose levels, and it takes a minute for results to display on the face of the device. Results of the day can also be displayed on the device, and all results over time are synced to a mobile app.

fig. 58 / fig. 59

K’Track Glucose

3.4.4 Fitness

Another area is wellness, where fitness and technology converge to support users not only during sports activities but throughout the day by tracing the outcomes of their lifestyle. For this reason, devices designed for fitness can have characteristics similar to those for healthcare and vice versa.
These products interact with smartphne, tablet, and pc that, using cloud computing, help improve their physical activity experience. Any device connected to the Internet can handle mobile and desktop applications that offer great support to organize training regimes and maximize results. In the gym, cloud platforms can be linked to machines to generate even more data. By creating this information, you can create in-depth reports to improve your long-term performance.
Fitness trackers can be divided into 3 categories, depending on the function and degree of autonomy in relation to the need to bind to a device (this classification can be extended to other areas of wearable design):

Complex Accessories: These devices are designed to work only partially independently and require connection to a smart connected device to be fully operational. This category includes many of the countless bracelets for fitness or control of sports activities. These collect data and in some cases communicate via display, however, they need a data offload on the internet via a connected device to save and process the data.

Smart Accessories: They are devices that have the ability to install third-party apps or software, which can then expand their functionality. However, for the full operation of these devices, it is still necessary to connect to a smart device, which is then connected to the Internet. Examples of this kind of device are many smartwatches, those not equipped with SIM, including Apple Watch.

Smart Wearables: They are devices that can run in full autonomy without having to rely on other devices. They connect themselves to the Internet and have the opportunity to install third-party apps and software, with the intent of expanding their functionality. An example of these devices are the Google Glass or smartwatches equipped with SIM, as the latest model announced by Samsung.

fig. 60

Smart bracelet by Misfit

fig. 61

Smartwatch by Sony

fig. 62

Moov now

In a wearable world where the screen is king, this unremarkable disc eschews a display yet still contains a huge amount of power.
It's got nearly all the top elements a fitness tracker should have: months of battery life, step tracking, sleep monitoring, fitness updates, cross training and run coaching.
You can even go swimming with it and get a decent boxing workout too – and the Moov Now is one of the cheapest on the market
The Moov Now design couldn't be simpler. It's a small disc that comes in variety of colors and sits in an attractive latticed black rubber strap.
It's very light and only has a small button on the top, which you'll click when you want to start an exercise or sync your fitness stats to get an up-to-date look.
It sits quietly and lightly on the wrist, and most of the time the user never even noticed it.
Moov features a host of training plans designed to help you achieve goals and then uses a voice coach to affect your performance in real time. And in this regard, it's the leader out of a handful of similar products.
When you go out for a run, you can choose training plans from running efficiency, intervals and open training (there is a great selection of training plans, for all levels of ability).
This device is really polyvalent, Moov can be used also for swimming, cycling and others: it will detect and count your swimming strokes, show your cycling cadence and power (only accessible through very expensive kit before) and even the power of your punches on the boxing bag.
Moov now belong to the "complex accessories" category, infact it needs a phone for coaching and GPS tracking and that's a real pain. Phones are massive now and strapping one on is starting to be a real drag. But Moov needs it because it takes the GPS data and plays the audio coaching through the phone app.

fig. 63

Forerunner 235

The Forerunner 235 does everything both casual and serious runners would want. It has GPS to measure pace and distance when running, it has an optical heart-rate sensor, and it can track daily activities like steps and calories.
It can display notifications from your iPhone or Android device and has access to Connect IQ, Garmin's third-party app store. Since it improve its performances being connected with smartphone, it can be considered into the "smart accessories" wearable category.
There's also a feature for predicting your race times and a recovery advisor to help you determine when you're ready for that next hard workout.
The watch can even estimate your VO2 Max (a metric used by athletes for measuring the maximum amount of oxygen that can be used during workouts). All of this is in addition to the basic running features like auto pause, auto lap, interval workouts and keeping track of your personal records.
This smart watch is primarily for running, but it has the ability to be paired with ANT+ speed and cadence sensors. Unfortunately, there is no support for any Bluetooth sensors.

fig. 64

3.4.4.1 Trackers Market research

Health & Fitness Tracker: About one in three respondents say they use it (or have done so in the past). According to a GfK survey that has involved more than 20 people in 16 countries - at an international level, a person in three to three percent uses general devices to monitor or trace their physical activity or to have a picture of their health. Considering who used them in the past, the percentage rises to 51%. In Italy, the spread of these products is growing, albeit at lower levels than the international average: 16% of respondents state they are currently using a monitoring device, while 14% admit to having done so in the past. A trend also confirmed by sales figures recorded by GfK: in the first six months of 2016, the wearable compartment grew by nearly 160% per unit and 167% in value. In the category of so-called health & fitness trackers or activity trackers, there are types of gaps, apps to install on your smartphone, counters, smartwatches and trackers with clips. Technological solutions that help monitor a wide range of parameters such as calories taken or consumed, sleeping hours, heart rate and distance traveled. At international level, China is the top spot for dissemination: 45% of respondents said they would use it at the moment. They followed in rank-with a remarkable post-Brazil and United States, both with 29%, then Germany with 28% and France with 26%.
As you can see more in detail in Italian responses, the trackers are most popular among men (19% declare to use one at this time) than among women (14%). By age, in the first place we find the twenty-one (26% use a tracker, 21% did it in the past), followed by the age group 30-39 (43% use or use a device) and that 15-19 years (33% used a tracker at least once in life). More than half (55% of those using health and fitness monitoring systems declare it "to maintain or improve physical fitness").
This is the most frequently motivated reason, at international level. "Motivating you to do physical activity" is the second most cited reason, indicated by 50% of

respondents. More than a third declares that they want to "increase their energy level" or "motivate themselves to eat and drink in a healthier manner".
29% of people claim to "sleep better" and about 1 out of 4 "to be more productive". Finally, 22% declare it "for fun", while only 14% watch their performances for "training for a specific event".

	PERCENTUALE DI PERSONE CHE STA MONITORANDO FITNESS E SALUTE	PERCENTUALE DI PERSONE CHE ORA NON STA MONITORANDO FITNESS E SALUTE MA CHE L'HA FATTO IN PASSATO
CINA	45%	16%
BRASILE	29%	28%
USA	29%	16%
GERMANIA	28%	13%
FRANCIA	26%	15%
SPAGNA	24%	17%
MESSICO	23%	32%
ARGENTINA	22%	33%
CANADA	19%	18%
UK	19%	16%
AUSTRALIA	19%	19%
RUSSIA	19%	20%
BELGIO	18%	14%
ITALIA	16%	14%
SUD KOREA	16%	18%
OLANDA	13%	10%

Tab.4

DISPOSITIVO	2015	2016	*2017*
SMARTWATCH	30,32	50,40	66,71
VISORI REALTà VIRTUALE	0,14	1,43	6,31
VIDEOCAMERA INDOSSABILE	0,05	0,17	1,05
CUFFIE BLUETOOTH	116,32	128,50	139,23
BRACCIALETTI INTELLIGENTI	30,15	34,97	44,10
VESTITI INTELLIGENTI	0,06	1,01	5,30
FASCIA TORACICA INTELLIGENTE	12,88	13,02	7,99
SPORTS WATCH	21,02	23,98	26,92
ALTRI DISPOSITIVI FITNESS	21,7	21,11	25,08
TOTALE	**232,01**	**274,59**	**322,69**

Tab. 5

4. Motivation

In the previous chapters the concept of motivation emerged both in the fitness world research and in the wearable devices research. At this point the motivation effectiveness in achieving goals i clear, but it seems appropriate to deepen the knowledge on this subject to understand what are the main causes and psychological relationships that can increase motivation.
Thalking about this design path, the study of motivation is fundamental to design a device that can favor the process of accepting the physical condition and adaptation of the patient.
Strengthening the motivational aspect means supporting the patient emotionally and helps to promote individual responsibility in the rehabilitation process.
There are several definitions of motivation. We might call it, however, in a pragmatic and clear sense, as "the cause of a certain behavior".
Motivation is what causes you to act in such a way as to reach a need or purpose.
Motivation involves the biological, emotional, social and cognitive forces to activate behavior. In everyday life, motivation is a term often used to describe why a person does something. It may also feel that you are demoted, lazy and in this case the awareness of feeling static leads to the search for solutions to feel motivated.
Motivation is determined by two elements: the skills that represent what the individual is capable of, and the personal values that represent the core of ideas that guide the person in the actions commonly performed. These two elements act as a means of determining motivational motivation in an action process.
The motivational drive appears when a person feels an imbalance between a current situation and a desired target situation. For example, if a person is thirsty is because his internal balance has been interrupted by a discomfort, thirsty. Motivation is the push that activates the individual

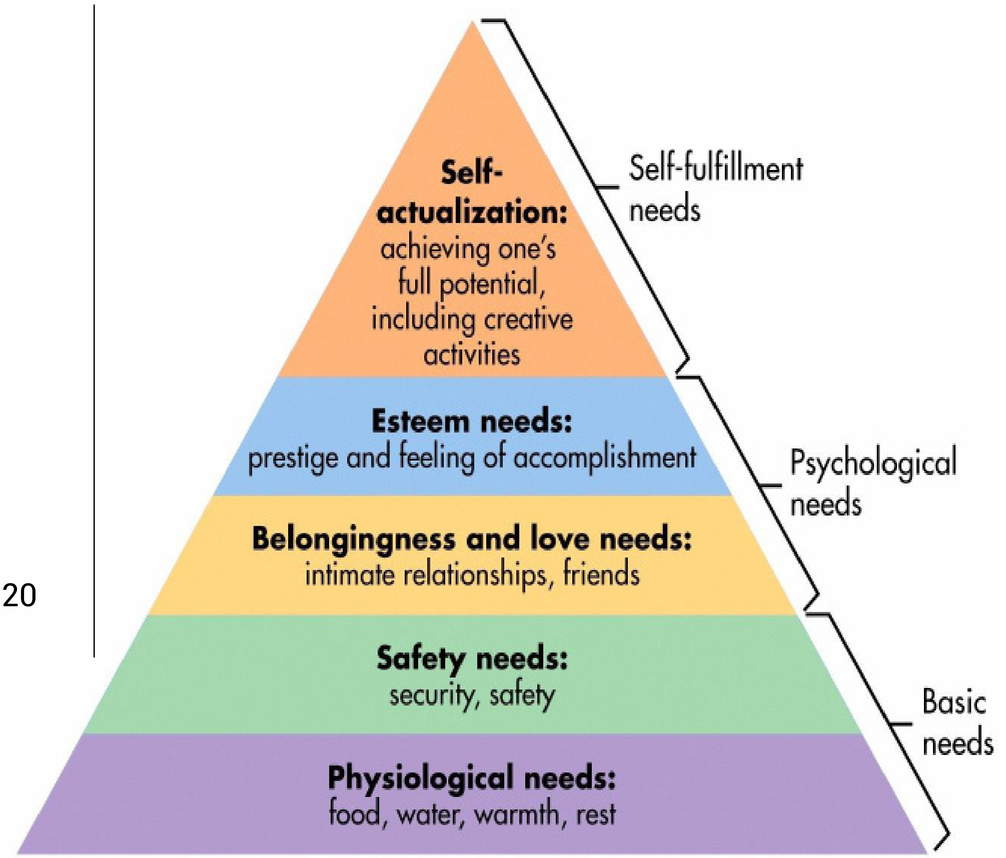
to take action to restore the previous equilibrium situation by drinking a glass of water. The same discourse may be valid in a context in which the condition of discomfort is represented by a state of physical illness following an accident; the motivational push in this case is the desire to restore their state of physical well-being.
For this reason it is important to analyze and understand the concept of motivation and all its derivations: this will allow to find effective solutions in the design phase.
The explanation of "motivation", besides tending to clarify the mechanism that stimulates and triggers the undertaking of a particular conduct, serves to interpret the individual differences of reactivity.
Human behavior is governed by factors primarily internal and then regulated from the outside: motivation is therefore a temporary modification of a constantly activated state. The relationship between motivational stimulus and action is essentially indirect and arbitrary: that is, a certain stimulus does not follow a certain behavioral response.
The answer is mediated by the personal experience of the individual in dealing with his own impulses. So the individual is free to deal with the impulse in a conscious and self-determined way, but there are always primary and secondary drives that can modify the behavior and actions in a contradictoryly way.
There are three categories of classification, of increasing complexity, of human motivations:

- Primary Motivations: They are physiological drives that essentially include essential needs for survival such as drinking, eating, and sleeping.

- Secondary motivations: are individual and social needs that have formed in the individual following the various socialization processes. They are, for example, success, cooperation and competition.

- Top Level Motivations: They are impulses that belong to each individual individually and concern the pursuit of their goals, consistent with their own values and with their own hierarchy of ideals. Examples of this category are pursuing their personal satisfaction in the field of affectivity, work and profession, living in accordance with their own moral principles.

Scheme 20



Theories and studies on motivation are so many, but in this analysis one of them is particularly interesting in the context of rehabilitation: the theory of attribution.

Theory of attribution by Weiner is based on retrospective judgments about the causes (internal or external) attributed to their performance. People who attribute their achievements to their personal abilities and their failures to undertake an insufficient commitment take on more difficult tasks and persist in spite of failures. Otherwise, those who associate their failures with capacity deficits and their own successes to situational and random factors will tend to undertake little and easily renounce the first difficulties.

Certainly a patient belonging to the first category will have a stronger motivation and a sense of duty that will allow him to constantly follow a rehabilitation path, otherwise a person who tends to consider a failure as a cause of some circumstance factors will be less inclined to persevere and face the difficulties.

Designing an educational system that will allow the user to structure a proper rehabilitation therapy will lead him to have a clear perception about the relationships between physical exercise and healing (cause-effect relationship).

5. Concept

The idea of the concept arises from the synthesis of the issues considered in the first phase of analysis.
The design field is that of rehabilitation gymnastics and was defined in the first phase of analysis (chapter 1.), the subsequent chapters on stimulation and wearable design products have instead defined the idea of the concept.
The concept is a wearable device with integrated electro stimulation system for full functional recovery of the lower limb after knee injuries.
The leg articulation has been chosen for several reasons: it represents the area most affected by injuries, and a full recovery of this limb is essential for the general well-being of the body because incorrect postures can lead to severe imbalances affecting the entire body .
For this reason, the design phase began with an analysis of the knee joint and thigh musculature and continued with an overview of the various shields and orteshis currently on the market.

5.1 Knee joint

The knee joint joins the thigh with the leg and consists of two articulations: one between the femur and tibia (tibiofemoral joint), and one between the femur and patella (patellofemoral joint).
It is the largest joint in the human body. The knee is a modified hinge joint, which permits flexion and extension as well as slight internal and external rotation. The knee joint is vulnerable to injury and to the development of osteoarthritis.

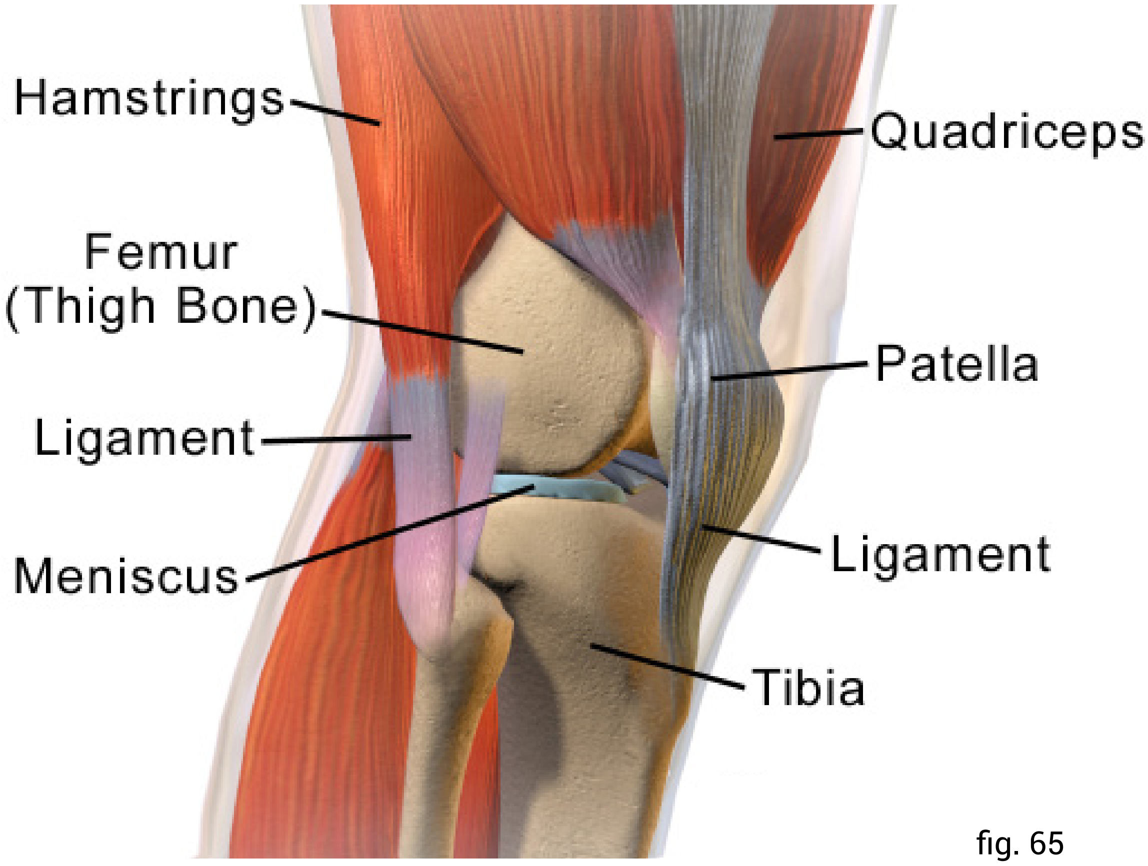


fig. 65

5.1.1 Strucrure

The knee is a type of synovial joint, which is composed of three functional compartments: the patellofemoral articulation, consisting of the patella, or "kneecap", and the patellar groove on the front of the femur through which it slides; and the medial and lateral tibio-femoral articulations linking the femur, or thigh bone, with the tibia, the main bone of the lower leg. The joint is bathed in synovial fluid which is contained inside the synovial membrane called the joint capsule.
The knee is the largest joint and one of the most important joints in the body. It plays an essential role in movement related to carrying the body weight in horizontal (running and walking) and vertical (jumping) directions.
At birth, the kneecap is just formed from cartilage, and this will ossify (change to bone) between the ages of three and five years.

Articular bodies

The articular bodies of the femur are its lateral and medial condyles.

The radius of the condyles' curvature in the sagittal plane becomes smaller toward the back. This diminishing radius produces a series of involute midpoints (i.e. located on a spiral). The resulting series of transverse axes permit the sliding and rolling motion in the flexing knee while ensuring the collateral ligaments are sufficiently lax to permit the rotation associated with the curvature of the medial condyle about a vertical axis.

The patella is inserted into the thin anterior wall of the joint capsule. On its posterior surface is communicate with the patellar surface which unites the two femoral condyles on the anterior side of the bone's distal end.

Articular capsule

The articular capsule has a synovial and a fibrous membrane separated by fatty deposits. Anteriorly, the synovial membrane is attached on the margin of the cartilage both on the femur and the tibia.

Behind, the synovial membrane is attached to the margins of the two femoral condyles which produces two extensions similar to the anterior recess. Between these two extensions, the synovial membrane passes in front of the two cruciate ligaments at the center of the joint, thus forming a pocket direct inward.

Cartilage

Cartilage is a thin, elastic tissue that protects the bone and makes certain that the joint surfaces can slide easily over each other. Cartilage ensures supple knee movement. There are two types of joint cartilage in the knees: fibrous cartilage (the meniscus) and hyaline cartilage. Fibrous cartilage has tensile strength and can resist pressure. Hyaline cartilage covers the surface along which the joints move. Cartilage will wear over the years. Cartilage has a very limited capacity for self-restoration.

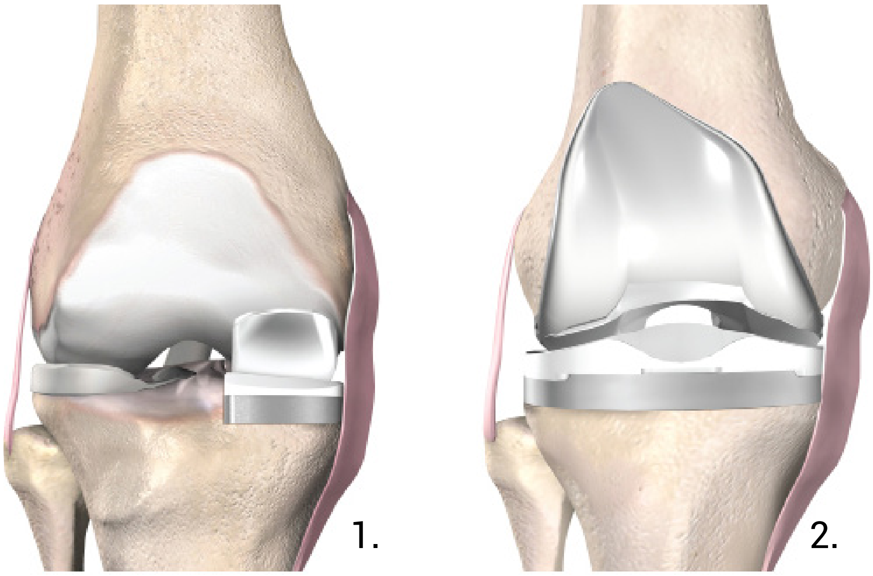


fig. 66 / fig. 67

Comparison between a normal cartilage and a reconstructed one.

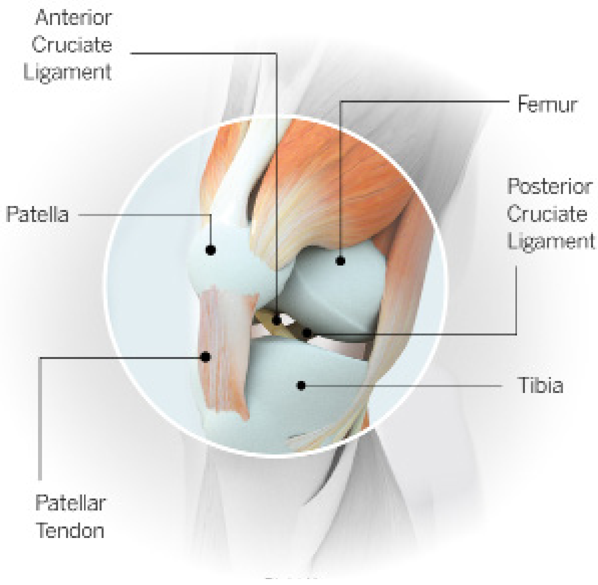
Menisci
The articular disks of the knee-joint are called menisci because they only partly divide the joint space.[14] These two disks, the medial meniscus and the lateral meniscus, consist of connective tissue with extensive collagen fibers containing cartilage-like cells. The menisci are flattened at the center of the knee joint, fused with the synovial membrane laterally, and can move over the tibial surface.
The menisci serve to protect the ends of the bones from rubbing on each other and to effectively deepen the tibial sockets into which the femur attaches. They also play a role in shock absorption, and may be cracked, or torn, when the knee is forcefully rotated and/or bent.

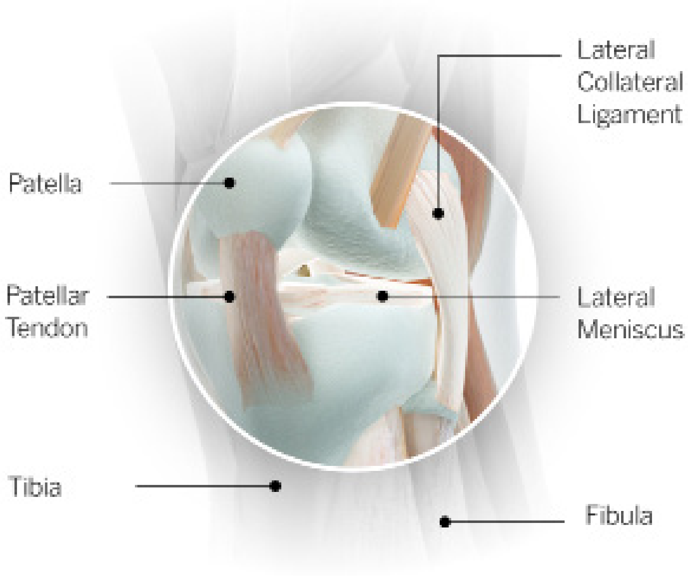
Ligaments
The ligaments surrounding the knee joint offer stability by limiting movements and, together with the menisci and several bursae, protect the articular capsule.

Intracapsular
The knee is stabilized by a pair of cruciate ligaments. The anterior cruciate ligament (ACL) stretches from the lateral condyle of femur to the anterior intercondylar area. The ACL is critically important because it prevents the tibia

from being pushed too far anterior relative to the femur. It is often torn during twisting or bending of the knee. The posterior cruciate ligament (PCL) stretches from medial condyle of femur to the posterior intercondylar area. Injury to this ligament is uncommon but can occur as a direct result of forced trauma to the ligament. This ligament prevents posterior displacement of the tibia relative to the femur.
The transverse ligament stretches from the lateral meniscus to the medial meniscus. It passes in front of the menisci.The two menisci are attached to each other anteriorly by the ligament.

Extracapsular
The patellar ligament connects the patella to the tuberosity of the tibia. It is also occasionally called the patellar tendon because there is no definite separation between the quadriceps tendon (which surrounds the patella) and the area connecting the patella to the tibia. This very strong ligament helps give the patella its mechanical leverage and also functions as a cap for the condyles of the femur. Laterally and medially to the patellar ligament the lateral and medial retinacula connect fibers from the vasti lateralis and medialis muscles to the tibia.
The medial collateral ligament stretches from the medial epicondyle of the femur to the medial tibial condyle. It is composed of three groups of fibers, one stretching between the two bones, and two fused with the medial meniscus. It protects the medial side of the knee from being bent open by a stress applied to the lateral side of the knee. The lateral collateral ligament (LCL) stretches from the lateral epicondyle of the femur to the head of fibula. It is separate from both the joint capsule and the lateral meniscus.It protects the lateral side from an inside bending force. The anterolateral ligament (ALL) is situated in front of the LCL.
Lastly, there are two ligaments on the dorsal side of the knee: the oblique popliteal ligament and the arcuate popliteal ligament.





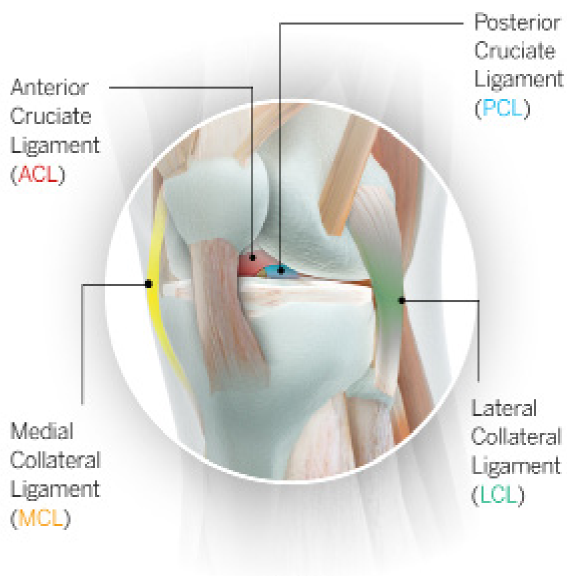


fig. 68 / fig. 69 / fig.70

Muscles

The muscles responsible for the movement of the knee joint belong to either the anterior, medial or posterior compartment of the thigh. The extensors generally belong to the anterior compartment and the flexors to the posterior. The two exceptions to this is gracilis, a flexor, which belongs to the medial compartment and sartorius, a flexor, in the anterior compartment.

Extensors

Tab. 6

Muscle	Action	Antagonists
Articularis genus	Pulling the suprapatellar bursa during extension of the knee	/
Sartorius	Flexion and medial rotation of the knee; flexion, lateral rotation and abduction of thigh	/
Quadricept femoris	Extension of the knee; flexion of the hip (rectus femoris only)	Hamstring
Rectus femoris	Extension of the knee; flexion of the hip	Hamstring
Vastus lateralis	Extends and stabilizes knee	Hamstring
Vastus intermedius	Extension of the knee	Hamstring
Vastus medialis	Extension of the knee	Hamstring

Flexors

Muscle	Action	Antagonists
Biceps femoris	Flexion of knee, laterally rotates leg at knee (when knee is flexed), extends hip joint (long head only)	Quadriceps muscle
Semitendinosus	Flexes knee, extends hip joint, medially rotates leg at knee	Quadriceps muscle
Semimebranosus	Flexes knee, extends hip joint, medially rotates leg at knee	Quadriceps muscle
Gastrocnemius	Minor flexion of knee and plantarflexion	Tibialis anterior muscle
Plantaris	Flexes knee and plantar flexes foot	Tibialis anterior muscle
Popliteus	Medial rotation and flexion of knee	/

Tab. 7

5.1.2 Function

The knee permits flexion and extension about a virtual transverse axis, as well as a slight medial and lateral rotation about the axis of the lower leg in the flexed position. The knee joint is called "mobile" because the femur and lateral meniscus move over the tibia during rotation, while the femur rolls and glides over both menisci during extension-flexion.

The center of the transverse axis of the extension/flexion movements is located where both collateral ligaments and both cruciate ligaments intersect. This center moves upward and backward during flexion, while the distance between the center and the articular surfaces of the femur changes dynamically with the decreasing curvature of the femoral condyles. The total range of motion is dependent on several parameters such as soft-tissue restraints, active insufficiency, and hamstring tightness.

5.1.3 Clinical significance

Knee pain is caused by trauma, misalignment, and degeneration as well as by conditions like arthritis. The most common knee disorder is generally known as patellofemoral syndrome.The majority of minor cases of knee pain can be treated at home with rest and ice but more serious injuries do require surgical care. The second major class of knee disorder involves a tear, slippage, or dislocation that impairs the structural ability of the knee to balance the leg (patellofemoral instability syndrome). Patellofemoral instability syndrome may cause either pain, a sense of poor balance, or both.
Age also contributes to disorders of the knee. Particularly in older people, knee pain frequently arises due to osteoarthritis. In addition, weakening of tissues around the knee may contribute to the problem.
Patellofemoral instability may relate to hip abnormalities or to tightness of surrounding ligaments.
Cartilage lesions can be caused by:

- Accidents (fractures)
- Injuries
- The removal of a meniscus
- Anterior cruciate ligament injury
- Posterior cruciate ligament injury
- Posterolateral corner injury
- Medial knee injuries

- Considerable strain on the knee.

Any kind of work during which the knees undergo heavy stress may also be detrimental to cartilage. This is especially the case in professions in which people frequently have to walk, lift, or squat. Other causes of pain may be excessive on, and wear off, the knees, in combination with such things as muscle weakness and overweight.

Anterior cruciate ligament injury

The anterior cruciate ligament is the most commonly injured ligament of the knee. The injury is common during sports. Twisting of the knee is a common cause of over-stretching or tearing the ACL. Besides swelling and pain, walking may be painful and the knee will feel unstable. Minor tears of the anterior cruciate ligament may heal over time, but a torn ACL requires surgery. After surgery, recovery is prolonged and low impact exercises are recommended to strengthen the joint.

Torn meniscus injury

The menisci act as shock absorbers and separate the two ends of bone in the knee joint.

When there is torn cartilage, it means that the meniscus has been injured. Meniscus tears occur during sports often when the knee is twisted. Menisci injury may be innocuous and one may be able to walk after a tear, but soon swelling and pain set in. Sometimes the knee will lock while bending. Pain often occurs when one squats. Small meniscus tears are treated conservatively but most large tears require surgery.

Fractures

Knee fractures are rare but do occur, especially as a result of motor vehicle accidents. There is usually immediate pain; swelling and one may not be able to stand on the leg. The muscles go into spasm and even the slightest movements are painful.

Surgery depends on the degree of displacement and type of fracture.

Ruptured tendon

Tendons usually attach muscle to bone. In the knee the quadriceps and patellar tendon can sometimes tear. The injuries to these tendons occur when there is forceful contraction of the knee. If the tendon is completely torn, bending or extending the leg is impossible. A completely torn tendon requires surgery but a partially torn tendon can be treated with leg immobilization followed by physical therapy.

Overuse

Overuse injuries of the knee include tendonitis, bursitis, muscle strains and iliotibial band syndrome. These injuries often develop slowly over weeks or months. Activities that induce pain usually delay healing. Rest, ice and compression do help in most cases. Once the swelling has diminished, heat packs can increase blood supply and promote healing. Most overuse injuries subside with time but can flare up if the activities are quickly resumed.Individuals may reduce the chances of overuse injuries by warming up prior to exercise, by limiting high impact activities and keep their weight under control.

5.2 The orthosis

Orthosis means a medical device or orthopedic device used in orthopedics or traumatology in the treatment of certain pathologies. In this regard, the definition of orthoses introduced by the International Organization of Standards is as follows:
"An external device used to modify the structural or functional characteristics of the neuro-muscle-skeletal apparatus". In particular, orthoses are used as body-correcting devices with corrective functions, but not to replace missing parts, unlike prostheses.
A key feature for the development of good orthosis is to align with the corresponding articular segments. For this reason, these devices are often called exoskeletals, as they mimic the characteristics of an external skeleton by approximating body movement.

It is precisely this specific that exoskeletals provide excellent results in terms of strength and muscle coordination, enabling their proper activation. Being compelled by the orthotic to perform a certain movement, the patient is not likely to expose the articulation to efforts that act on a muscle group incorrectly and can be dangerous.

5.2.1 Orthosis classification

In turn, if classified according to a clinical nature, they can be divided into orthoses of:

Position or Exhaust
They are predominantly used in the presence of fractures and necrosis, requiring a certain degree of mobility to the articulation so as to avoid unwanted movements and allow them to be recovered in a timely manner.

fig.71

O R T H O S E S   V S   E X O S K E L E T O N

fig.72

Correction
They are used to correct movements that due to malformations, congenital or trauma, do not allow normal movement of the limb.

Functional
Indicated to cope with disabling diseases such as paraplegia, hemiplegia and peripheral neuropathies.

The orthoses act essentially on three components:
• the moment present on the joints
• the direction of forces applied
• axial forces

In this way, the orthosis on the joint applies a system of external forces on it; the momentum change on the joint is the most common way to modulate and set the orthoses, in this way it supports and/or controls the joint movement on one or more reference planes.
In this work we will analyze the orthoses involving the lower limb. The ISO classification splits the lower limbs according to the body segments involved, inserting the letters from the proximal to the distal joint.
We have thus named orthes:

• FO (FootOrthosis)

• AFO (AnkleFootOrthosis)

• KO (KneeOrthosis)

• KAFO (KneeAnkleFootOrthosis)

• HKAFO (HipKneeAnkleFootOrthosis)

• THKAFO (TrunkHipAnkleFootOrthosis)

fig. 73

THKAFO (TrunkHipAnkleFootOrthosis)

fig. 74

KO (KneeOrthosis)

fig. 75

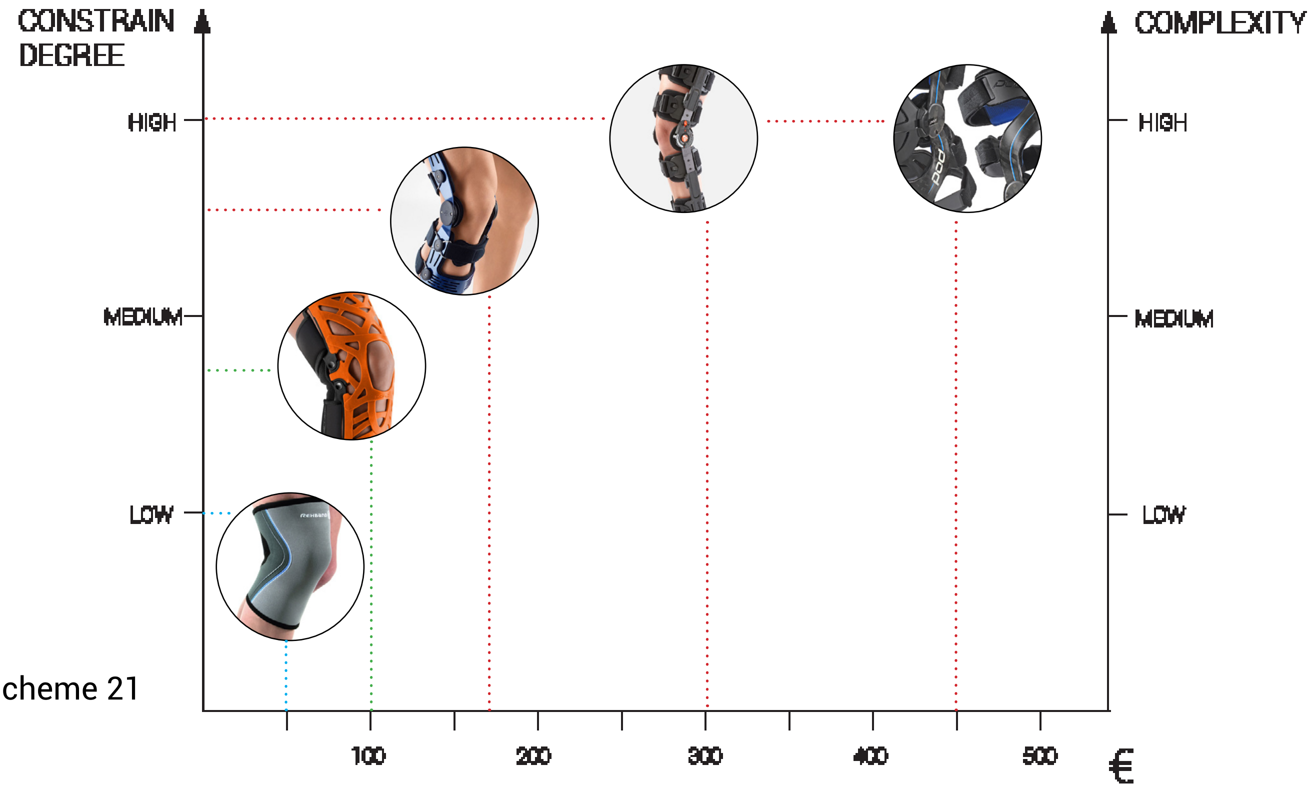
FO (FootOrthosis)

5.2.1.1 KO (KneeOrthosis)

Considering the orthoses for the knee joint, it's possible to notice different types of products that differ for:

-use of materials
-complexity
- joint movement control

These three aspects are closely related to the cost of the device, which can vary from a minimum of about 40 € to a maximum of 300-400 € and sometimes even more.
The cheapest products are generally made of technical fabric (neoprene in most cases), have velcro closures or without any closure if they are tubular.
The cost increases with the use of thermoplastic materials that are add to the fabric to increase the device stiffness, limit movement and protect the knee from any trauma. From about 80 € it's possible find the orthoses that regulate the degree of flexion of the knee with a ring mechanism and metal joints (Don joy). The use of metal alloys (usually stainless steel or aluminum) increases the cost and complexity of orthoses. Again, the rigid parts are fixed to the lower limb with a velcro straps system. In the last product category, the price can rise from about 100 € up to 500 €, this difference being due to the quality of the used components, the use of carbon replacing the metal alloys and the degree of mechanical complexity of orthosis.



Scheme 21

- **MATERIALS:** technical fabrics (neoprene)
- **COST:** 30-50 €

- **MATERIALS:** technical fabrics + polymers
- **COST:** 50-80 €

- **MATERIALS:** technical fabrics, polymers, alloys
- **COST:** 100-250 €

- **MATERIALS:** technical fabrics, polymers, carbon fiber
- **COST:** 350-500 €

5.2.2 Main features

Orthoses have some common features that will be discussed in this chapter.

- Comfort: comfort is definitely an important feature, wearing a guard often leads to some pain, the orthosis should gives relief to the user.

- Wearability: a good wearing orthosis should take a short time and easy to carry out by the person wearing the orthodontist without the help of another person.

- Versatility: this feature is important not only for the user but also from the point of view of marketing. Versatility on the one hand is the ability of orthosis to adapt and change its behavior over time and with improvements / worsening of the user. From a commercial point of view, designing a variable device means thinking of a tutor that can be use for multiple pathologies.

- Cost: cost problem is a feature to keep in mind in any type of product. In the case of this type of product, a high cost may be justified by the fact that orthoses and shields are medical devices and therefore serve to improve the health and quality of life.

- Aesthetic: the aesthetic aspect is not a feature to be overlooked because it is capable of changing the perception of the product that is directly related to the psychology of the user. The fact that these orthoses are often visible lead the user to show their disability as a symptom of weakness. Design and form choices in this case can make the difference to try to move these objects away from a medical archetype.

5.2.2. Medical Devices Directive 93/42 / EC

To be sold within the European Union, the products must conform to the relevant product guidelines and be CE marked. Requirements for medical devices are more restrictive than most other categories, and in many cases the manufacturer is obliged to contact a Notified Body to affix the CE mark to their device.

The Community directives separately regulate three categories of medical devices

• medical devices (generally) - Directive 93/42 / EC (MDD)
• in vitro diagnostic devices - Directive 98/79 / EC (IVD)
• active implantable medical devices - Directive 90/385 / EC

Steps of directive medical devices 93/42 / EC

1. Product classification: edical devices are grouped in four classes, depending on their complexity and potential risk for the patient: I, IIa, IIb, III (Annex IX of the MDD Directive). Classification depends on the intended use indicated by the manufacturer:
Class I: Low Risk Devices. They can be produced for the patient's external help, such as crutches or wheelchairs, but also products like stethoscopes. Devices falling within this class do not require the intervention of a Notified Body (apart from sterile and / or measuring functions) and must be registered with the local authorities.
Classes IIa and IIb: Medium-risk devices, many electromedicals fall into these classes.
Class III: High risk devices, such as cardiovascular catheters

2. Determination of the certification process depending on the device class;

3.evaluate compliance with harmonized standards (such as EN 6060-1-2 for EMC and EN 60601-1 for electrical safety) and meet the essential MDD requirements.

In addition, as required by Annex I, the manufacturer must provide:

• technical file: it must contain all the construction details and the verification and validation data of the device compliance, to prove the product's conformity to the MDD directive

• Risk assessment: the assessment of the risk of the device must include assessment of the construction, the materials used, biocompatibility, risk of infection or cross-infection, and also the potential risks during use. The resulting documentation will be part of the technical file

• Quality System: The manufacturing company as a whole must also be confident of the quality requirements expressed in the MDD. Compliance with ISO 13485 is a way of demonstrating compliance with the applicable MDD Annexes.

4. Establish a monitoring system: manufacturers have to implement a surveillance system on their devices once they are placed on the market in order to be able to intervene in case of device problems

5. Establish an Accident Monitoring System: If an accident or quasi-accident involves the device involved, the manufacturer is obliged to report it to the authorities

6. issue a statement of confusion

7. Record the device at the competent authorities

8. Keep the documentation for 5 years: Declaration of Conformity, Technical Documentation, Reports and Certified Certificates Notified Bodies, among other documents, must be kept for at least 5 years after the discontinuation of the device (for implantable devices, The new revision of the Directive requires a period of 15 years)

5.3 Analysis of some interesting product

iTENS

The iTENS is a electrotherapy device that merges wearable technology with the effective and lasting pain relief of a TENS unit. The iTENS device is controlled with an IOS or Android based app via Bluetooth.

Positives
It is thin, lightweight and can be discreetly worn underneath your clothing. There are no wires to get in the way, and the device can be easily controlled.
The iTENS uses an energy efficient lithium-ion battery that provides battery life for on-the-go daily use.
Two different wings sizes are included: the large wings are designed to provide a bigger coverage area of pain relief.

Downsides
The gel pads are good for 7-15 applications.
iTENS can be used just on a body part, so it gives pain relief just on a little body area.
The user often hasn't the knowledge of the product positioning, for this reason the treatment effect may be less effective.

fig. 76

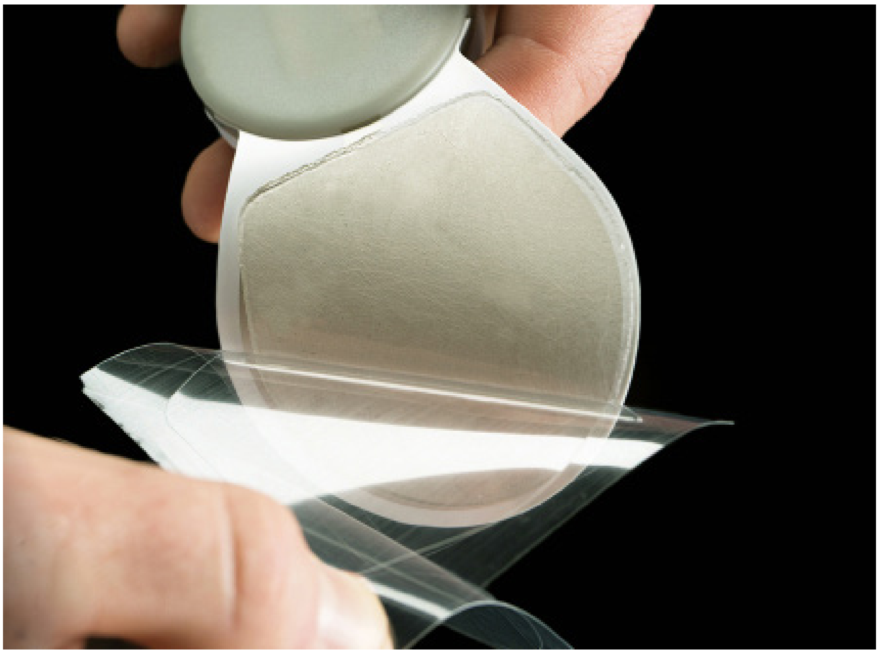


fig. 77

COMPEX SP wireless (6.0 and 8.0)

SP wireless by complex is a high level quality electro stimulator with a wireless technology.
The electrodes can be placed on the body without taking care about wires encumbrances.
SP 6.0 and SP 6.8 are equipped with best complex technology that include 40 different programs, Mi-scan technology able to setting and change automatically the current intensity.

fig. 78

Positives

For sure the main positive of this product is to have a professional electro stimulator without wires, this leads to have the chance to put the electrodes over the cloths or do some movement (like training and do exercises) while the product is working.

Downsides

The absence of wires made the structure around the electrodes quite bulk and sometimes make the wearability worse

As in all common electro stimulators the "plasters" need to be changed all times.

In relation to the high cost and the market segment to which the product is addressed, some more optional and feature could be integrated in this product: for example the connection with a smartphone and the possibility to receive feedback from the device.

fig. 79

Kneehab XP

The Kneehab XP is an innovative and clinically-proven device that offers Multipath NMES for post-surgical quadriceps strengthening and improved knee stability. This product delivers quadriceps contractions to accelerate recovery.

Positives
An advantage over the classic electrostimulator affects electrodes positioning, in fact in this case the user have just to wear the product without take care about electrodes positioning.

Downsides
Old conception product: the controller is connected to the device with a wire, there's not the possibility of a wireless controller or check any kind of feedback on a smartphone. This device should only be used during treatment.
Aesthetics is not really a downsides since this product is not designed to be worn at all times, anyway it could be improved.

fig. 80

E-vive

Designed to deliver wireless, app-controlled muscle stimulation therapy, e-vive helps keep patients engaged with their rehab by tracking their progress and allowing data sharing with clinicians.
The conductive garment holding the electrodes in place to ensure effective quadricep activation.

Positives
Well connected with devices like smartwatch and others, the app gives useful feedback parameters.
This product combines a easy wearable electrostimulating system with a classic orthoses product, furthermore there is the possibility to add a bracket system to control the knee movement and lock the rotation.

Downsides
wearability could be better and the device may be lighter is some parts: neoprene is useful near the knee joint to give more stability but less useful and quite unconfortamble on the quadriceps and leg.

fig. 81

5.4 The expert's opinion

During the orthoses' research, I began to get in contact with some professional figures in the field of medicine and orthopedics who could give me help during the design phase.
In this regard, I have contact with Dr. Nicola Maffiuletti, an expert in sports medicine, rehabilitation and university professor at various universities in the world. Nicola Maffiuletti believes electro stimulation therapy is a very important part in the recovery phase after numerous types of injuries. After explaining my idea, his feedback was positive: "The idea of a wearable product with integrated electrodes is great, and surely represents the future of stimulation." He also added that it is common to use a device with integrated electro stimulation for postoperative knee joint surgery (Kneehab X, cap. 4.3).
After this positive and authoritative response to the electrostimulation, I focused on the orthoses and I contacted physiotherapists and orthopedists.
I had the opportunity to visit the Borghi Brebbia Foundation in Varese, here I had not only the chance to make some questions to doctors but I could see also how they work and their relationship with the patients.
This allowed me to critically observe some situations, discover unexpressed wishes of patients, and understand the dynamics of a rehabilitation path.
Alessandro Brasca, a physiotherapist at the Borghi Brebbia Outpatient Clinic, explained to me the importance of personalizing treatment on the patient and his clinical experience with both young, sporty and elderly patients.
He has confirmed to me the tendency not to use particularly rigid supporters for the rehabilitation of the LCA and other knee ligaments, underlining that a constriction to movement in some cases is counterproductive and leads to loss of proprioception.
Equally important was the meeting with orthopedic Giovanni Pegoraro specialized in the manufacture of

custom orthoses.
At a first meeting I watched him in a laboratory while he was modeling wrist orthosis directly on the patient's hand.
During the second meeting, a week away, I asked Dr. Pegoraro about the possible improvements that should be made in the prosthesis industry, and I also attended some passive treatment and exercise in the gym of the clinic.
From the viewpoint of Dr. Pegoraro the most important feature that a orthosis needs to have is that of personalization, so according to his point of view, orthoses on the market are often a bad solution cause don,t fit exactly the body part. When I asked about the possibility of changing the type of material used, he expressed a favorable opinion and was interested in the possibility of a different use of materials and fabrics depending on the stiffness required in the orthosis areas.
At a later time, while treating on a patient, I could see how the doctor had seen the patient's little commitment in performing the assigned exercises: the patient probably did not understand the importance of these exercises and only relied on the orthopedic treatments (with clear loss of results).
The peculiarity of the concept of creating a connection between passive treatment and physical activity has been considered extremely interesting by both the physiotherapist Alessandro Brasca and the orthopedist .
Another important advice in my design course was given by Sonia Maggi, orthopedic at Limbiate's xxxx clinic.
Even from her I received a positive opinion on the possibility of encouraging the patient to perform rehabilitation exercises, his advice has allowed me also to understand the correct positioning of the electrodes and the need for a more rigid brace for some circumstances (such as sport or physical activity).

5.5 Identification of design aspects

The analysis of orthoses, wearable on the market and knee joint has allowed me to identify some aspects to improve to design a product that combines the typical benefits of orthosis with the comfort and lightness typical of wearable products design.

Wearability

Fitting is definitely a very important feature for this category of products. For many types of orthosis, especially in those where there is a need to limit the movements of the joint, fit and comfort is rightly sacrificed in favor of greater rigidity and corpusity of the guardian.
As seen from the analysis of orthoses, the most widely used materials in this field are neoprene, thermoplastic materials, aluminum, steel and rare carbon cases.
The widespread use of neoprene is due to the fact that it is a material that adapts well to the body and at the same time guarantees a partial limitation of movements.
Thermoplastic materials and metal alloys are used instead when high rigidity or exoskeleters are desired.
In the rehabilitation of the knee and leg musculature today the use of orthosis is very limited (especially in post-surgery ligaments).
Thanks to advances in surgery, physiotherapists and orthopedists tend to start therapy immediately after surgery, often without the use of tutors that may somehow limit movement or diminish proprioception.
In this regard, the use of neoprene as a support material for the integration of a Tens electrostimulator appears to be too invasive and uncomfortable.
I therefore thought it appropriate to replace the neoprene with a more elastic, lightweight and breathable material that could increase comfort and fit.

This basic material will then be added an extra device capable of giving greater stiffness near the articulation if needed.
The ability to modulate stiffness makes the product more flexible and versatile not only for the various moments of the day, but also for the treatment of various pathologies.

Closing system

Another important aspect is related to the way the device is worn. In classic Neoprene products, the most used system is Velcro closure to provide a minimum range of modularity and thus to the low elasticity of the neoprene.
In the case of the use of a more elastic material, the use of a zip closure may be suitable for several reasons: lightness, speed of connection and aesthetic quality (this topic will be discussed below).

Correlation between electro stimulation and physical activity

The will to develop a rehabilitation device that can stimulate and educate the patient to exercise physical activity is an unprecedented feature in this field.
Educating the user means communicating them through the product about the importance of physical activity in support of passive therapies such as electrostimulation.
Creating a device that partially binds the use of Tens therapy with physical activity is intended to motivate the user to perform rehabilitation optimally.
These considerations also derive from the observation of orthopedic xXX of the Borghi Brebbia Foundation during some treatments for patients who often did not respect the training protocols that the orthopedist provided but relied only on passive treatments.

Aesthetics

In designing a wearable product, aesthetics plays a very important role in this type of product must be worn all day by the user.
It is important to design an aesthetic that can ennoble the product and enhance its perceived value. Aesthetics also play an important role in the perception of the (temporary) disability that people have towards the user. Creating an eye-catching product that can detach itself from the classic medical layout would surely help to dampen the perception of disability and the psychological discomfort of the patients.
In this case, aesthetics has also the purpose of communicating the function and values of the product, that is the element of electrostimulation and its correlation with exercise.

5.6 Piezoelectric materials

5.6.1 The reasons why

In this project I investigated the use and potentials of piezoelectric materials mainly for two reasons.
First of all, the ability to take advantage of body movement to produce energy and reload the batteries of the product would fill one of the biggest design conflicts of the wearable design.
As mentioned earlier (cap) among the features of wearable products is to stay connected with the body for so long, this necessity often leads to large batteries that represent an annoying weight to wear. In this context, piezoelectric materials could be integrated into the design of wearable products and lead to drastic reduction in batteries with great weight and environmental sustainability advantages.
The second motivation concerns my project and is the ability to create a strong bond between physical activity and passive muscle stimulation.
Creating a link between active and passive activity is a motivational choice linked to the motivational aspect that was identified in the first analysis' phase.
In fact, electro stimulation is often seen as a surrogate or substitute for physical activity that is neglected by the patient.
A concept with these features would be educational for the user who would be aware of the exact path of rehabilitation.

5.6.2 Features

Piezoelectricity is the electric charge that accumulates in certain solid materials (such as crystals, certain ceramics, and biological matter such as bone, DNA and vari ous proteins) in response to applied mechanical stress. The word piezoelectricity means electricity resulting from

pressure. It is derived from the Greek piezō (πιέζω) or piezein (πιέζειν), which means to squeeze or press, and ēlektron (ήλεκτρον), which means amber, an ancient source of electric charge. Piezoelectricity was discovered in 1880 by French physicists Jacques and Pierre Curie.
The piezoelectric effect is understood as the linear electromechanical interaction between the mechanical and the electrical state in crystalline materials with no inversion symmetry. The piezoelectric effect is a reversible process in that materials exhibiting the direct piezoelectric effect (the internal generation of electrical charge resulting from an applied mechanical force) also exhibit the reverse piezoelectric effect (the internal generation of a mechanical strain resulting from an applied electrical field).
Materials with piezoelectric characteristics can have both natural and artificial origins. In both cases, the fundamental principle that a material has piezoelectric features is the decentralized position of the central atom (which can be Titanium or Zirconium) in its crystalline structure. In fact, a symmetric crystal, if subjected to pressure, does not develop an electric charge because it does not have an electric dipole. A stress (traction or compression) applied to a piezoelectric crystal changes the separation between the sites containing the positive and negative charges in each elementary cell, leading to a net polarization on the outer surfaces of the crystal.

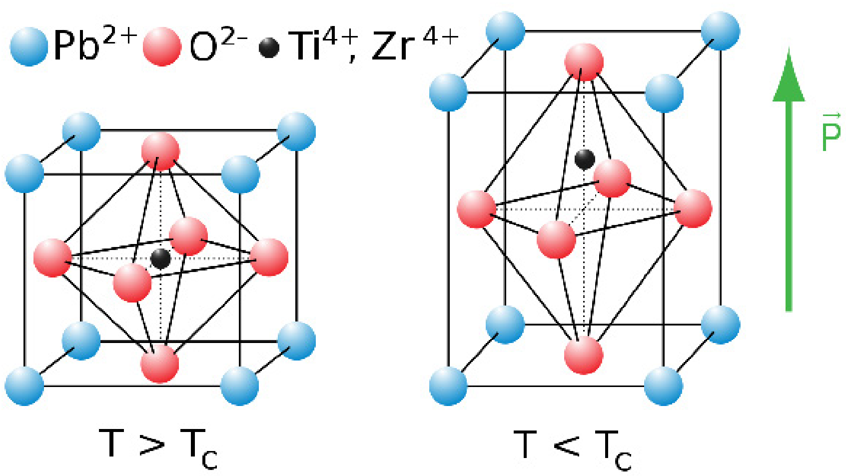


fig. 83

fig. 82

The effect is practically linear, and is also dependent on direction; according to this principle, compression or traction stress generates electric fields, and hence voltages, of opposite polarity.
Although in nature there are some piezoelectric minerals such as quartz or Tormaline, nowadays most piezoelectric materials are made in the laboratory and are so-called "piezo-ceramics".
The reason why piezo-ceramic materials are preferred are many, from the ability to create ad hoc materials for certain applications, the ability to modify the starting compound to improve its mechanical properties and many more. Natural piezoelectric materials, as already written, are for example quartz, the most popular and known mineral, and its applications range from watchmaking to electronics to other fields. Another group of piezoelectric minerals are the Tourmalines. Among the less common natural materials there are some natural sources of minerals such as lithium tantalum, lanthaxite, lithium niobate and zinc oxides.

5.6.3 Production of a piezoelectric sample

To obtain a piezoelectric ceramic sample, a series of processes is required. The microstructure and, consequently, the characteristics of the ceramic depend directly on all stages of the process and, in particular, on the characteristics of the powder. Below is a description of the production stages of a piezoelectric ceramic.

Calcination
In the calcination, the precursors (carbonates, nitrates, oxalates, etc.) of the interest system are subjected to a heat treatment in the air, in which they are decomposed and reacted to obtain the crystalline phase.

Grinding
The calcination stage involves a more or less irreversible aggregation of the dust particles, which makes it necessary, prior to consolidation, to have a powder grinding passage.

Forming
After the calcination stage, the forming process takes place which gives the material a shape similar to the final one. The optimum forming method depends on the desired end characteristics; The main forming processes can be divided into three basic categories:

- consolidation in the dry state
- dispersal consolidation
- plastic consolidation (extrusion)

Sintering
Sintering is the hot consolidation process of a pre-consolidated powder agglomeration in the forming process. Through the sintering, the bond between the grains (increasing the contact surface between them) and decreasing porosity (transferring matter from particles to empty

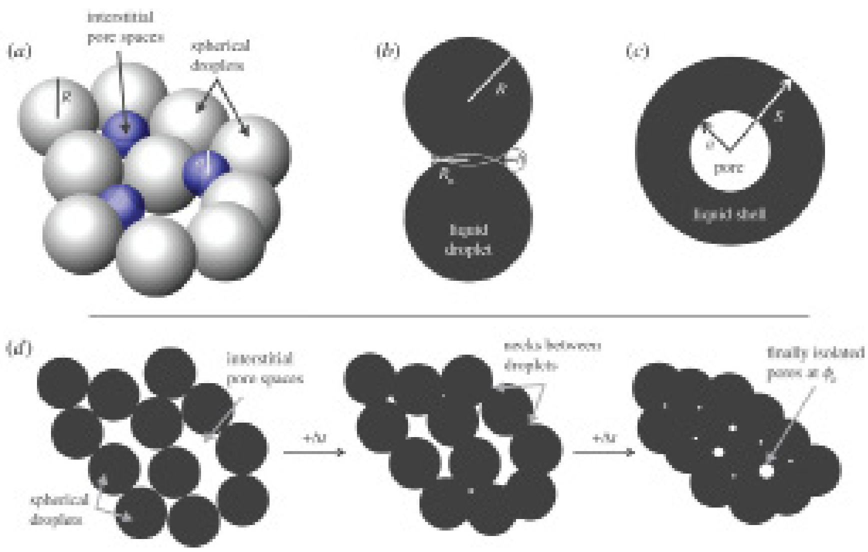
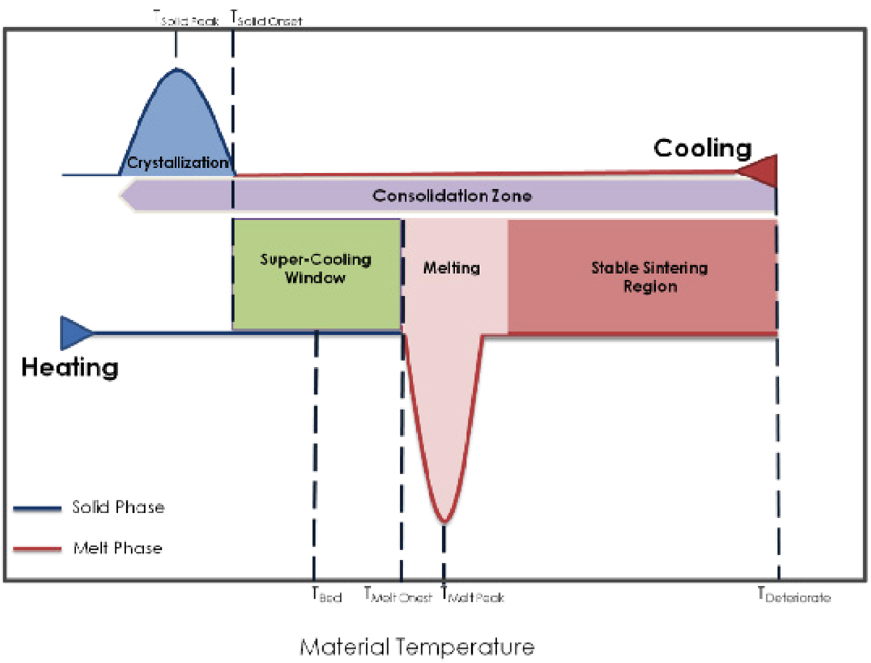


fig. 84



Scheme 22

Laser sintering proces temperature

spaces) is strengthened.

Application of electrodes

The metallization stage is essential to polarize the ceramic sample and make it piezoelectric, since it is necessary to apply electrodes to the faces of the sample. The application is carried out by screen printing on the most resistant and thick specimens, or by brush or sputtering on the thinner ones

Polarization

The polarization process is necessary to give piezoelectric properties to a ceramic and is possible thanks to the dielectric hysteresis phenomenon. Obviously the degree of polarization depends on the electric charge used.

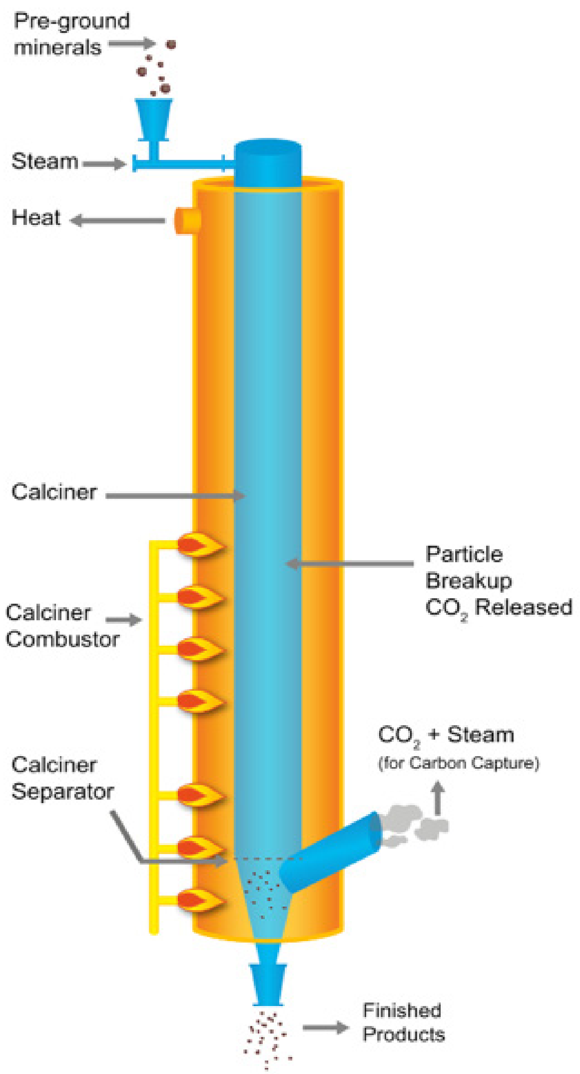


fig. 85

Calcination

5.6.4 Piezoelectric physical and constant properties

The complexity of the piezoelectric effect study lies in the simultaneous presence of several different phenomena, both mechanical and electrical. In order to interpret the existing correlation between the various phenomena present, some definitions of the magnitudes involved need to be introduced. Piezoelectric ceramics are anisotropic, so all of their physical constants are quantity of tensor type.
The involved quantities are:

Mechanical stress: means the uniform pressure applied to the material along one or more directions; Is expressed in ***N/m2*** and is indicated by T.

Deformation: is the deformation that occurs in every solid body subjected to mechanical stress. It is a dimensional magnitude and is indicated by S.

Young Form: It is the proportionality constant that binds S and T

Piezoelectric charge constant: indicated by d and refers to both the direct and the piezoelectric effect. It expresses the electric polarization generated in a material applied to the mechanical stress unit applied (direct piezoelectric effect); Conversely, it may also indicate the mechanical strain exhibited by the applied electric field unit (reverse piezoelectric effect).

Piezoelectric voltage constant: It is defined as the electric field generated in a material applied to mechanical stress units.

Dielectric constant: The dielectric constant (absolute) is defined as the electrical displacement per electric field unit.

Effective electromagnetic coupling factor ($K_{eff.}$): This coefficient can provide a global measure of the magnitude of the piezoelectric effect. It represents, given an applied electric field, the fraction of electrical energy converted into mechanical energy (or vice versa) by a piezoelectric effect. From the energy point of view, the following relationship can be defined:

$K_{eff.}$ = Converted energy / applied energy

Since it is not possible to have full energy conversion, the electromechanical coupling factor is always smaller than the unit: ***keff.2 <1.***

This factor can be useful for comparing directly, piezoelectric, materials with very different values of Permettivity and yieldability.

5.6.5 Application

Computer: Hard Disk Drive, Keyboard, Inkjet Printers, etc.

Consumer goods: grill lighters, humidifiers, smoke detectors, jewelery cleaners and contact lenses,hard disk drives, keyboards, inkjet printers, and so on.

Industrial: accelerometers, pollution detectors, flowmeters, air bubble detectors in pipes, impact sensors, level gauges, micropositioning equipment, pressure sensors, non destructive controls, ultrasonic cleaners, ultrasonic degreasers, ultrasonic grinders , Ultrasonic welder, etc.

Doctor: ultrasound equipment, dental cleaners, nebulizers, ultrasound therapies, etc.

Military: ballistics, sonar, driving systems, etc.

Telecoms, optics and acoustics: microphones, loudspeakers, tweeters, resonators, filters, scanning microscopy, camcorders, etc.

fig. 86

Energy Floors' kinetic energy-generating dance floor:
to demonstrate the tech, the company created a translucent floor with a dynamic LED display powered by motion from each shimmy and shake. Motion is transferred through the floor to a small generator, and each 30-inch square floor tile can produce up to 35 watts of sustained output.

fig. 87

The racket, which is a version of its best-selling Pure Drive, has gyroscopes, accelerometers and a piezoelectric sensor in the handle. These sensors pick up a variety of data, including where the ball hits the strings, how much power goes into a shot and how much spin a player puts on a ball.

fig. 88

These tiles are thus designed to generate energy from the sidewalk. Its operation is based on the principle of piezoelectricity, whereby kinetic energy is collected from a moving body and than converted to electricity.

5.6.6 Piezoelectric fabrics: the future of wearable design

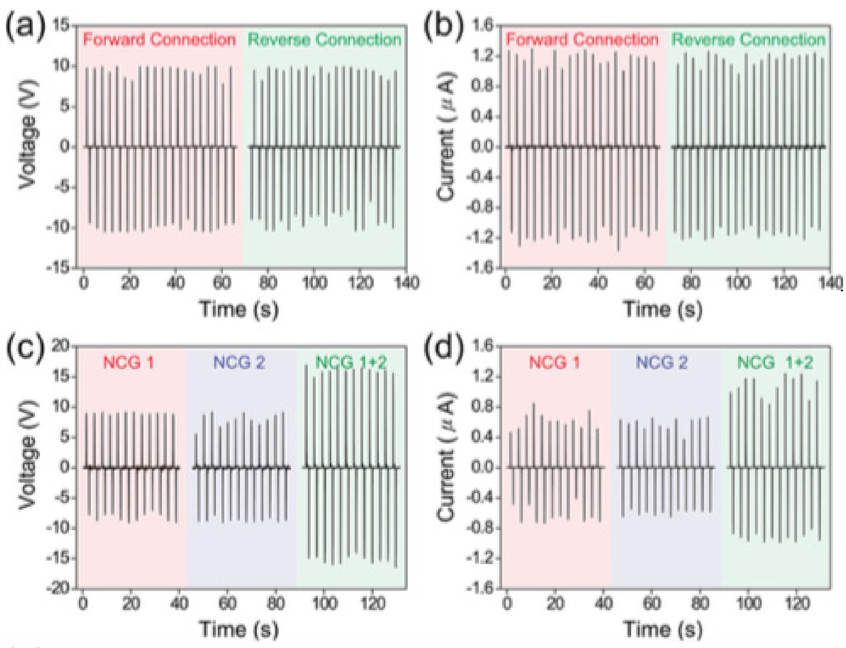
Numerous laboratories around the world are focusing their efforts on producing Energy Harvesting fabrics.
Energy Harvesting means all those processes where there is a recovery of energy that is captured and saved, and this comes mainly from alternative sources, that are coming and available in the environment. Energy therefore, through a whole series of conversion mechanisms, is therefore reduced to electricity. Alternative energies that apply to Energy Harvesting can be, for example, thermal, kinetic, chemical, solar, or the like.
The fabrics, unlike the metallic and polymeric materials, are able to generate electrical current even after a minimal stimulation. This feature, in fact, differentiates polymeric fibers from previous experiments, composed not of nanofiles but of thin film of polymer, which, in order to generate energy, require greater stimulation, which goes to the order of finger pressure up. In new materials, instead, energy conversion occurs simply if a small insect posing on the surface, the equivalent of a detection of pressures 10,000 times lower.
This feature makes piezoelectric fabrics particularly suitable to perform the function of pressure sensors and displacement in numerous experimental applications.
The peculiarity of these fabrics, called Generic E-textile, is that they can be made at low cost and therefore adapted to a very wide scale of application. First of all is their use in support of MEMS (Micro Electro-Mechanical Systems).
An interesting use of E-textiles is in the medical field as regards the design of upper limb prostheses that may be able to facilitate grip or partially restore the sensitivity of the epidermis.
But a future in which, when we leave home, we will wear a jacket that recharges the tablet or a pair of pants to plug in the unlocked smartphone to find it a few hours after fully charged is it really possible? And how much will we have

to wait for us to use such inventions?
The answer comes from Dr Luana Persano, Cnr engineer, head of the research project that in 2013 led to the production of the first tissue (called Nano Jet) with piezoelectric properties obtained through nanofilature: *"Probably a few years. At international level, they are already working on prototypes of fabrics that can produce electricity in different laboratories. The most studied mechanisms consist of the production of high-tech fibers coupled to suitable electrodes, which can generate electricity by photovoltaic or piezoelectric effect. Of course, to switch to real applications it is essential that research laboratories interfere with the textile and fashion industries, studying the performance that these new fabrics can aspire in terms of durability, endurance, perspiration, and maneuverability. "*

fig. 89 / fig. 90

Sperimental E-textile applications

Nano Ject is a flexible piezoelectric material that consists of sheets of electrospun fibres of the polymer (vinylidene-fluoride-co-tri- fluoroethylene). The flow and mechanical conditions associated with the spinning process yield free-standing, three-dimensional architectures of aligned arrangements of such fibres, in which the polymer chains adopt strongly preferential orientations. The resulting material offers exceptional piezoelectric characteristics, to enable ultra-high sensitivity for measuring pressure, even at exceptionally small values (0.1 Pa).
The characteristics of this material are shown schematically in scheme 10. From the graphs and values shown, it is possible to see that the current intensity that the material is able to generate is very low.
Potential applications range from self-powered micro-mechanical elements, to self-balancing robots and sensitive impact detectors.
This material, as well as all E-textiles, can now be used as a sensor but it is not yet able to guarantee an efficient energy harvesting and use of electonic consumer products.



Scheme 23

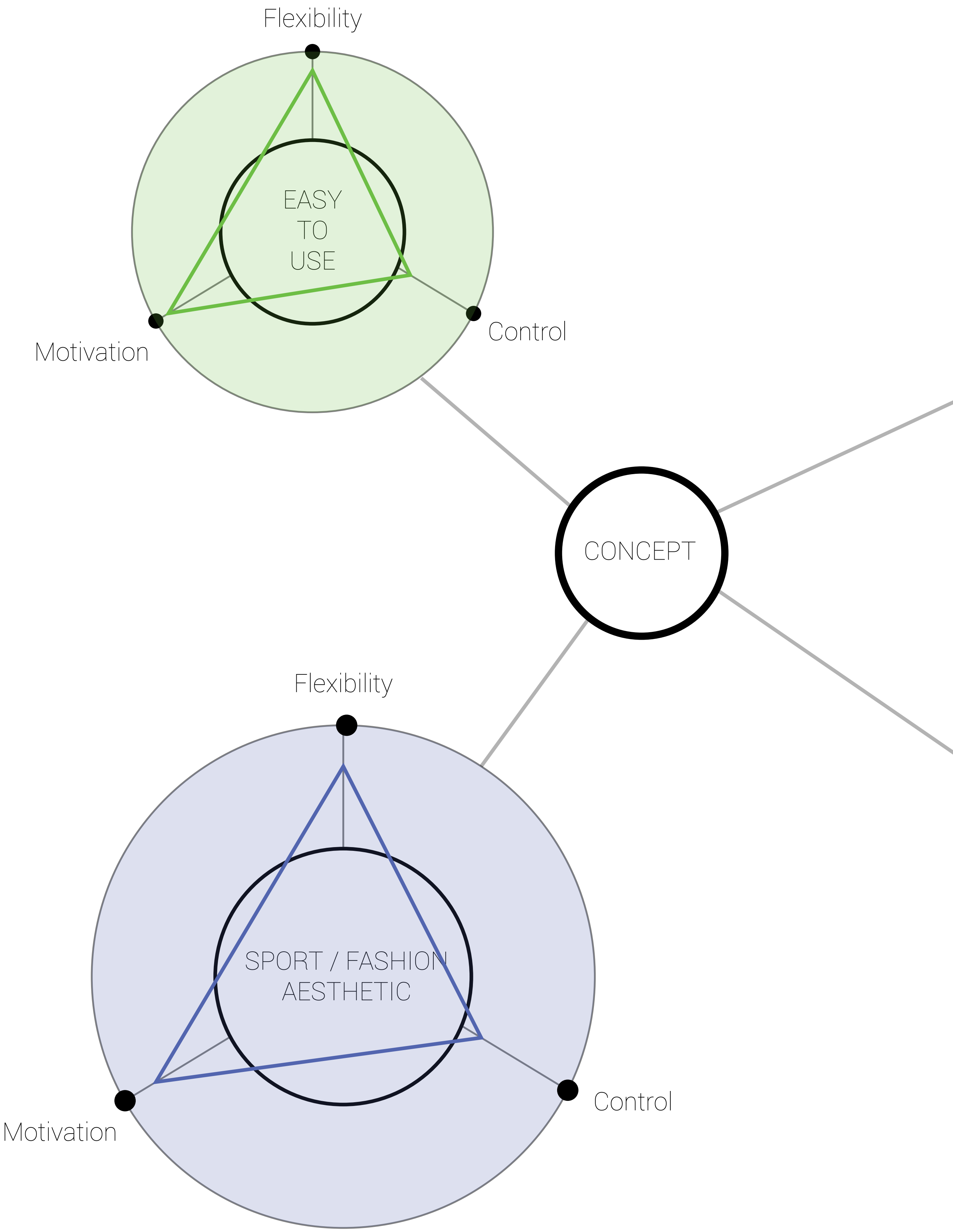
5.7 The starting idea of the project

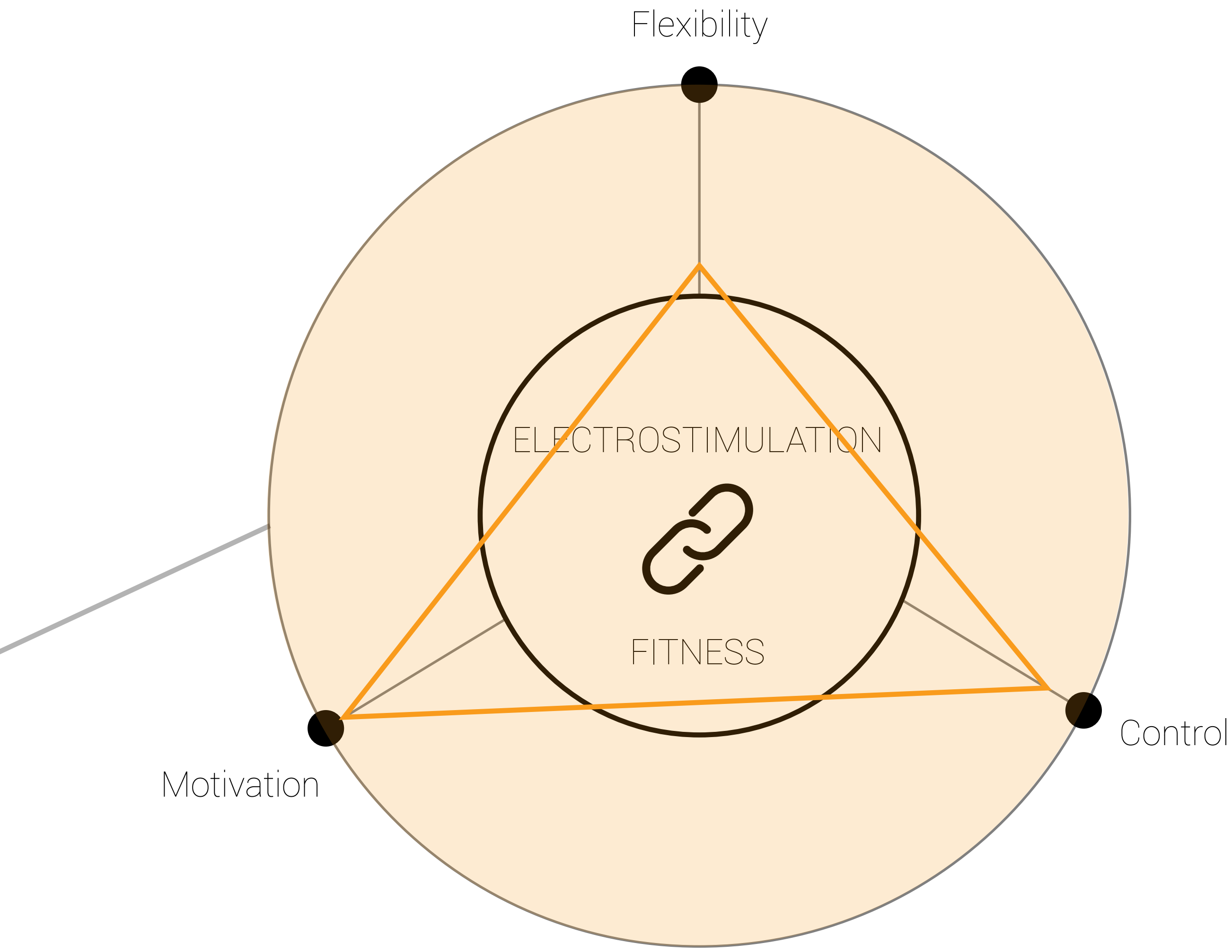
The concept's idea was born during the analysis phase and it has evolved with that.
The idea represents the formal synthesis of the design aspects found during the research, in particular I wanted to pursue the concepts of motivation, flexibility and control.
The product must therefore be able to follow the user throughout the rehabilitation path, which implies a product's ability to adapt to different contexts and user needs.
The electro stimulation system must be easy to use and avoids some difficult and complex operations that classic electro stimulators have. This aspect will be important to increase the user's motivation to use the device as easily as possible in different situations.
Another important aspect is the correlation between physical exercise and electro stimulation which will be represented by a system that, using a piezoelectric material, will be able to recharge the battery, thus transforming the mechanical energy into electrical one.
After having critically analyzed the world of orthoses and medical devices, I decided to design a product that could distance the hospital from an aesthetic point of view. This choice is linked to motivation: the user will be more enthusiastic to wear a product with aesthetic linked to fashion and sport trends.
The first point I focused on was the study of the system for the recovery of electricity.
This aspect was certainly the most difficult challenge of my thesis project, but it was at the same time important to understand the potentials, limitations and future developments of piezoelectric materials.
First of all I evaluated the possibility of using a fabric that thanks to tribo-nanotubes could recharge the battery also due to minimum pressures and movements.

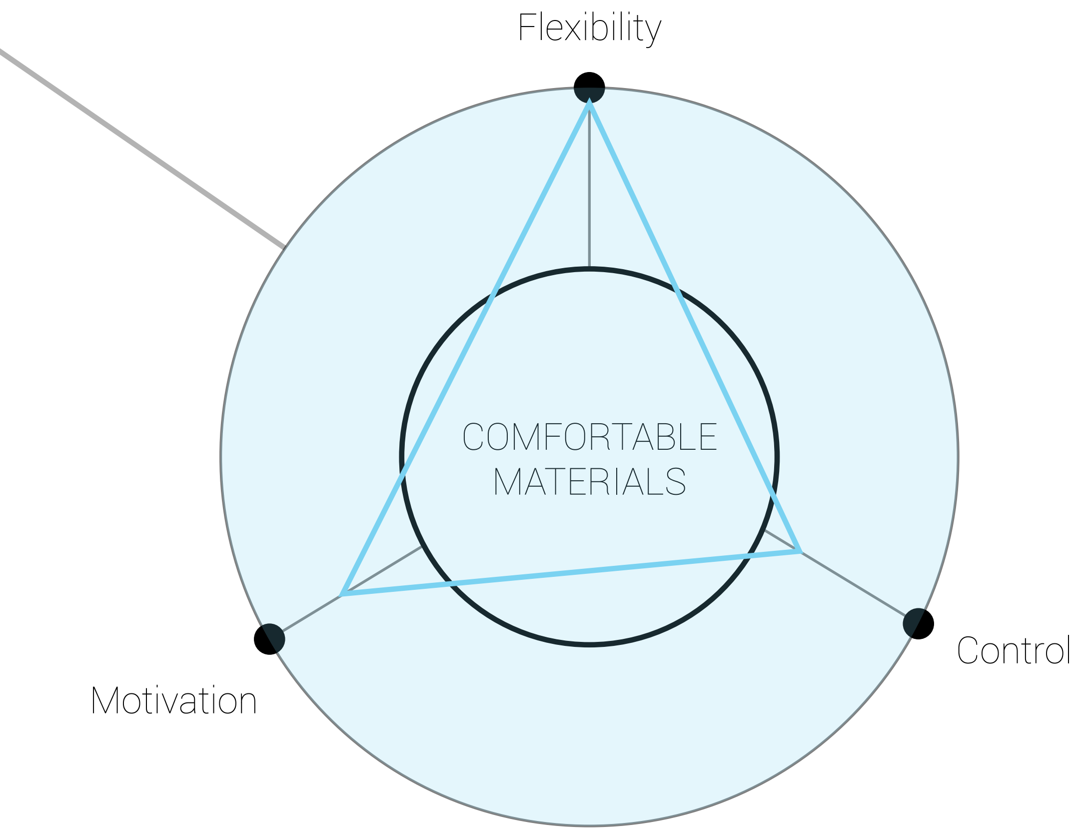
While this solution had the advantage of being perfectly integrated into the fabric and not being perceived by the user, on the other hand it turned out to be too ineffective from the standpoint of the amperes production, voltage and frequency (Hz).
So I decided to look for more energy-efficient solutions that could better contribute to battery recharge.
The most suitable materials for this are ceramic piezos that have much higher piezoelectric capacities. The use of this type of material seemed the only possible solution, even taking in consideration the positive and negative sides that the use of a piezo ceramic material could lead to the project.
Surely the use of a ceramic material, which is obviously less flexible than a fabric, results in a loss of fit and needs higher stresses to produce electricity. This will certainly lead to design a system capable of integrating piezoelectric material on the stocking and adjusting its deformation.

fig. 91 / fig. 92

Exaple of how two very impressive wearables things can have a completely different effect and values: the woman's boots (by vetements) are strongy polarizing and fashion at the same time, so the person is happy to show them in public.


Flexibility
EASY
TO
USE
Control
Motivation
CONCEPT
Flexibility
SPORT / FASHION
AESTHETIC
Control
Motivation


Flexibility
ELECTROSTIMULATION
FITNESS
Control
Motivation


Flexibility
COMFORTABLE
MATERIALS
Control
Motivation

Scheme 24

5.8 The first concept

After understanding that the use of ceramic piezo material would be the only possible solution, I analyzed the problematic aspects that this choice entailed and I tried to turn them into project opportunities that could add value to my concept.
It is true that a fabric has a higher fit and deforms better than a piezo-ceramic material, but this entails less control over the correlation between produced electrical energy and physical movement: a fabric also produces a reaction also due to imperceptible pressures that are not linked to knee joint movement or exercise.
The use of ceramic piezoelectric material may therefore also carry the function of the sensor, that gives inputs that are closely related to the physical activity that can be recorded by a processor.
To avoid compromising the general wearability of the concept, I designed a device that could be worn only during physical activity.
At this stage the researches on orthotes was particularly useful, especially on all those rigid motion control systems like the patented don joy system. These systems are effective for motion control and have a mechanism that modulates the maximum degree of flexion and extension of the knee.
Taking inspiration from these systems I wanted to think of a system that, apart from being smaller, could leave more degrees of freedom to the knee joint and not totally limit the rotation.
For this reason, I totally redesigned the mechanism by placing it behind the knees, making it less restricted, thanks to the possibility of rotula translation.
The mechanism provides four steps of maximum leg flexion, the piezoelectric material plate is fastened to the medial proximity of the calf and follows the flexion of the thigh by sliding inside a track until it reaches the limit point where the plate contracts to produce energy.

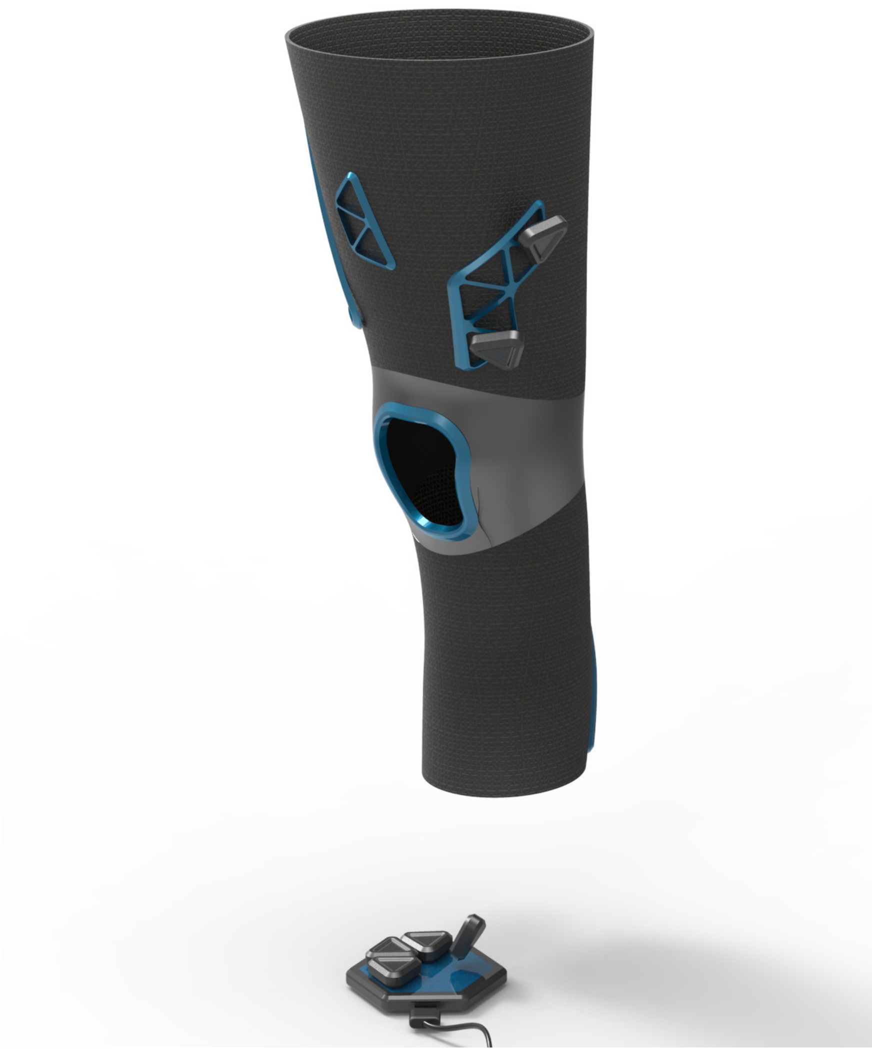


fig. 93

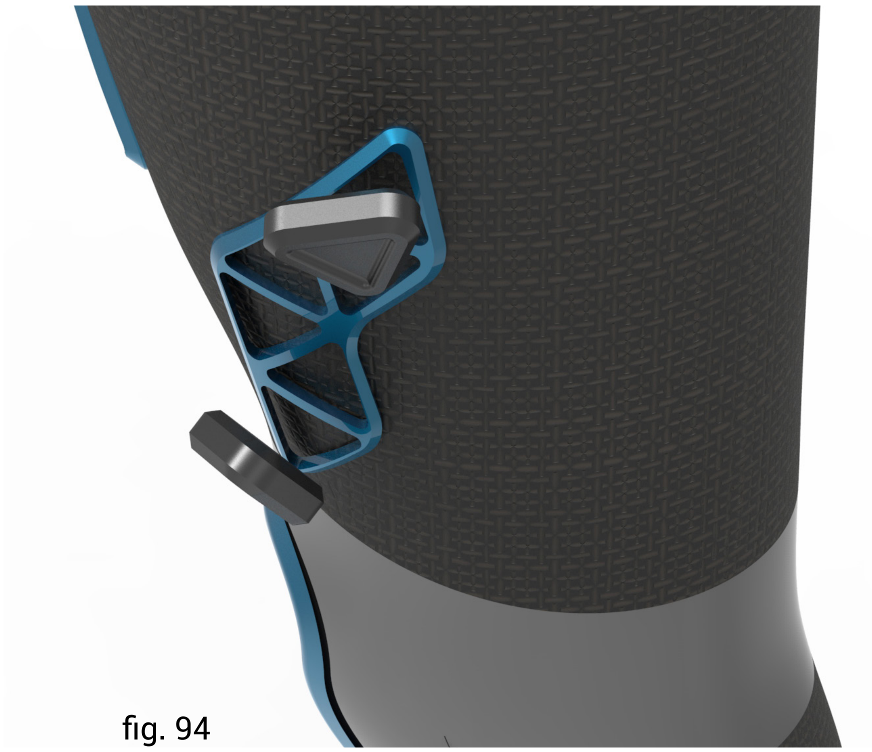
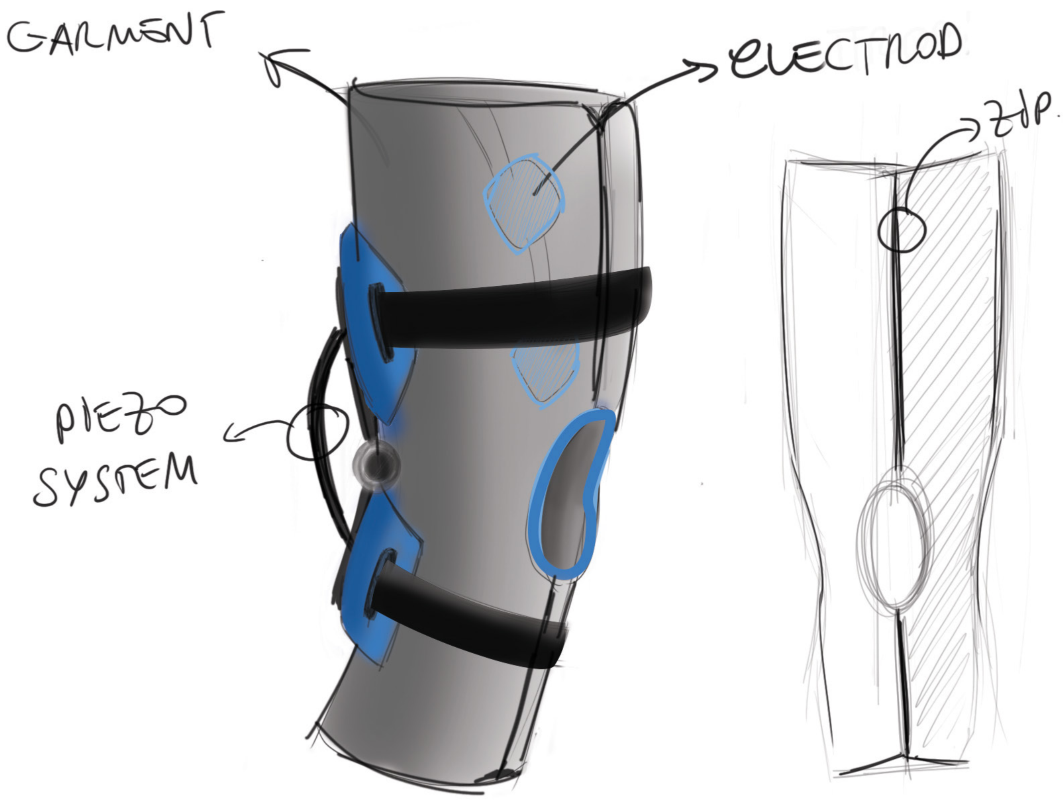
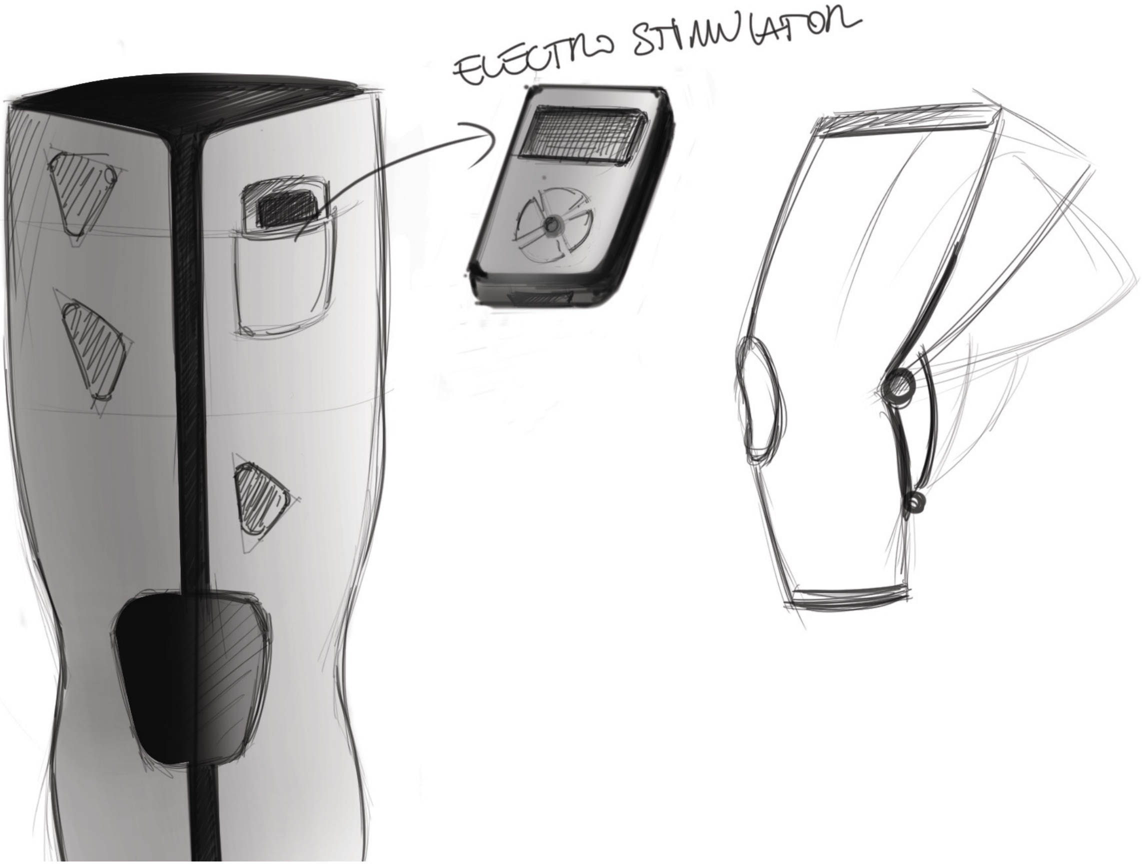
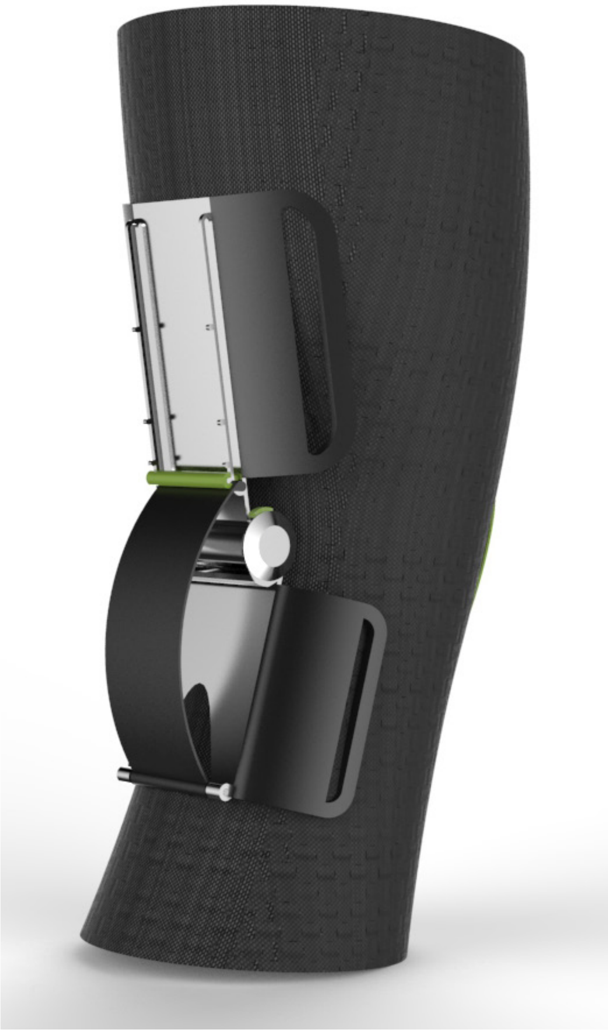


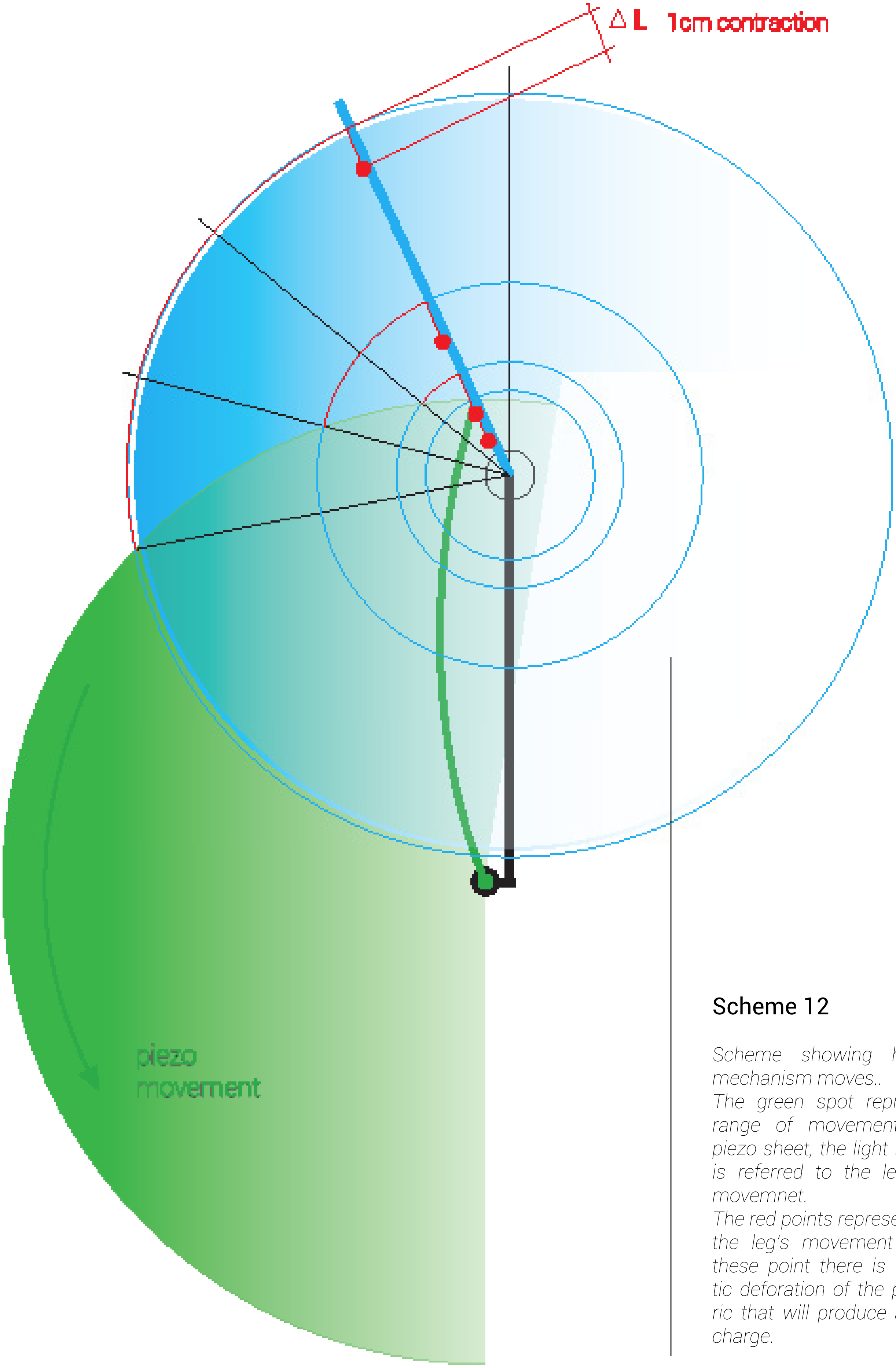
fig. 94

The mechanism settings are two: the first concerns the setting of the bending degree and is done by pressing and moving a small button at the end of the hinge, the second is a bracket that must be fixed along the track to control the piezoelectric deformation (it must follows the set bending degree).
The mechanism engages with 2 flexible components, from here the hooking system that band the leg and fixes with velcro.
Taking in consideration the electro stimulation I decided to integrate an electrostimulator system inside a sock made of a technical and very flexible fabric.
I did not deliberately choose the neoprene as a sock stock because this system is not a orthosis and therefore there is no need for any leg compression but only comfort and lightness. An elastic technical fabric also allows for better fit to the different leg circumferences, always ensuring a good positioning of the electrodes. The wires that carry the electrical impulse from the battery to the electrodes have been replaced by a conductive fabric that is less bulky and visible.
The technical component is enclosed within 2 enclosures that are connected to the sock with a metallic connection that can transfer the electrical impulses to the muscles, the interface of the electro stimulator is represented by an app to be installed on a portable device that interacts with the electro stimulator with a bluetooth module.


GARMENT
ELECTROD
ZIP
PIEZO
SYSTEM


ELECTRO STIMULATOR



Scheme 12

Scheme showing how the mechanism moves..
The green spot represet the range of movement of the piezo sheet, the light blue spot is referred to the leg flexion movemnet.
The red points represent where the leg's movement stop, in these point there is the plastic deforation of the piezoeletric that will produce a electric charge.

5.9 The concept definition: E-knee

E-Knee is a wearable device with integrated electro stimulator, designed to accompany the patient throughout the recovery of muscle tone following injuries to the knee joint. E-knee is designed to educate the patient and motivate him to follow an appropriate path.

It creates a strong bond between active physical activity and passive electrical stimulation and creates a balance between these two phases. This bond is realized by the use of a mechanism which, by exploiting the properties of a piezo-ceramic material, can produce electricity as a result of the knee movement.
The definition of the concept started from piezoelectric material because it is the component that determined the sizing of the mechanism.
The material chosen is a sheet made of polymeric material (FR4), copper and piezoelectric sheet produced by Mide technology.
This company proposes different solutions that vary by property and size, and also offers a personalization service to create piezoelectric material plates with the features and dimensions desired by the customer. For my project, however, I decided to use a model already in the catalog: I chose the PPA-4011 (size 35x70x1.3) plate that has the highest performance in terms of power generation.
The next step was to calculate the energy consumption for a medium duration electro stimulation treatment (about 15min) to recover muscle tone.

Taking in consideration a 15 min treatment, the effective time current supply is about 7-8 min. long (intermitted current 1:1)

Calculation of energy consumption

Data:
- **I** = 15 mA = 0,015 A
- **f** = 20 Hz ---> T = 1/20 = 0,05 sec.
- **V** = 3,5

- T_{use} = 8 min. = 480 sec.
- **f** = 480 x 20 Hz = 9600
- I_{tot} = 9600 x 0,015 A = 152,23 A
- $P_{(8\ min.)}$ = I x V = 152,23 A x 3,5 V --> $P_{(8\ min.)}$ = 532,3 W

Calculation of piezoelectric energy harvesting

Single piezo- sheet propperties : 3,5 mA / 60 Hz

Properites of 6 pieces (with parallel connection):

21 mA / 60 Hz

To find the numer of deformation to ideally full recharge the battery, the Itot is dived by the Ipiezo.

$N_{deflection}$ = 152,23 A/ 0,021 A = 7200

This value is not the final one cause result has to take in account the frequency of the piezoelectric

7200 x 60 Hz = 432.000.

A person when performing a light run normally does 100 steps per minute (50 steps for each leg).
Since the piezoelectric sheets produce a electric charge both during compression and elongation, the period required to fully recharge the amout of energy used seems to be about 70 hours.

432.000 / 100 = 4.320 min ---> 72 hours

The comparison between the results obtained on the TENS treatment energy consumption and the properties of piezoelectric material have shown that the contribution of a piezoelectric device can not support the full recharging of the battery.
However I wanted to try to take advantage of the most preferred piezoelectric material and therefore I chose to use six connected plates in a parallel circuit to increase the mAh output and keep the voltage that was already high compared to the battery.
Not being able to count on a full battery charge, at this stage I decided to use piezoelectric energy also as a sensor to create a binding link between exercise and TENS therapy. Basically, by inserting a chip in the microprocessor and battery connection, it is possible to subordinate the use of the electro stimulator only after reaching the percentage of established battery recharging derived from the piezoelectric material.
The development of the mechanism has been improved in the dimensioning and has been modified following the change of the interface. In the first concept proposals, the button that adjusts the degree of flexion was perpendicular to the hinge axis . This solution could created some problems caused by an accidental push of the button, possibly following a contact with the thigh in the highest degree of flexion.
I therefore chose to move the button and the spring orientation parallel to the hinge axis to increase comfort and to avoid any possible accidental contact.
The design of the mechanism has considered the deformation of piezoelectric material plate, in fact the deformation must be controlled not only to avoid irreversible deformation in the plastic field but also because excessive elastic deformations do not lead to higher energy production but only to a life cycle decrease of the material properties. In this case the maximum deformation is 1 cm for the chosen material.

The mechanism provides four degrees of maximum bending (25 ° -50 ° -75 ° -100 °), the adjustment of these steps must be done together with the positioning of the bracket which, by limiting the piezoelectric plate sliding, sets the maximum deformation to 1 cm.
The button, when pressed and turned, compresses a spring that unlocks the pin that fixes the position of the cylinder which limits the maximum degree of flexion, releasing the button extends the spring and fixes the pin in the desired position.
The structural parts of mechanism are made of aluminum which guarantees lightness and good mechanical properties.

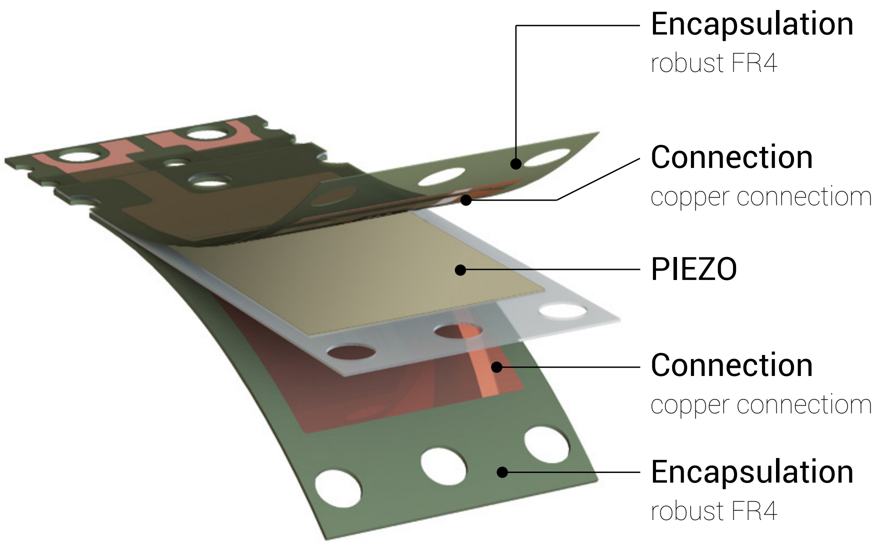


fig. 104

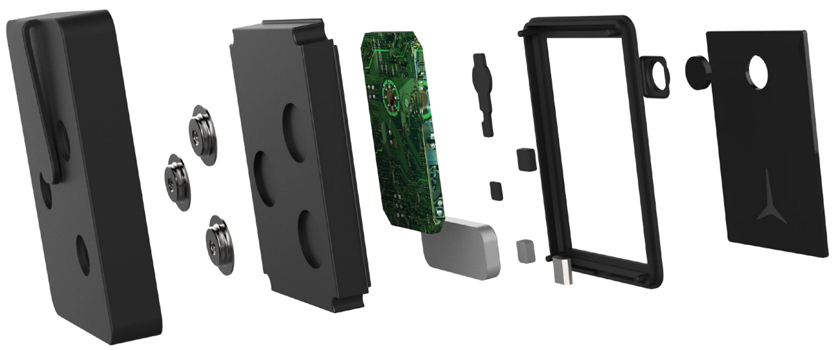
Layers structure of the piezo-eletric sheet

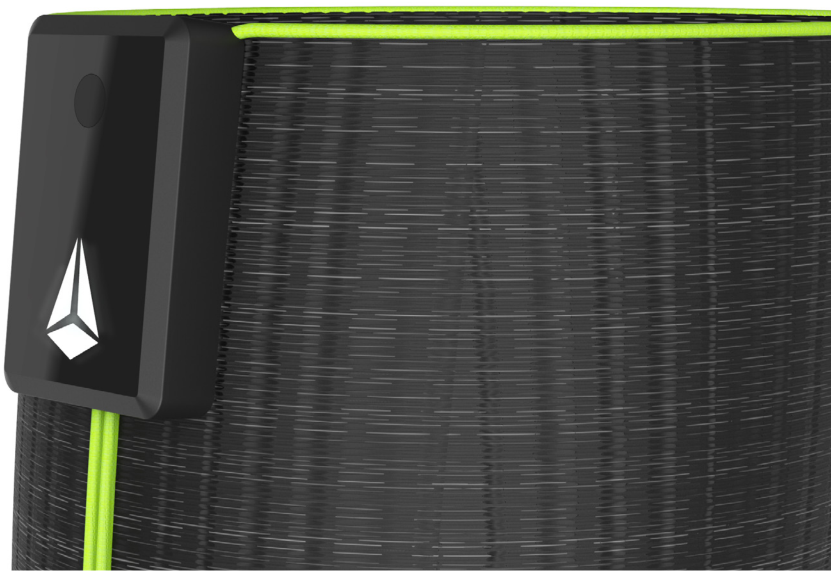
The lower and upper bars (X and X pieces) have been redesigned with a concave shape to better support the anatomical shapes of the leg.
These two parts connect with the two flexible components with velcro system that ensure excellent fixing and disassembly options for piece replacements or end-of-life product disposal.
The two flexible parts are made of a polymeric foam that gives comfort and fits perfectly to any shape and size of the leg. From these 2 components the elastic bands start the whole mechanism to the body with a Velcro closure.
The final design definition of the sock was about the choice of electrodes and their positioning also chosen thanks to the opinion of some experts. The electrodes measure 40mmx60mm and are arranged in pairs (positive pole and negative pole): 4 electrodes for quadriceps , 4 for hamstring and 2 for calf. Electro stimulation works independently for each muscle area allowing the patient to choose the degree of stimulation desired for each district.
The electrodes are connected to the electrostimulator by means of a conductive fabric, I have chosen to use the Circuitex conductive fabric because it has already been used in many applications and the company also has the ability to design the fabric according to the needs and on the basis of the final application .
The material chosen for the stocking is a fabric with great elasticity: this feature allow to reduce the product sizes to two sizes that have been established following the anthropometric dimensions.
The electro stimulator is connected to the conductive fabric through 3 small button clips, each of which represents an electrical signal output channel for a specific muscle area. The male clip buttons are attached to the stocking, while the female buttons are fastened to the back of the electro stimulator. The electro stimulator consists mainly of two outer shells plus an inner shell, all of them made of polymer material.

fig. 106

The electrostimulator is fixed o the fabric with steel clip that also allows to the current to pass trought conductive fabric.

The inner shell has the function of fastening the electronic components and fastening the metal clip buttons, it encapsulates between the two outer shells that block its movement.
The top shell is actually made up of 2 pieces, a frame that comes with the lower body and a flat, light and slightly transparent surface that is glued to the frame. This component has both aesthetic and functional function, on the one hand it creates a contrast of interesting materials, on the other it allows the light of a LED to signal the connection state between the electro stimulator and the device from where you handle all the options.





While the stocking and energy harvesting mechanism work essentially in two different moments, the electro stimulator is present both during the passive treatment phase and during physical activity. For this reason, I have designed the back shell of electro stimulator in order to give it the possibility to be attached to straps close to the mechanism: the piezoelectric material will be connected to the battery through a miro USB cable.
The on-off button is the only way to interact with electro stimulator, when the user press ON there is the automatic ignition of the bluetooth. Using the installed app on an external device handles all the parameters, the user can check the battery charge level, see if physical activity is enough and decides when to give way to therapy.

fig. 109

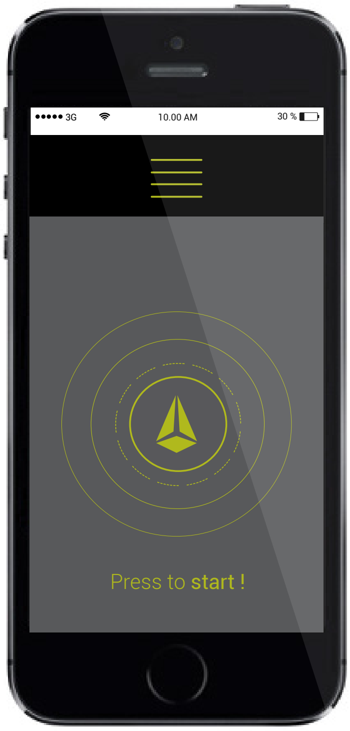
During sport or phisical activites the electrostimulator is attached on the lower strips thanks to the bottom shell geometry.
As showed in the pick, a wire with microUSB recharge the battery.

The choise to control this product with an application has several reasons:

- allows the user to wear the product even under long clothing.
- significantly reduces the bulk of the electro stimulator
- reduces the cost of installing a touch screen
- reduces energy expenditure for interface operation (power required by bluetoth module is very low)
- allows you to receive notifications and alerts on a device (for example, a smartphone) that usually is with the user all day long.

The application mockup has been structured to allow the user easy and intuitive management, even to people who have little confidence in the technology equipment.
In fact, the initial screen of the application is essential and with a simple click allows activating the TENS treatment, this allows the patient to set the stimulation parameters from a physiotherapist and thus interact with the application as easily as possible.

HOME

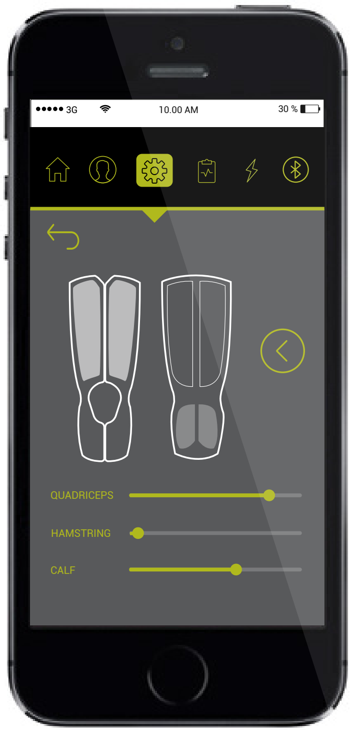


SETTING

Time and current parameters

SETTING

Muscles stimulation

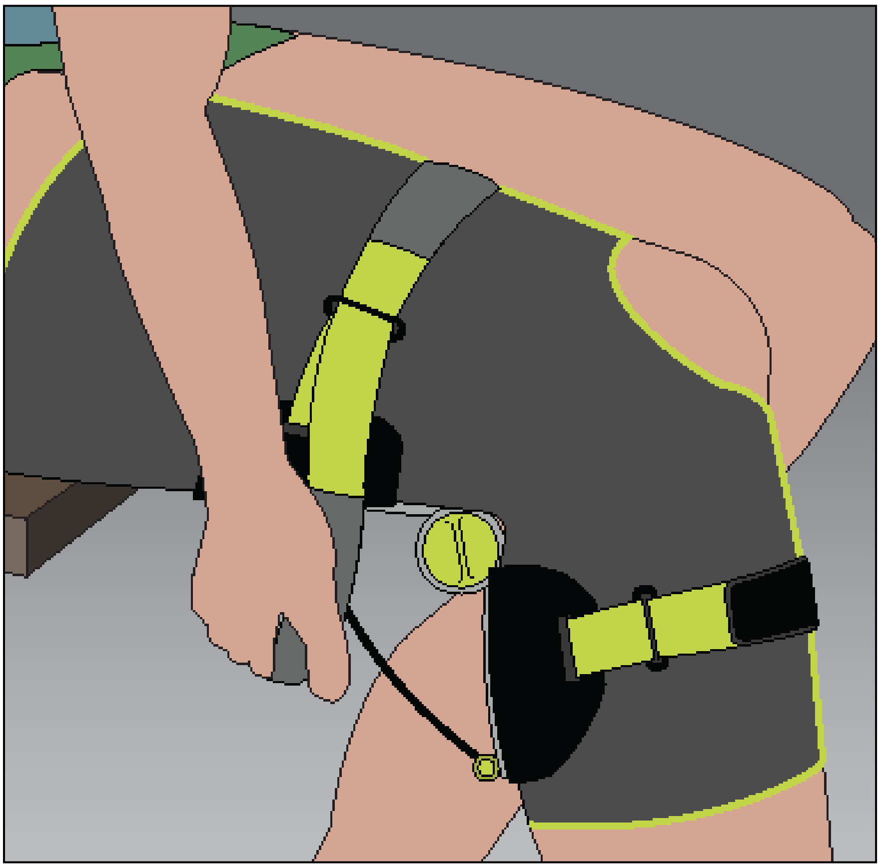


CHECK STATISTICS

LEVEL BATTERY CHECK


Press to start !
10:00
INTENSITY
FREQUENCY
AMPLITUDE
QUADRICEPS
HAMSTRING
CALF

5.9.1 Storyboard



1.

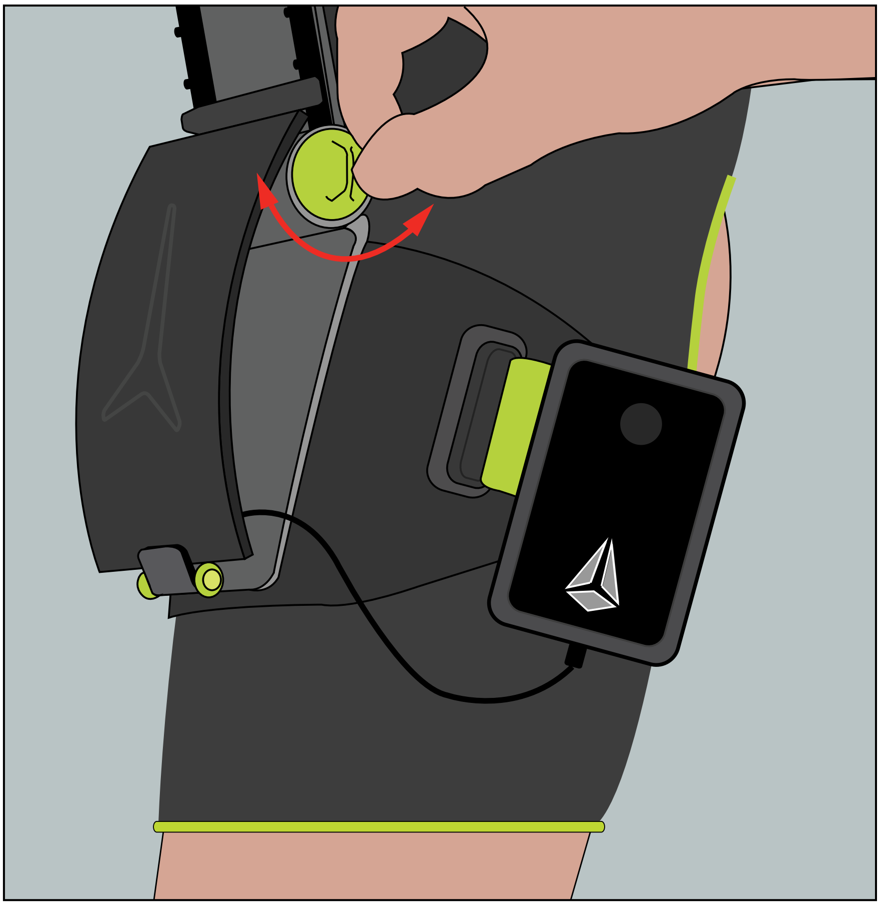
Wear E-knee (both the stocking and mechanim) before starting do exercises.

2.

Connect the electrstimulator with the mechanism with a microUSB cable. Then attach the electrostimulator on the strip.

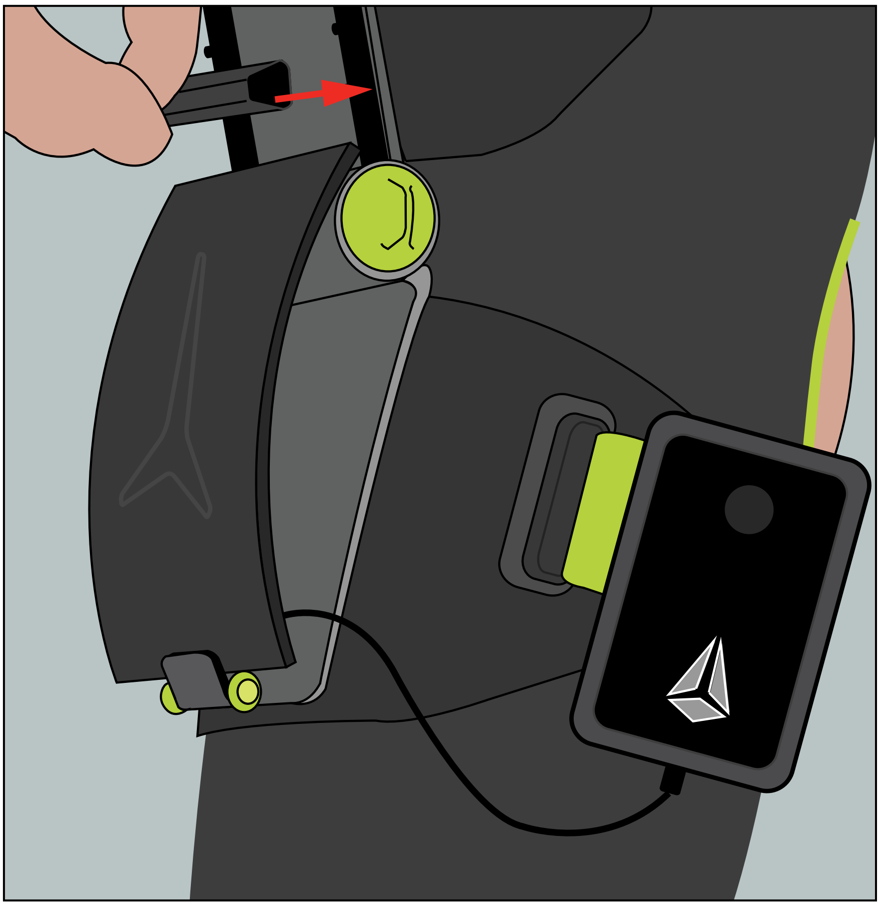
3.

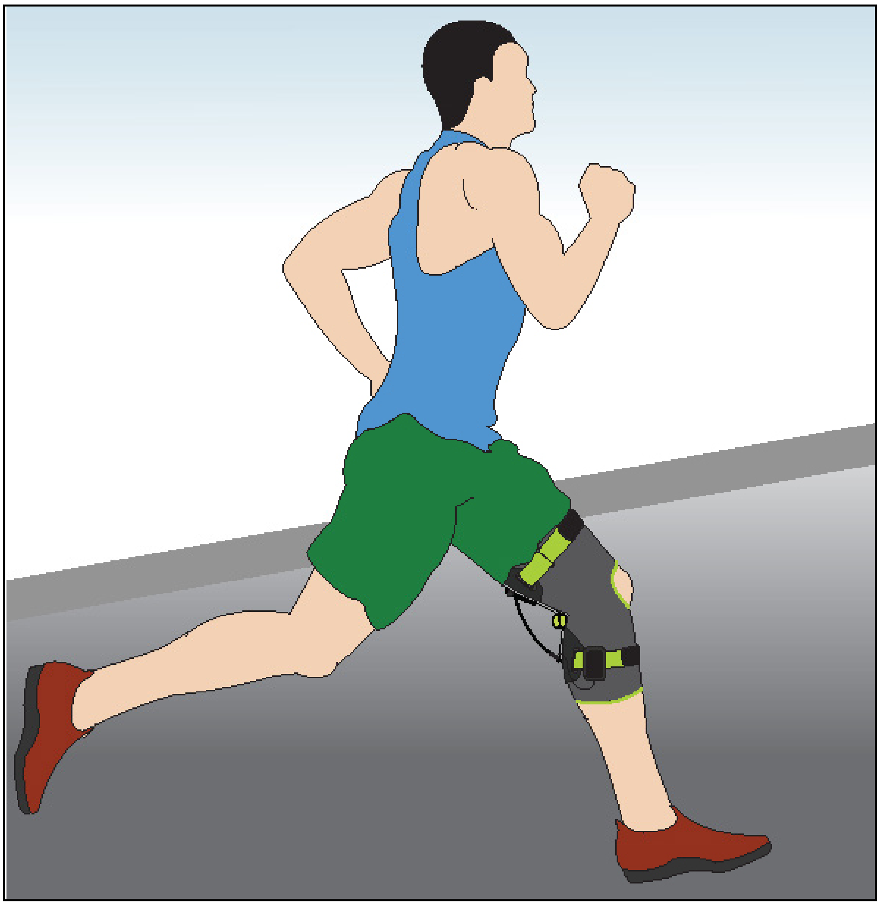
Establish the range of movement and regulate the mecanism.



4.

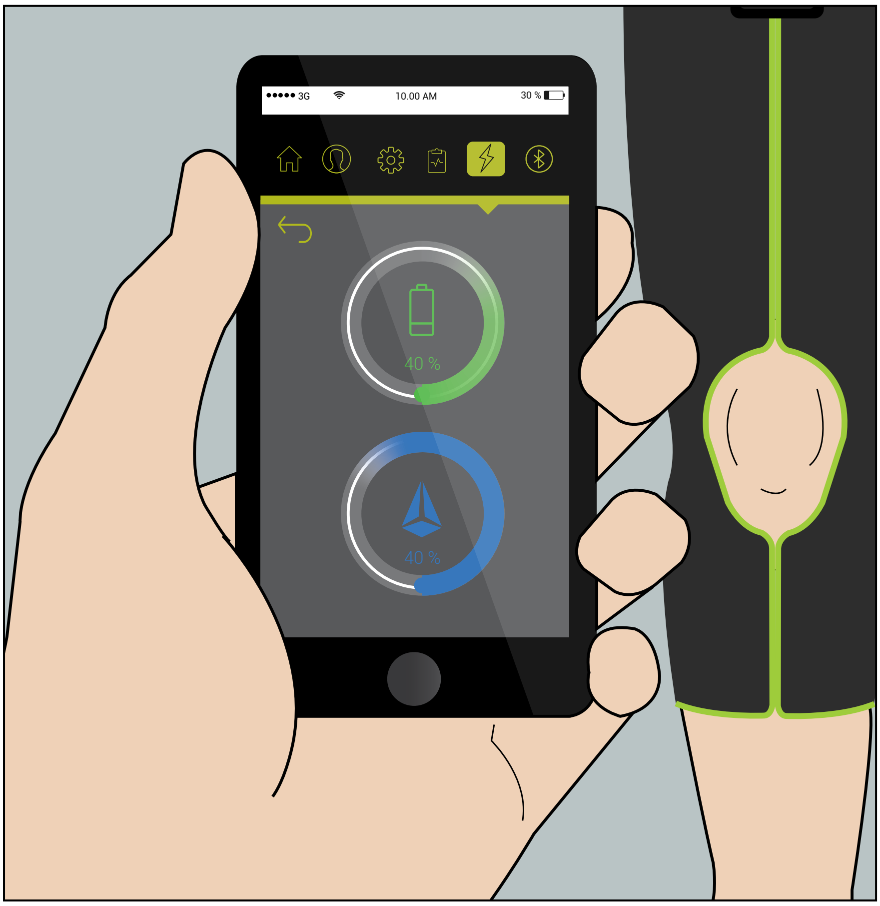
Fix the limitator coherently with the stabilished range of movement.





5.

Play sport or any kind of exercise.

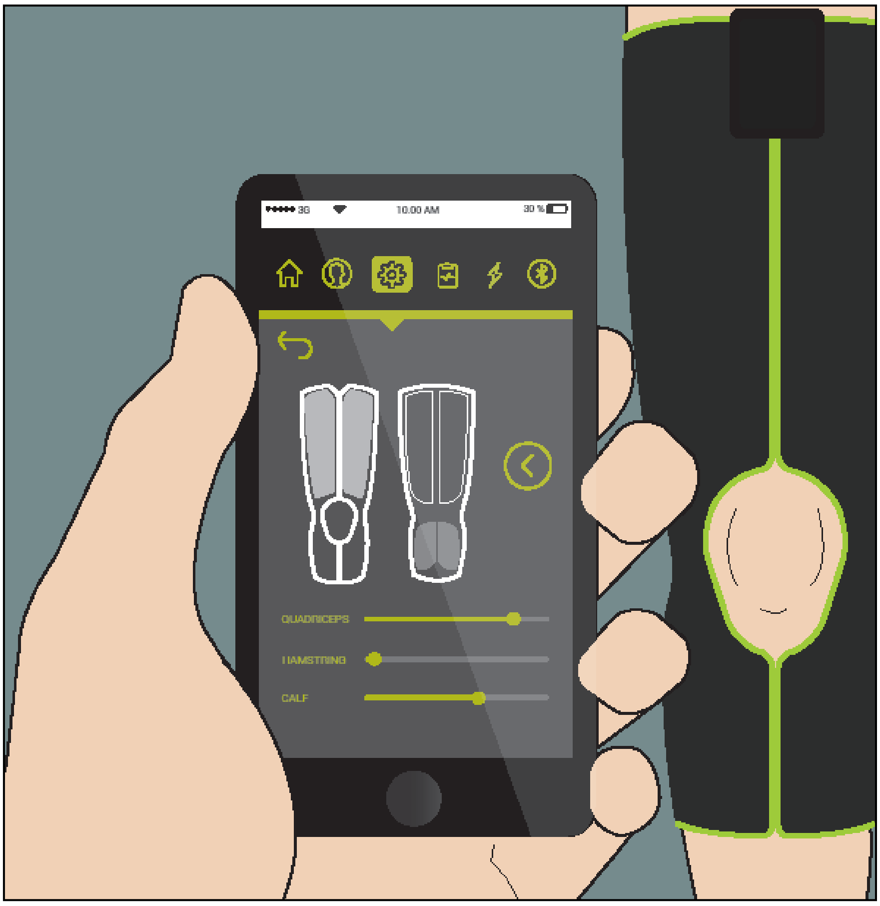


6.

Using the app, verify how much phisical activitie contributed to recharg battery and if it is enought to starting use electro stimulation teraphy.

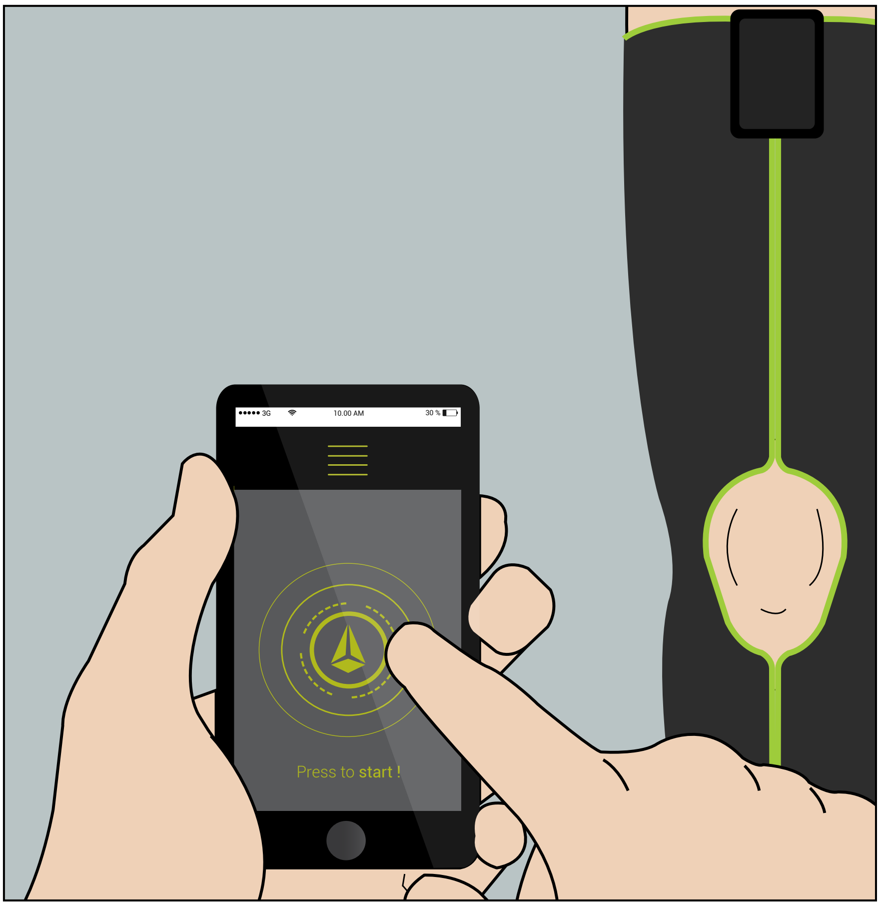
7.

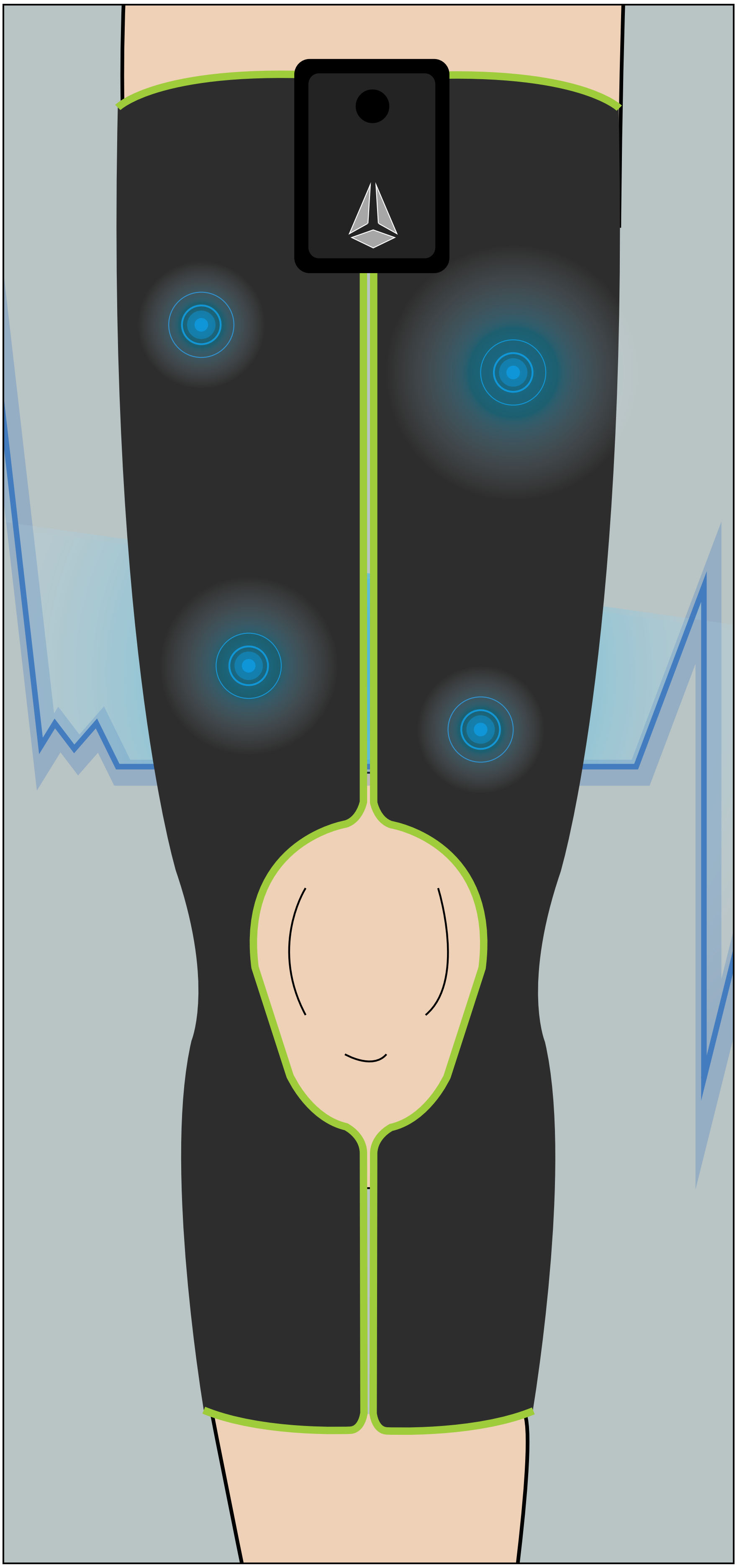
Modify the electric parameters and decide which muscles stimulate most.



8.

After have set parameters and muscles target, start the teraphy simply touching E-knee logo on the screen.





9.

E-knee lightness and its comfort allow to start a electro stimulation tera-phy in any places, also wearing E-knee under pants.

5.9.2 Definition of aesthetic features

The aesthetic aspect of E-Knee plays a central role in my project. The aesthetic choices affect the perception of the project, they communicate the values that E-knee wants to convey.

Even if E-knee can be included into wearable medical devices category, it wants to get away from the classic etiquette archetype (more generally from medical products) to get closer to the world of fitness and sports: the athletic attitude of the product has the function of remembering to the user the importance of exercise. It also encourages the user to wear E-knee with greater ease and no shame.

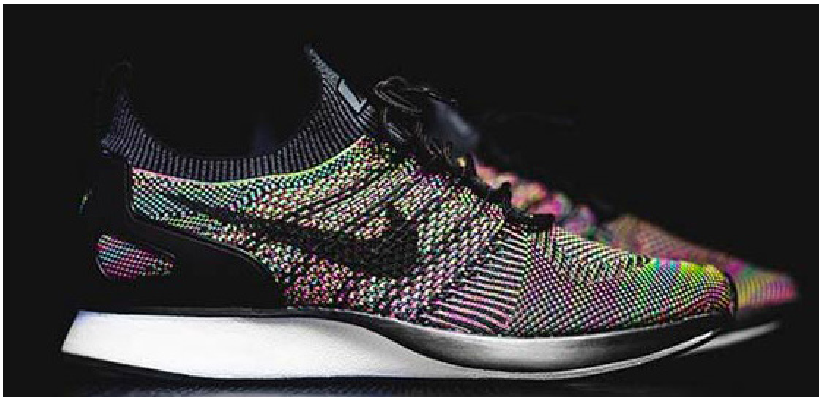
To make the stocking as appealing as possible I decided to take inspiration from the trend of fashion sportswear that has been growing in recent years. This trend, carried out for example by major sports brands such as Nike and Adidas, has allowed the diffusion of sporting articles with a strong technical connotation in casual wear. The secret of this trend is the care of the details, the ability to give interesting aspects to technical materials and to use typical fashion details to make sporty shoes and sportswear more versatile and suitable for any situation. I decided to give this impression to the concept to try to reduce a patient's embarrassment or discomfort to wearing a medical device in public.

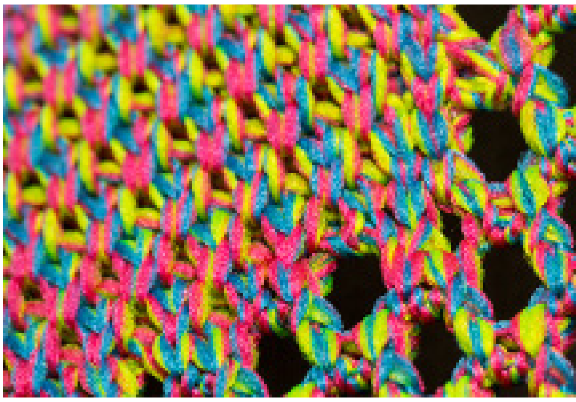
I have been researching in the sportswear sector not only to find inspiration in aesthetic details and stylistic choices but also to find comfortable and breathable technical materials.

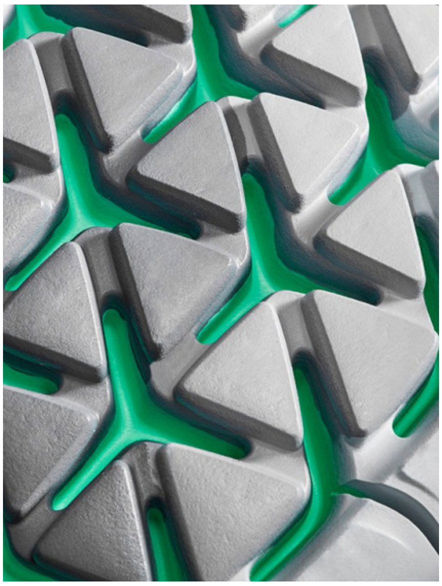
The stocking closes with a zip system, unlike the classic orthoses that often use velcro. The choice of this kind of lock is practical and functional, it also increases the perceived value of the product and brings it closer to the fashion environment. The two zip systems are partially hidden by a profile that runs through the whole stocking.

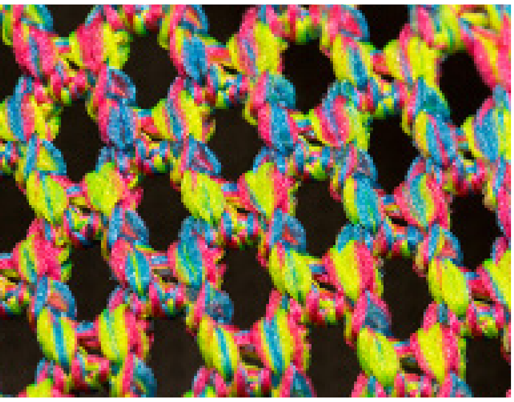
Considering the mechanism, I wanted to underline the metal parts and the technical aspect in general. The strips that lock the mechanism on the stocking are inspired by the world of running shoes, the fabric weave remembers the upper part of a shoes and creates a contrast with the smoother surface of the stocking. Applying a rubber layer on the strips gives a greater grip, thanks to the logo reproduced in series, creates a texture that resembles the sole of the shoes.

MOODBOARD | Sportswear fashion










NIKE FREE

5.9.3 Color choises and material finitures

The role of color is very important in design because, as well as form, it plays an essential role in the holistic perception of the project.

The visual stimuli we receive from the outside produce emotional and physical-emotional effects and reactions that, through a targeted study, work positively to improve the quality of life. Color can not be considered only as a matter of art and beauty or a simple decorative element [1]. Actually, the function of color is much more important because it implies human and psychological factors. Every designer should feel called to reflect, elaborate, or share a rational method in solving color-related problems by searching for the “right color” for each particular function (didactic, hospital, home and other) and according to final user expectations.

However deceptive, color respects the rules, mainly related to physical aspects, visual aspects and emotional aspects, through which we can speak of “functional color” [2].

The “functional color” is used according to the intended use (of environments, products, web, etc.) and the type of user. If properly studied and chosen in the right shade, saturation and brightness, color becomes an effective design tool, modifying the proportions and perceptions of spaces in architecture, determining expectations, differentiating attention situations and signaling object functions in design field.

The relevance of the functional color design is given by the study of the effects that color, in the physical magnitude of electromagnetic wave, produces on the people and the environment, in particular the photo-biological effects (vision, light, autonomic nervous system variations) communication effects (Verbal and non-verbal information, sensory interaction), psychological (behavior, cultural models, perceptual sinesthesia, choice of clothing or accessory), therapeutic (psychosomatic medicine, chromotherapy, anti-stress techniques, environmental well-being) [3] 4].

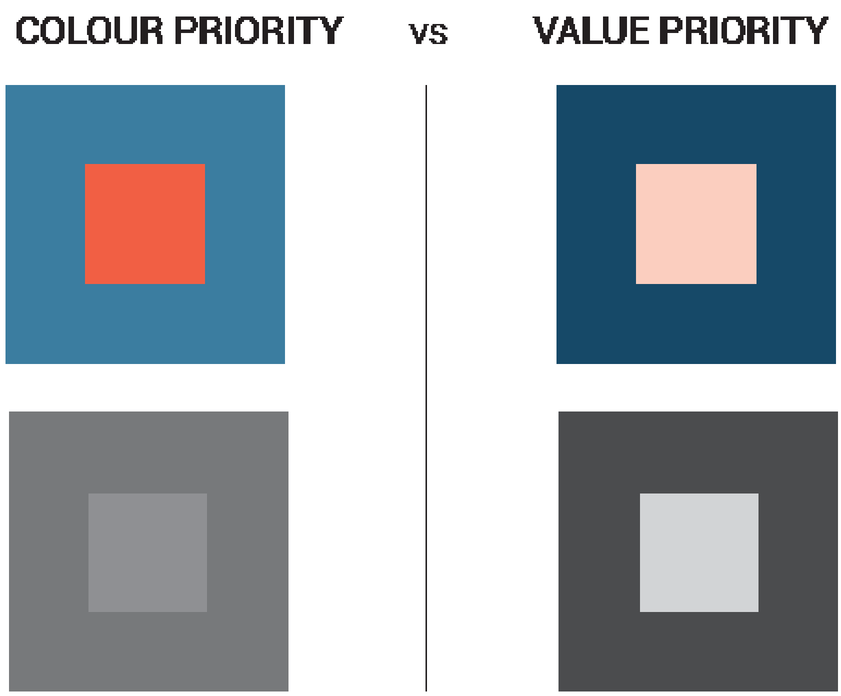
Color has effects on brain activity, stimulates emotional, symbolic and aesthetic associations. During the cognitive process, we perceive any form of stimulus that passes through sensory cells with mere optical perception. Then everything is activated in our brain by understanding what is stored, transforming the stimuli into conscious perceptions [5]. Chromatic gradations, determined by the corresponding electromagnetic wavelengths, act in different ways on the body's functions, mind, and emotions: they are sensory experiences that produce concurrent perceptions (sinesthetic phenomena).

fig. 135

Use of green colot in a interior design project. The aim is to add a sensation of peacful and relax,

Research and the application of the "right color" is fundamental in a project, because through the knowledge of its physical characteristics and its effects the designer succeeds in pursuing sensory ergonomics.
First of all is indispensable study and consider the "theater of color", that is the action and the relationship between the colors: no color appears as it is in its physical reality, but is altered by contrasts, quantitative relationships, and proximity to other colors. The eyes modifie color tones through the influence of surrounding colors [8].

The difference between color priority and value priority can be seen with these color samples. In the left coupling, the intensity reaction is obtained exclusively through the color contrast, a complementarity relationship between orange and blue.
When this sample is converted to black and white we see that the values of these two colors are almost identical: the contrast has no reaction outside the color context. The right solution, on the other hand, is based on the degree of saturation of the two colors: since the orange is so light and the blue so dark, in the value-priority coupling, color and black-white samples have almost the same power.



Scheme 25

For the study of color relations I have been inspired by the artistic current of Impressionism.
Much of the attention on the impressionistic color theory focuses on their use of brighter and more saturated colors. This was an essential part of their overall strategy and worked mainly because of their way of controlling the values of those colors. More specifically, they were well aware that the relative value of a color deeply determines its chromatic identity.
When colors become very dark or very clear, their identity becomes much less obvious.
For example, if a shadow is very dark, it will be perceived primarily as a dark value and will show little of its intrinsic coloristic identity. Likewise, an extremely clear or almost white passage will also have much less color identity. The full personality of a color is expressed when its value is neither too dark nor too light, but when it is in the middle range. Light or very dark colors reveal less their coloristic identity; Therefore, they are less able to act as colors.

fig. 136 / fig.137

Claude Monet, The Monet family in the garden at Argenteuil, 1874.

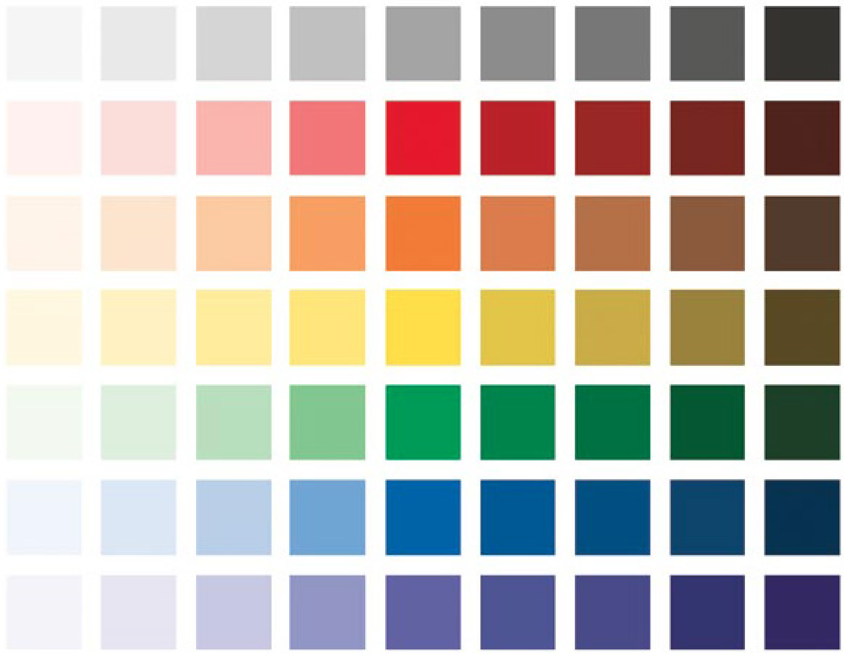
Many use lighter values in shadows and very saturated colors. This framework is based on the priority of the value which is about 60% (40% color priority).
When converted to black and white, the color body is obviously lost, but the overall value structure is strong enough so the black and white version can stand alone.

fig. 138 / fig. 139

Claude Monet, Rouen Cathedral, west facade, sunlight, 1894.

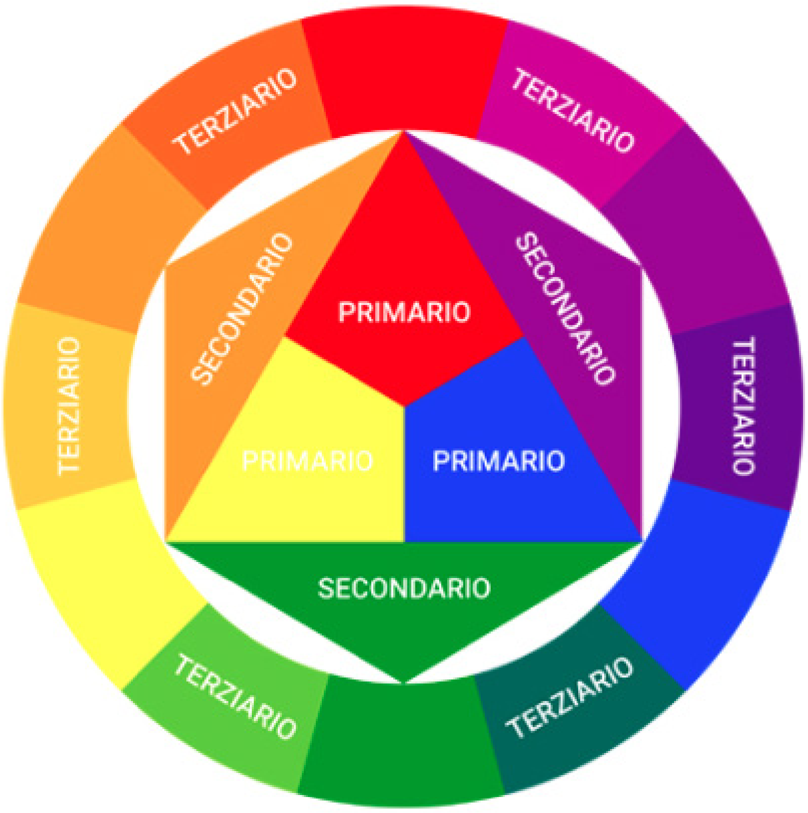
When the color is extracted, the painting becomes a ghost of itself. Most of what works the picture is lost, because contrasts are based primarily on color, not on value. This frame is based on 80% color and 20% on value.

In this scale of 9 values (above), the colors on the left have a very light, almost white value with only a small amount of tonality present. Likewise, the colors on the right have very dark, almost black values, and little of their intrinsic color is visible. If you look at the chart, the colors in the central area appear brighter. This shows a fundamental truth about color: the full color identity of a color is expressed when its value is neither too dark nor too clear, but within the mid range.



Scheme 26

Colors have not only effects on brain stimulation, their perception is often influenced by socio-cultural implications. For this reason a color can be perceived differently by the observer.
Colors are classified in 3 main categories: primary, secondary, and tertiary colors (scheme 15)



Scheme 27

Schematic rappresentation of colours division.

Often in architecture and design, colors are classified in warm, cold and neutral colors.

Warm colours

The warm colors are red, orange and yellow and the variations of these three colors. These are the colors of fire, fall and fall of leaves and sunsets. They mainly represent energy, passion and positivity.
Red and yellow are primary colors, while orange is the union of the two colors, which means that all warm colors are created by two warm colors, and do not mix a hot and cold color. Using warm colors in a project primarily serves to reflect passion, happiness, enthusiasm, energy, or danger.

Cold colours

Cold colors include green, blue and purple, and are of course more "content" than warm colors. They are the colors of night, water, and nature and are usually soothing, relaxing and somewhat reserved.
Blue is the only primary color within the spectrum of cool colors, which means that the other colors are created by combining blue with a warm color (yellow for green and red for purple). Green assumes some of the attributes of yellow and purple assumes some of the attributes of red. The cool colors used in a design give a sense of calm and professionalism.

Neutral colours

In this category there are white, black and all varieties of gray.
Neutral colors are commonly combined with brighter colors but can also be used alone to give a sophisticated feel to the project (both of objects and web layouts).
The meaning and perception of neutral colors are highly influenced by the colors surrounding them and can have the same meanings of hot or cold colors. Often the combination with brighter colors tends to emphasize the sensation and meaning that color wants to convey.

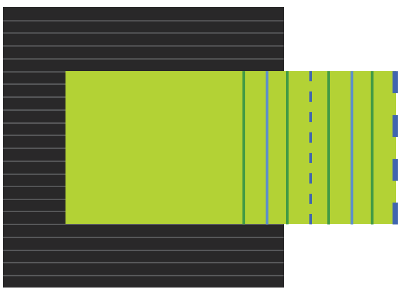
As already written above, colors have different meanings by cultural rules (even within gradations of the same color), but it is possible to associate a color with some generally valid messages all over the world:

- YELLOW: it is the color of optimism and dynamism
- ORANGE: corresponds to friendship and energy
- RED: it is the color of excitement, passion, and love
- VIOLA: it is the color of creativity, fantasy and meditation
- BLUE: It is the color of confidence and security
- GREEN: it is the color of nature, well-being and tranquility
- GRAY: It is the color of balance and wisdom
- BLACK: it matches the power and elegance
- WHITE: it is the color of purity and change

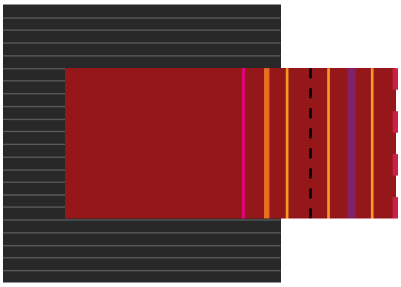
Following this research I worked out some color pairs to communicate the value of my product. I decided to use a neutral color on the shades of black and gray as a base color. These colors in fashion are perceived as elegance and sophistication, they fit well in every situation. The base color is associated with a vivid color that communicates energy, positivity and desire to move.
Trying not to let the stocking too much heavy by visual point of view, I've choosen to use a melange fabric that is more dynamic and increases the perceived fabric value without being polarizing.
Vivid colors are used in some details of the mechanism, strips, and sock profile.
The colors chosen are a yellow lime, a particular gradient of red and blue.
Lime color belongs to the yellow family but tends to green, this color communicates dynamism and optimism, but with a feeling of tranquility and reminiscent of nature.

Red, on the other hand, communicates energy and excitement, and thanks to they particular gradient and melange effect is far from the idea of danger that sometimes red colour could exprime.
Blu communicates confidence and calm, the match between blue and light gray give to the product a general sense of lightness.

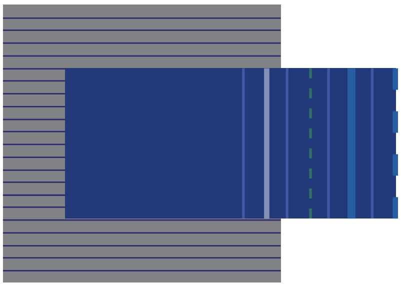
The metal alloy (in this phase I hypothesized an aluminum alloy) of the mechanism components is subjected to anodizing not only to increase the corrosion resistance but also to make it darker for a better integration with the stocking and helps to enhance color access.



C : 35
M : 0
Y : 100
K: 0



C : 20
M : 100
Y : 100
K: 30



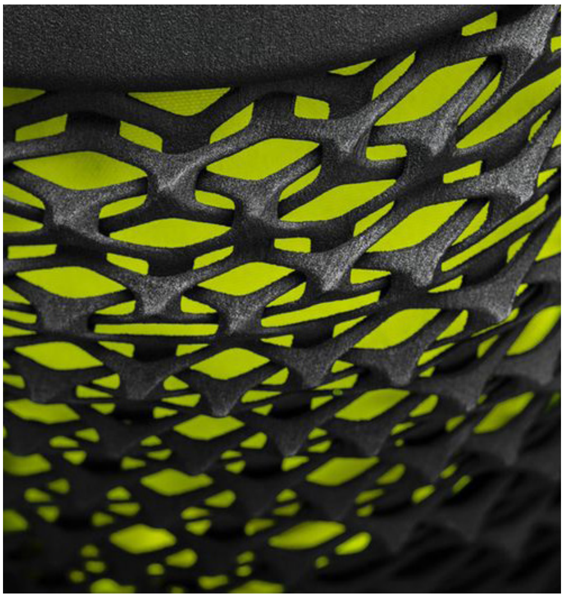
C : 100
M : 90
Y : 20
K: 10

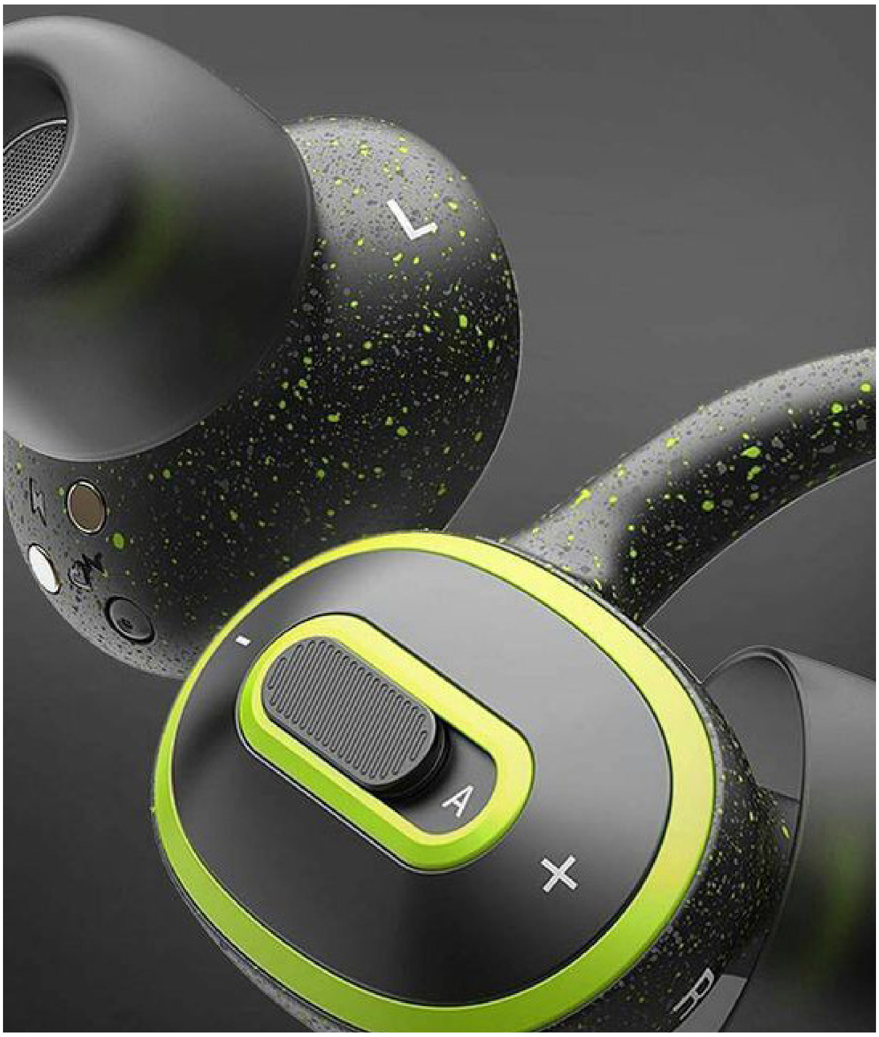
COLOUR PRIORITY

VALUE PRIORITY

Scheme 28

MOODBOARD | Cromatic proposal 1

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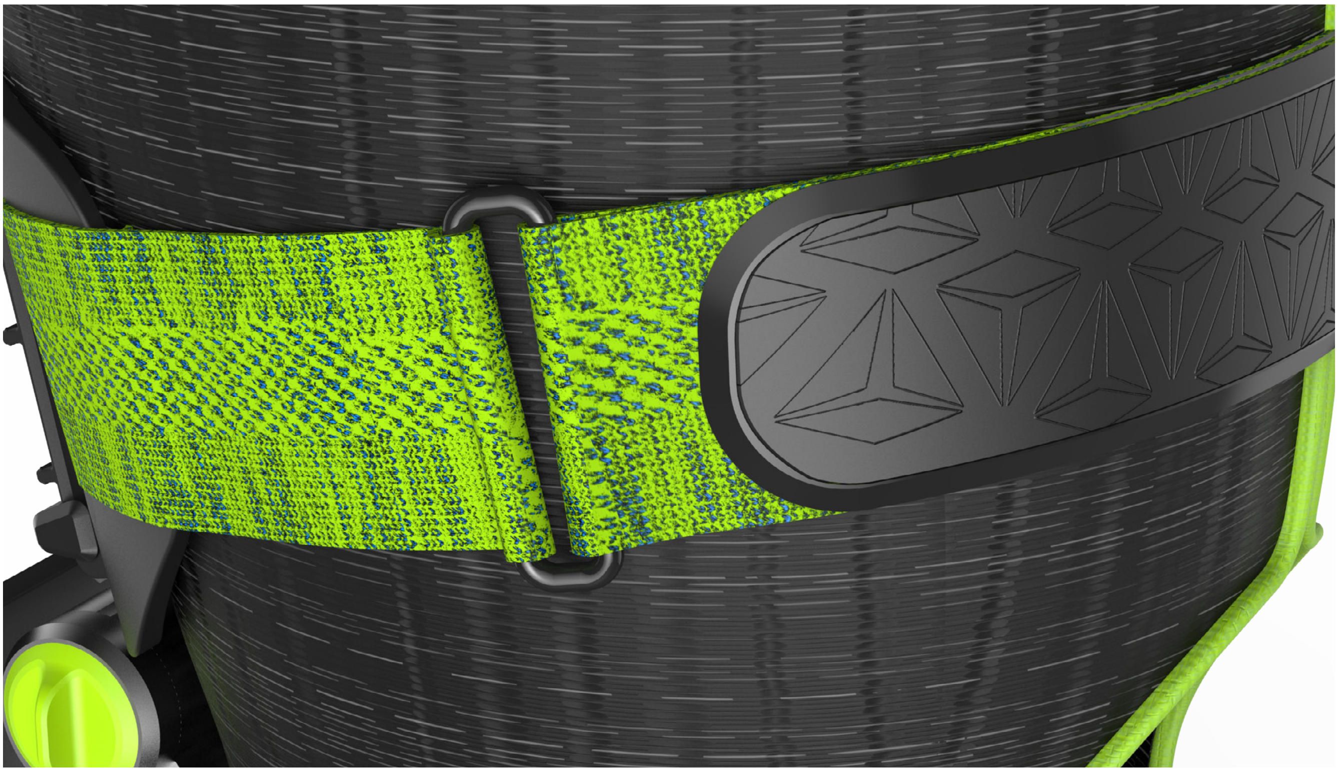
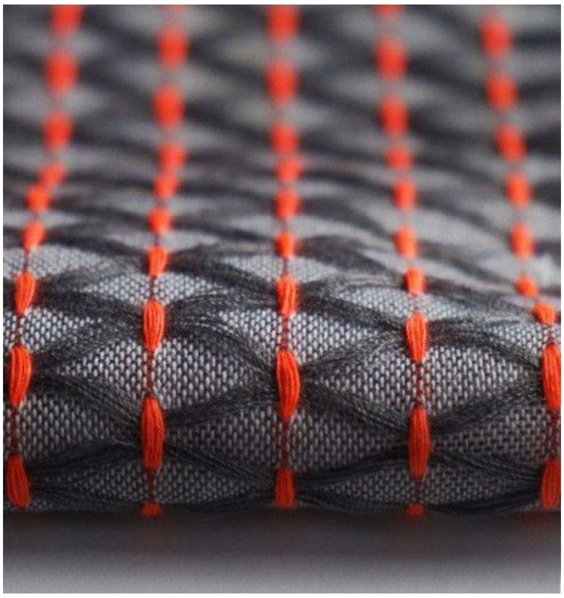
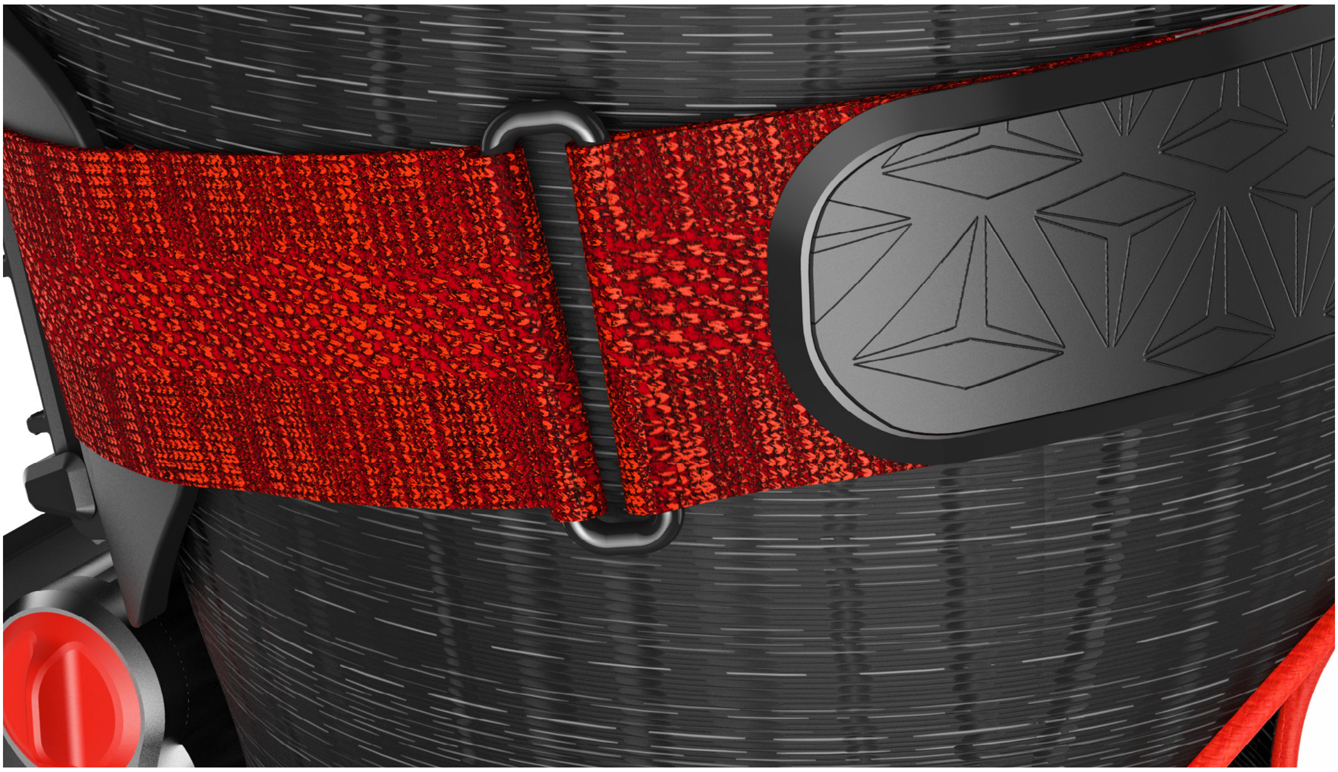


MOODBOARD | Cromatic proposal 2




SPLY-350



MOODBOARD | Cromatic proposal 3


Jabra


KEVLAR

6. Engineering product development

6.1 Materials selection

The engineering phase began with the definition of materials for all components, taking into account design constraints, functions and objectives.
At first, a generic choice was made on the material categories, and then, within each category of material, the most suitable material was chosen.

Energy harvesting system

As shown in Table (fig.207), these components must ensure leg support: they must have a good rigidity and they should be as light as possible.

FUNCTION	Motion control
CONSTRAINS	Stiffness Resistance to body weight Resistance to corrosion
GOALS	Lightness Minimize cost
VARIABLES	Material choise Geometry

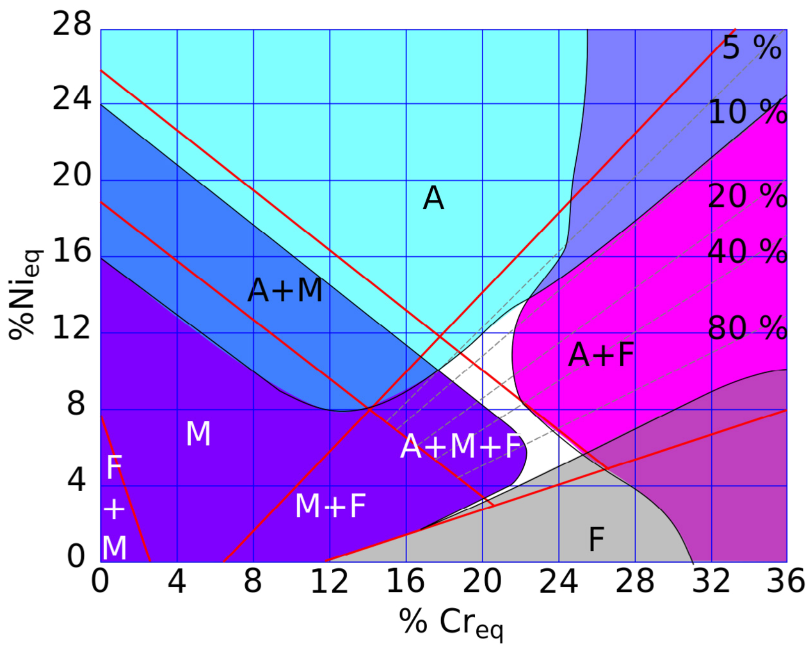
Tab. 8


M11
M12
M13
M14
M15
M16
M17
M18
M10
M1
M2
M3
M4
M5
M6
M7
M8
M9

Stainless steel, aluminum and titanium: these are the materials taken into consideration for the structural components of the mechanism. Comparative analysis took into account weight, mechanical and physical properties, cost.

Stainless steel

Stainless steel alloys are ferro-carbon-chromium alloys (often also nickel) with a density of 7.8-8 gr / cm3.
They are used for their good mechanical properties, excellent corrosion resistance (thanks to chromium> 12%) and good aesthetic value. Stainless steel alloys are divided into martensitic steels (denominated in series 200 and 300), ferritic and austenitic (belonging to the 400 series).
To get a snapshot overview, use the Schaeffler diagram where the steel grades are reported based on the percentage of chromium and nickel.



Scheme 29

Schaeffler diagram show the percentage of chromium and nickel.

The percentages of these elements affect the mechanical, physical properties and the cost of the alloys.
A synthetic comparison between martensitic, austenitic and ferritic steels is given in table (fig 210).

COST	ferritic > martensitic > austenitic
MEC.PROPERTIES	austenitic > ferritic > martensitic
CORROSION RES.	martensitic > ferritic > austenitic
WORKABILITY	ferritic > martensitic > austenitic

Tab. 9

Consider the constraints and functions of the mechanism's components, the chosen steel is **AISI 304** (0.06C-18Cr-8 / 10Ni) for its high corrosion resistance. This alloy belongs to the family of authentic steels with an elastic limit of about 200 MPa. The geometry of the two main components of the mechanism can be produced with the bending process: this consideration has influenced the choice of steel because the hardened austenitic steels can increase the elastic limit up to 800-1000 MPa.

AISI 304

MECHANICAL PROPERTIES	
HARDNESS / Brinell	123
HARDNESS / Knoop	138
HARDNESS / Rockwell	70
HARDNESS / Vickers	129
Tensile strength / Ultimate	505 MPa
Tensile strength / Yield	215 MPa
Elongation at break	70%
Modulus of Elasticity	193-200 Gpa
Poisson's Ratio	0,29
Shear Modulus	86 Gpa

Tab. 10

Aluminum alloys

Aluminum alloys have a density of about 2.7 g / cm3.
Their most important feature is the lightness, about 1/3 of that of steel. This feature, along with good corrosion resistance, makes aluminum alloys a possible solution for this components although aluminum alloys have lower mechanical properties than stainless steel.
Aluminum alloys (and pure aluminum) are classified with the Aluminum Association system, a 4-digit system where the first indicates the family:

- 1xxx: pure aluminum
- 2xxx: aluminum-copper alloys
- 3xxx: Aluminum-manganese alloys
- 4xxx: aluminum-silicon alloys
- 5xxx: Aluminum-magnesium alloys
- 6xxx: aluminum-magnesium-silicon alloys
- 7xxx: aluminum-zinc alloys
- 8xxx and 9xxx: different alloys

The alloy chosen is Al 7075 T6 belonging to the 7xxx series, these alloys have the highest tensile strength and mechanical properties higher than the other alloys.

Titanium alloys

Titanium has a density of 4.5 g / cm3 (1.7 times the density of aluminum and 60% of that of stainless steel).
Titanium alloys combine good lightness with excellent mechanical properties compared to steel.
Titanium alloys are divided into 3 categories (alpha, alpha + beta, beta) that have different properties.

MEC.PROPERTIES	alfa > alfa + beta > beta
WELDABILITY	beta > alfa + beta > alfa
WORKABILITY	beta > alfa + beta > alfa

Tab. 11

Even in this case, the choice was influenced not only by the functional constraints of the components but also by the production processes. The category that has the best compromise between mechanical properties and weldability is that alpha + beta. The chosen alloy was the **Ti 6Al 4V**, that is already used in the field of orthopedic prostheses.

The three alloys identified were then compared to find the best choice to use in the project.

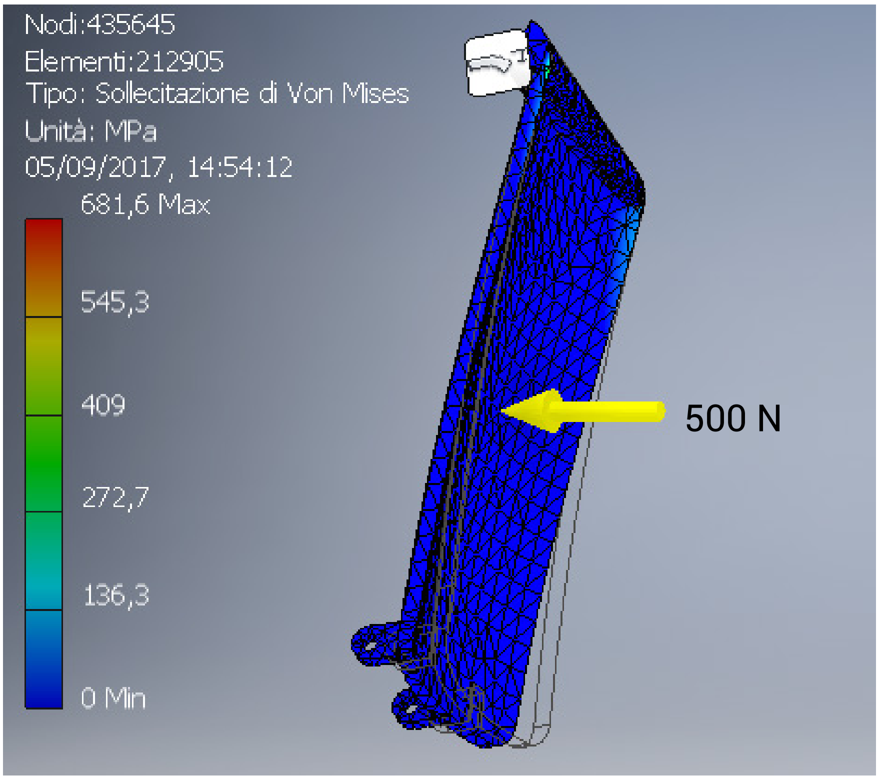
	Units	TI 6Al 4V	Al 7075 T6	AISI 304
Density	Kg/dm^3	4,4	2,7	7,9
Tensile strength	N/mm^2	902	600	587
Yield strength	N/mm^2	824	530	285
Stretching	%	12	8	54
Modulus of elasticity	(N/mm^2)	108.000	70.000	199.000
Cost	€/Kg			

Tab. 12

Since the goal is to **maximize the flexural strength and lightness**, the material that has a better relationship between these two qualities is **Al 7075 T6**.
To test the choice, a FEM analysis was performed to evaluate stress and deformation values on components that have higher stresses (M6 and M16 components).

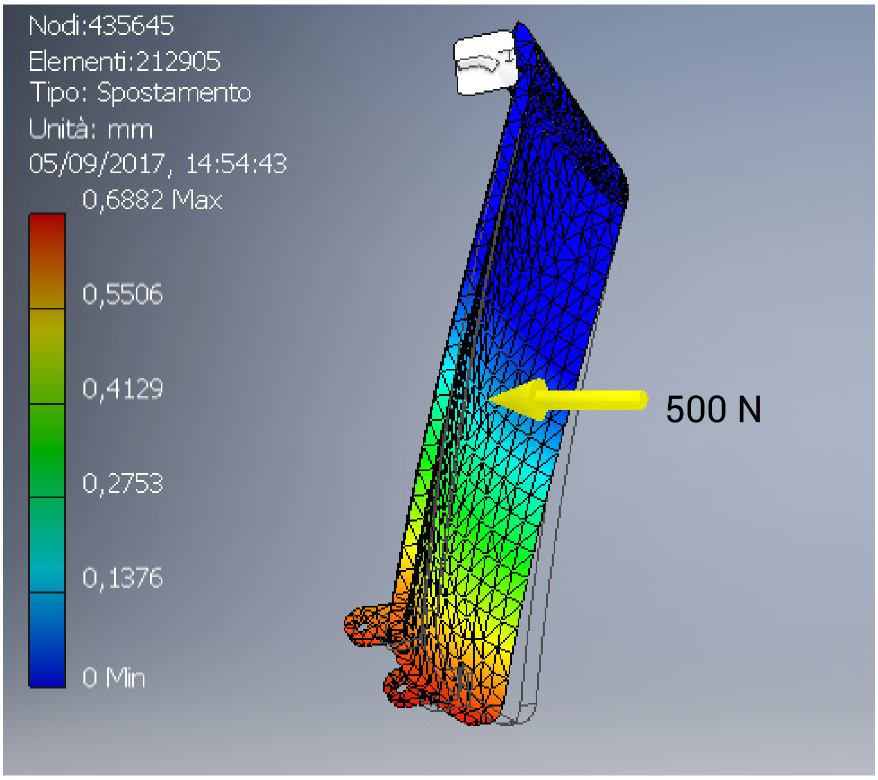
AISI 304 - Von Mises stress

MAX stress: 681 Mpa



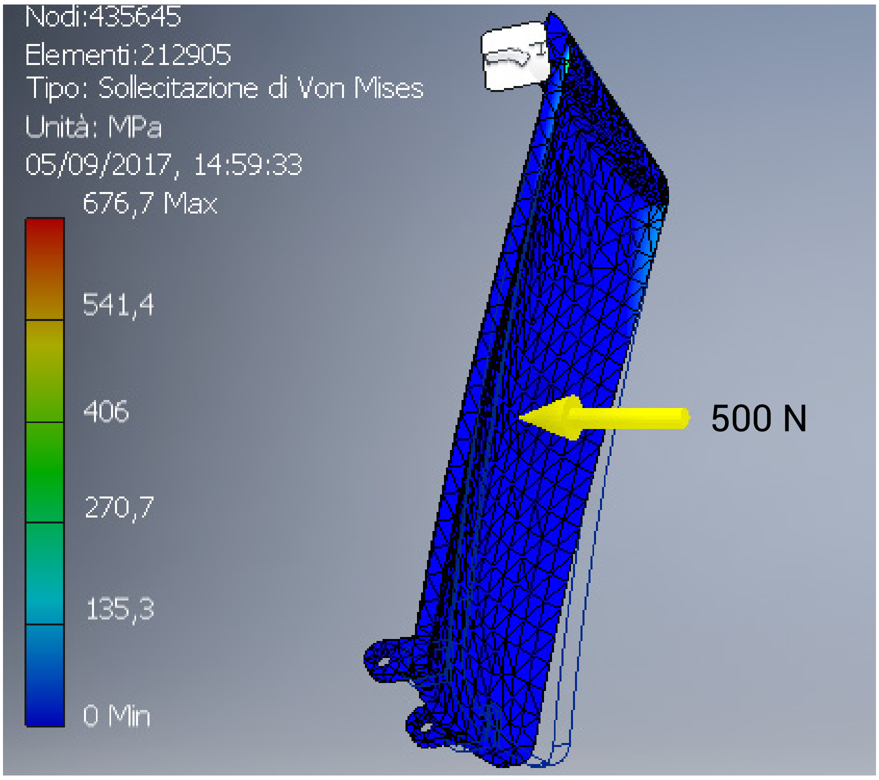
AISI 304 - U deformation

MAX deformation: 0,68 mm



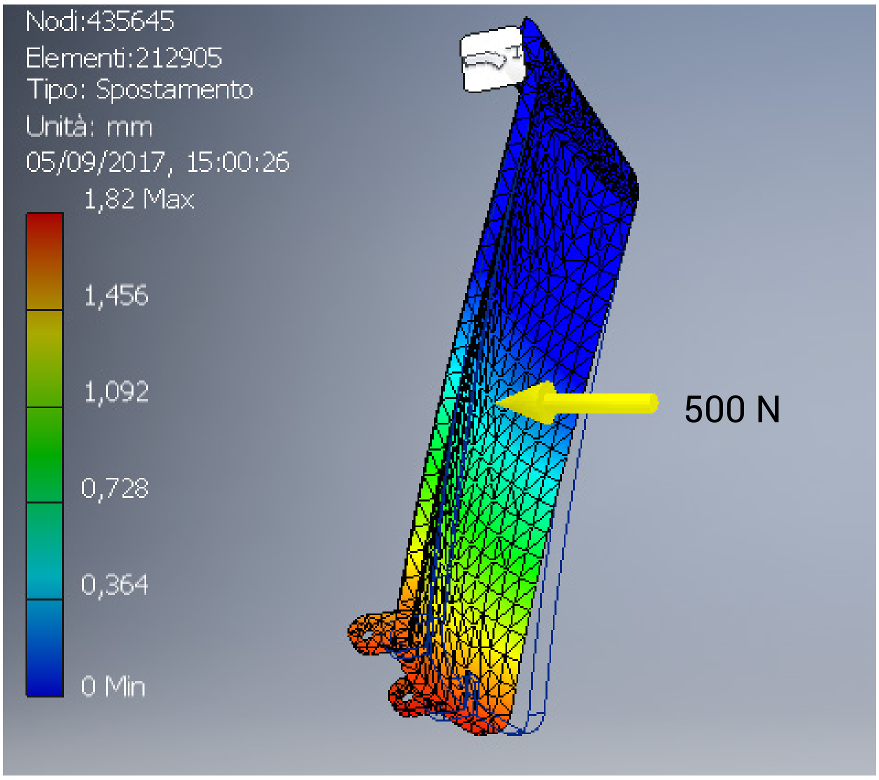
Al 7075 T6 - Von Mises stress

MAX stress: 676 Mpa



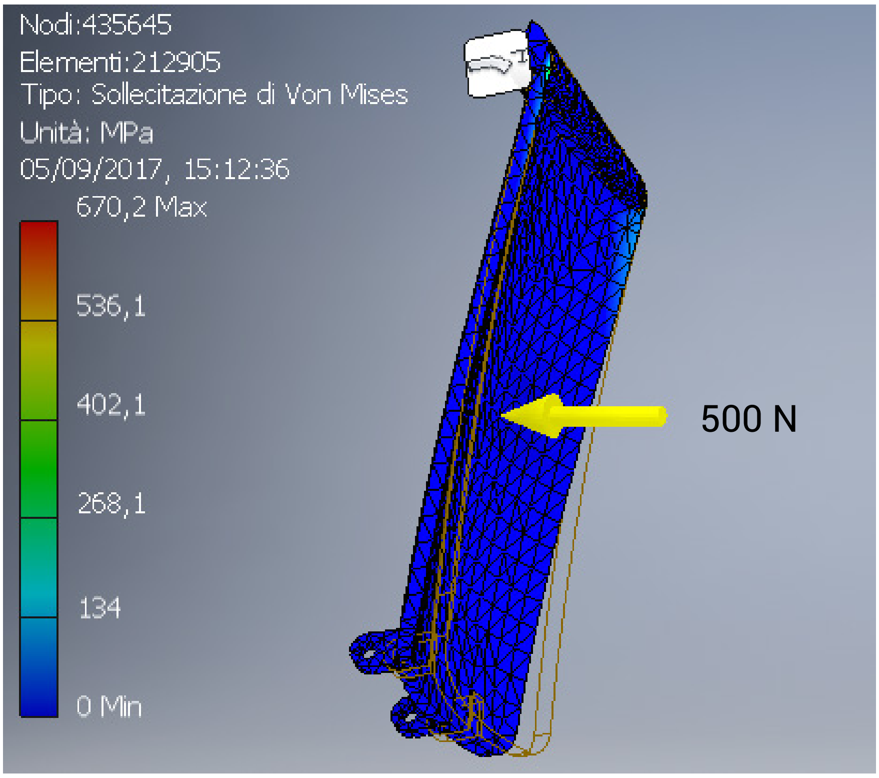
Al 775 T6 - U deformation

MAX deformation: 1,8 mm



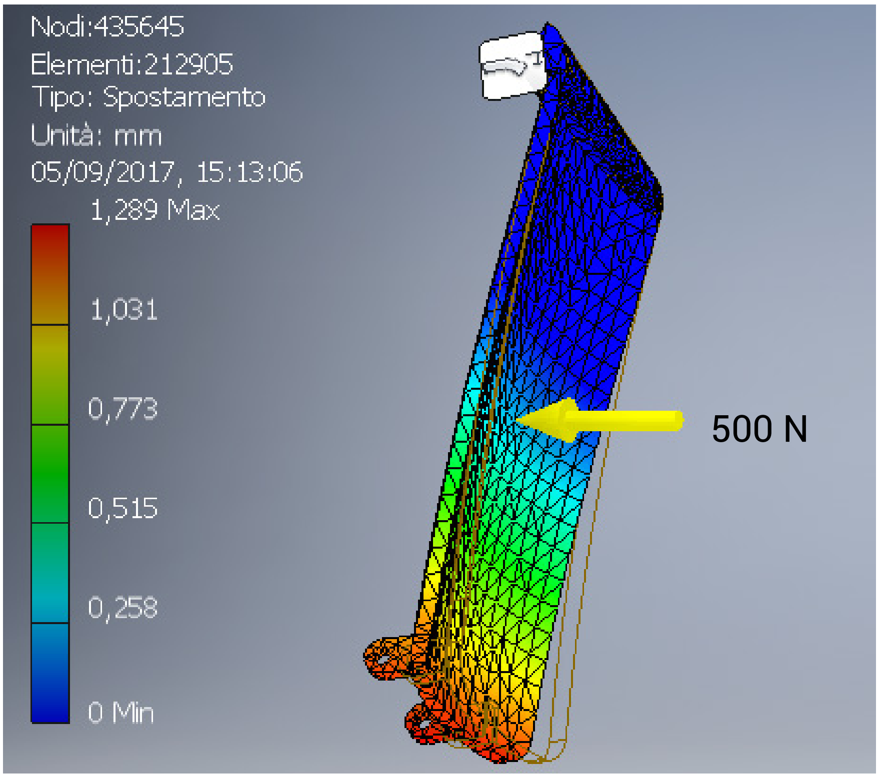
TI 6Al V4 - Von Mises stress

MAX stress: 670 Mpa



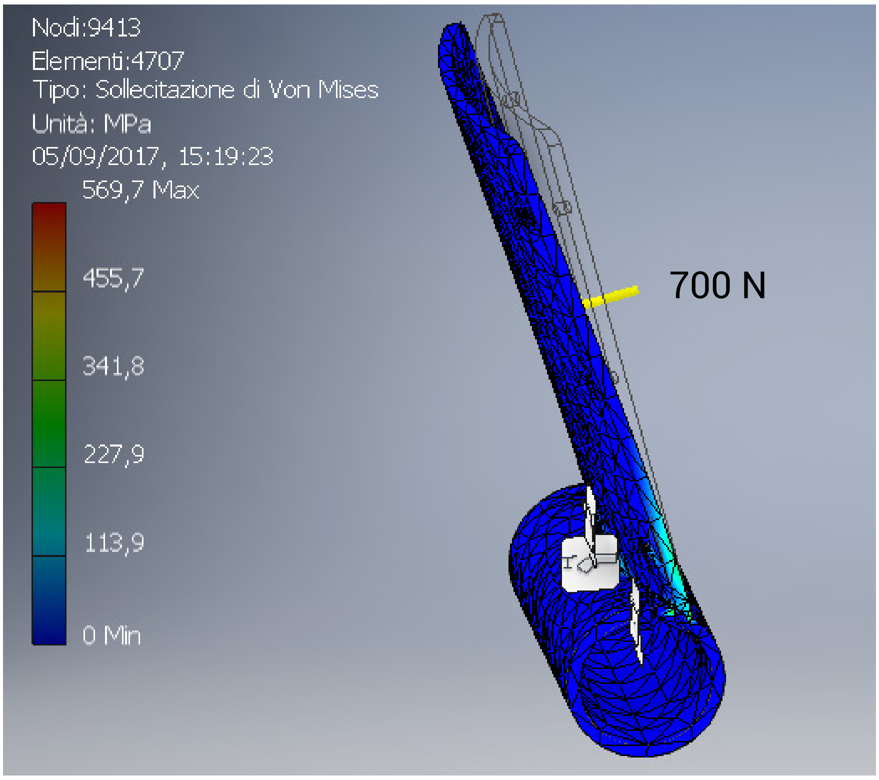
TI 6Al V4 - U deformation

MAX deformation: 1,28 mm



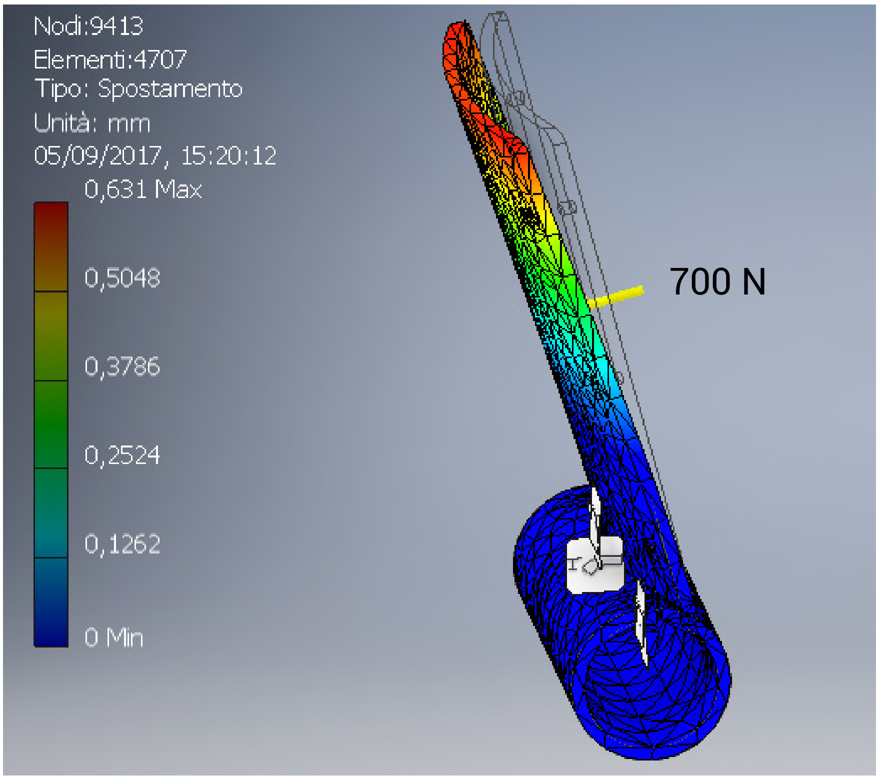
AISI 304 - Von Mises stress

MAX stress: 569 Mpa



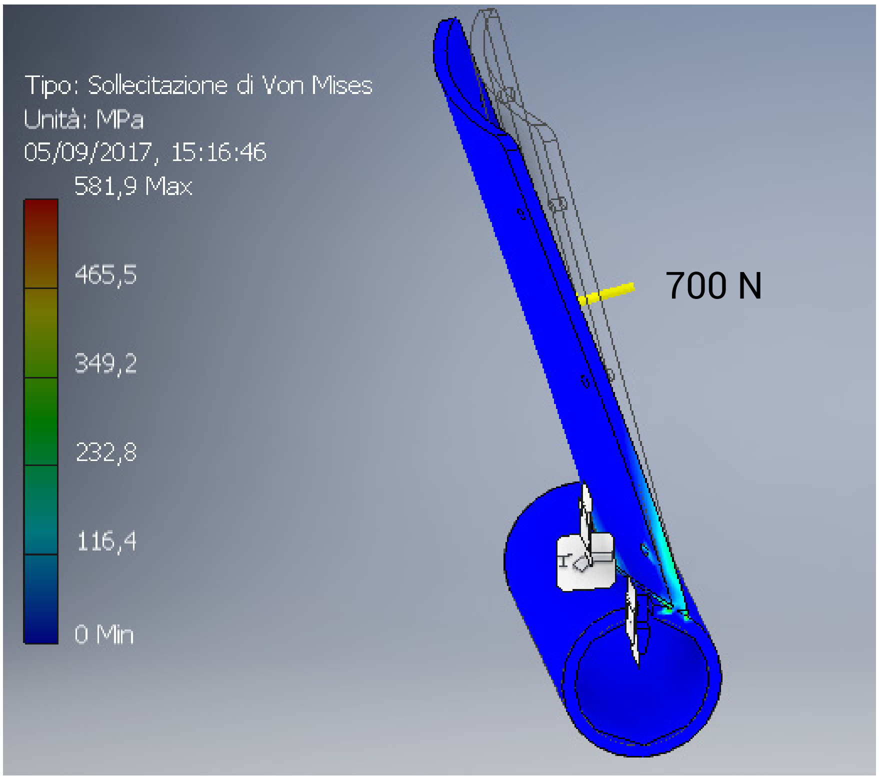
AISI 304 - U deformation

MAX deformation: 0,63 mm



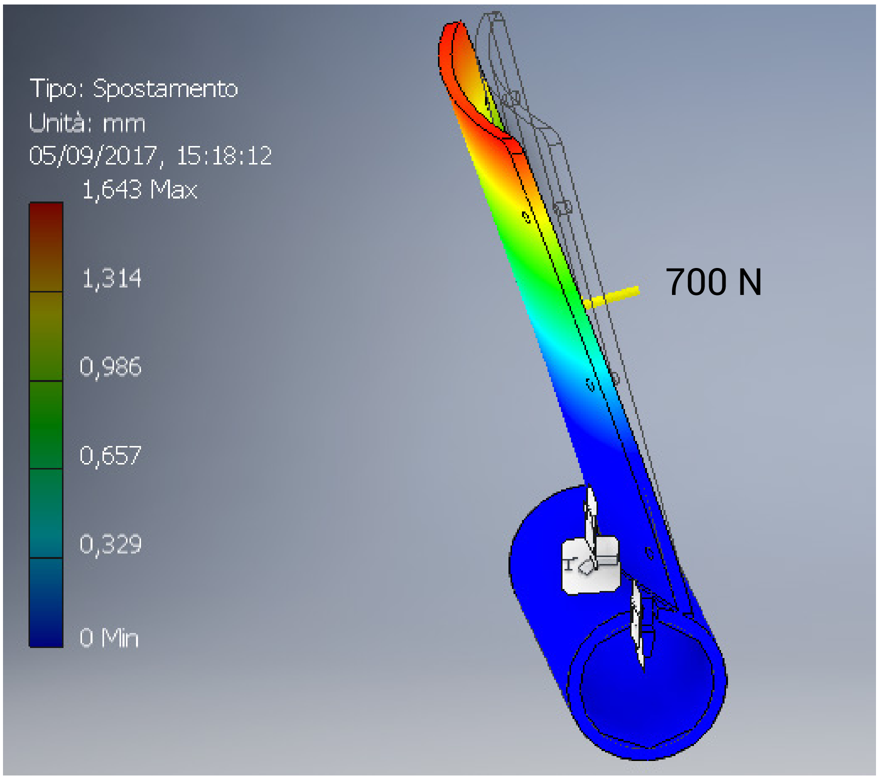
Al 7075 T6 - Von Mises stress

MAX stress: 581 Mpa



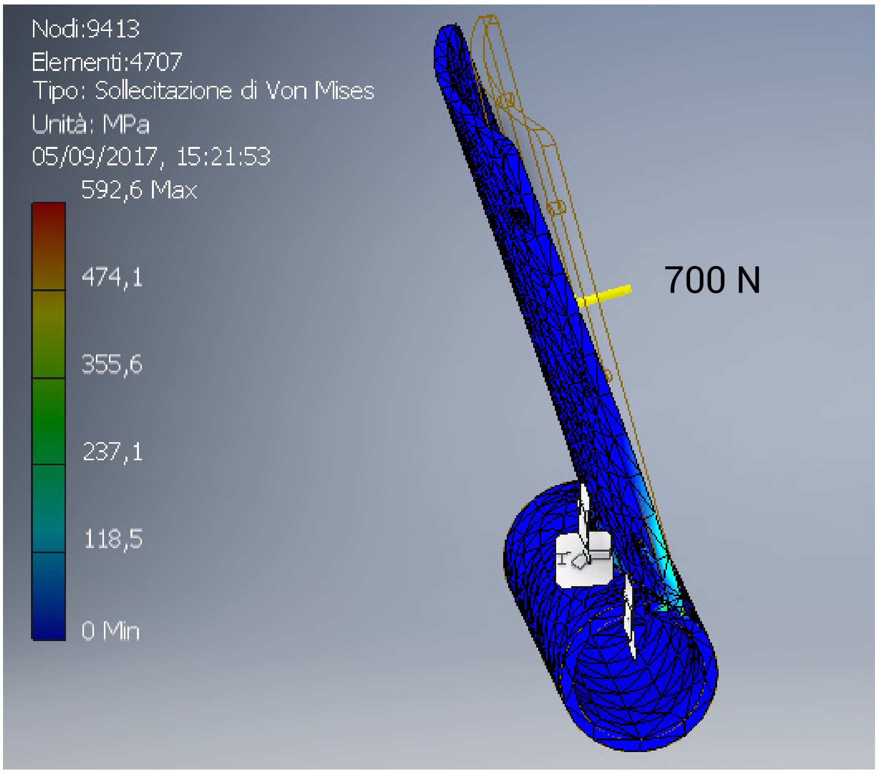
Al 775 T6 - U deformation

MAX deformation: 1,64mm



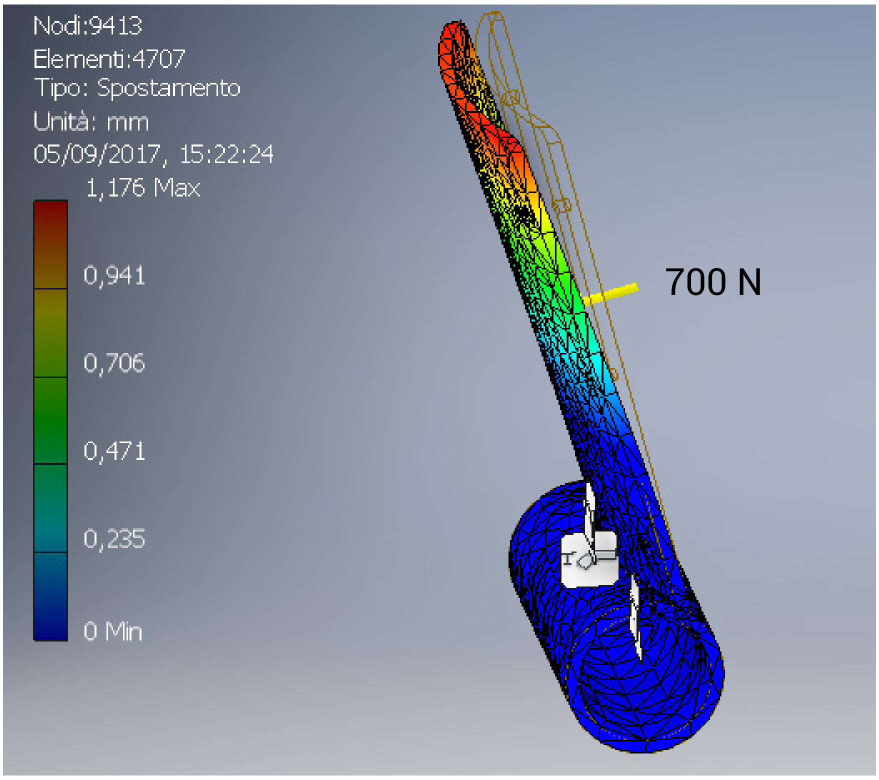
TI 6AI V4 - Von Mises stress

MAX stress: 592 Mpa



TI 6AI V4 - U deformation

MAX deformation: 1,17 mm



For some components of the mechanism (M3, M8, M13), a plastic material was chosen because the analysis of design constraints and objectives revealed cost minimization and maximization of lightness without the need for mechanical features such as metal alloys.

FUNCTION	Interaction / Movement range setting
CONSTRAINS	Stiffness Resistance to corrosion
GOALS	Great aesthetic finiture Lightness Minimize cost
VARIABLES	Material choise Geometry

Tab. 13

PP, PP-H and HDPE were analyzed for these components: these three crystalline polymers are low in cost, excellent workability and resistance to chemical and corrosive agents.

PP : It is a semi-crystalline thermoplastic material such as Polyethylene (PE), but it is more rigid and harder and merges at a higher temperature.
Polypropylene has high resistance to chemical agents, it is weldable and is normally used at temperatures between + 5 ° C and + 90 ° C.
Due to the non-polarity characteristics, the PP has an high chemical resistant: up to 120 ° C maintains its resistance properties in the presence of aqueous solutions containing strong salts, acids and alkalis.

PP-H: It has many of the features of PP, but thanks to the monomer chains it is made of, it has greater resistance and stability, but has a lower flexural strength.

HDPE: It is a very light thermoplastic polymer belonging to the polyethylene family. Its mechanical performances are higher than normal PE, but lower than PP-H. HDPE has good chemical stability, which makes it resistant to numerous solvents and chemicals, is resistant to saline, alcohol and gasoline solutions. HDPE (like PE) is only affected by oxidizing acids such as nitric acid, sulfuric acid and halogen.

The main features are:
• Excellent resistance to corrosion and chemicals
• Excellent resistance to abrasion
• Impact resistance
• Low coefficient of friction
• Easy to weld
• Good workability for tool stains
• Dimensional stability

	Units	PP	PP - H	HDPE
Density	gr/cm^3	0,85	0,90	0,96
Modulus of elasticity	GPa	1,34 - 1,59	2,61 - 3,38	0,91 - 0,96
Breaking strength	MPa	32,8 - 36,5	27,8 - 33,5	19,3 - 26,8
Stretching	% ²	160 - 600	6,80 - 13,2	170 - 800
Cost	€/Kg²	1,65	1,75	1,93

Tab. 14

The material chosen for these components is the PP-H for its mechanical characteristics.

For component M1, M4, M10, and M15, project constraint and target analysis highlighted cost minimization and maximization of lightness, but the need to have higher mechanical characteristics than PP-H.
For this reason, the PA6 GF30 was chosen; This material belongs to the polyamide family which has the best mechanical properties between the polymers.

FUNCTION	Control the piezoelectric contraction
CONSTRAINS	Good mechanical properties Stiffness Resistance to corrosion
GOALS	Lightness Minimize cost
VARIABLES	Material choise Geometry

Tab. 15

Compared to the normal PA6 types (PA6 6, PA6 10, PA6 12), the **PA6 GF30** h features much higher mechanical properties thanks to the fiberglass charge. The table gives a comparison of the mechanical properties of a generic PA6 and the PA6 GF30.

	Units	PA6	PA6 GF30
Density	gr/cm^3	1,15	1,4
Modulus of elasticity	GPa	2,4 -2,6	6,1 - 7,6
Tensile strength	MPa	66,5	110 - 140
Yield strength	MPa	37,5	120 - 150
Compressive strength	MPa	31	140 -160
Stretching	%	21	4,8 - 6,9
Cost	€/Kg	0,8 - 1	4

Tab. 16

For deformable parts that stabilize and fix the mechanism on the leg, expanded PU was chosen.

FUNCTION	Ergonomic function
CONSTRAINS	Flexible Good Softness Resistance to corrosion Washability
GOALS	Great aesthetic finiture Lightness Maximize comfort
VARIABLES	Material choise Geometry

Tab. 17

In this case, empirical evidence was determined to understand how the material deformed and was able to follow the shape of the leg.

The strips are made in Flyknit, a patented Nike material that has excellent breathability, washable and with a degree of elasticity ideal for this type of application.
The material was also chosen for its aesthetic characteristics as the particular weave.
The strips are joined together by a metal hollow.
The stitched component on the end of the strips is made of PU.

FUNCTION	fix the mechanism on the leg
CONSTRAINS	Great elastic elongation Adhering to the skin Washable Breathable
GOALS	High perceived value Lightness Maximize comfort
VARIABLES	Material choise Geometry

Tab. 18

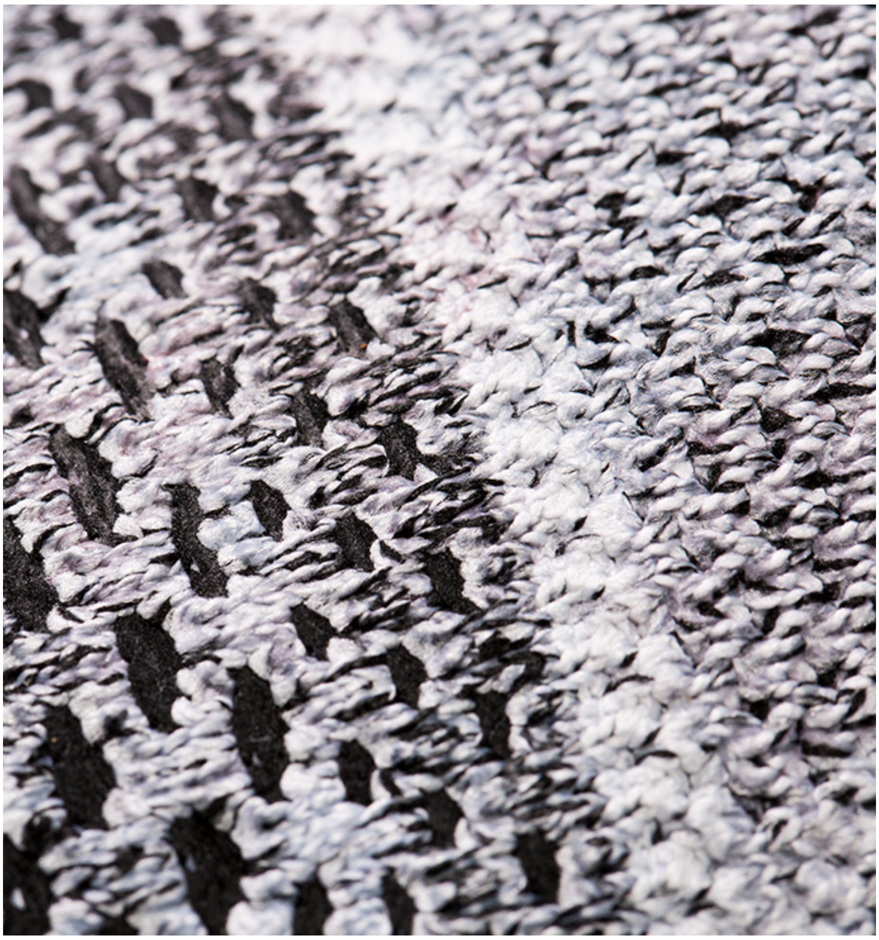


fig. 183

Fly-Knit fabric sample patented by Nike

Stocking

Stocking is made by **HEATGEAR®,** a very elastic and breathable fabric patented by Under Armor.
It is a form of polyester microfiber blended with elastane/ spandex that is light in weight and engineered to wick moisture away from the body and move it from the skin to the outer side of the garment where it can evaporate and help the wearer keep his or her body temperature lower. Unlike cotton, which is hydrophilic and soaks up the sweat until it is throughly wet, HEATGEAR® does not hold the moisture any longer than it takes to move it to the outer surface of the garment. Its elasticity gives a pleasant and light sensation on compression that also help to fix the electrodes.

FUNCTION	fix the electrodes on the leg
CONSTRAINS	Excellent elastic elongation Adhering to the skin Washable Breathable
GOALS	High perceived value Lightness Maximize comfort
VARIABLES	Material choise Geometry

Tab. 19

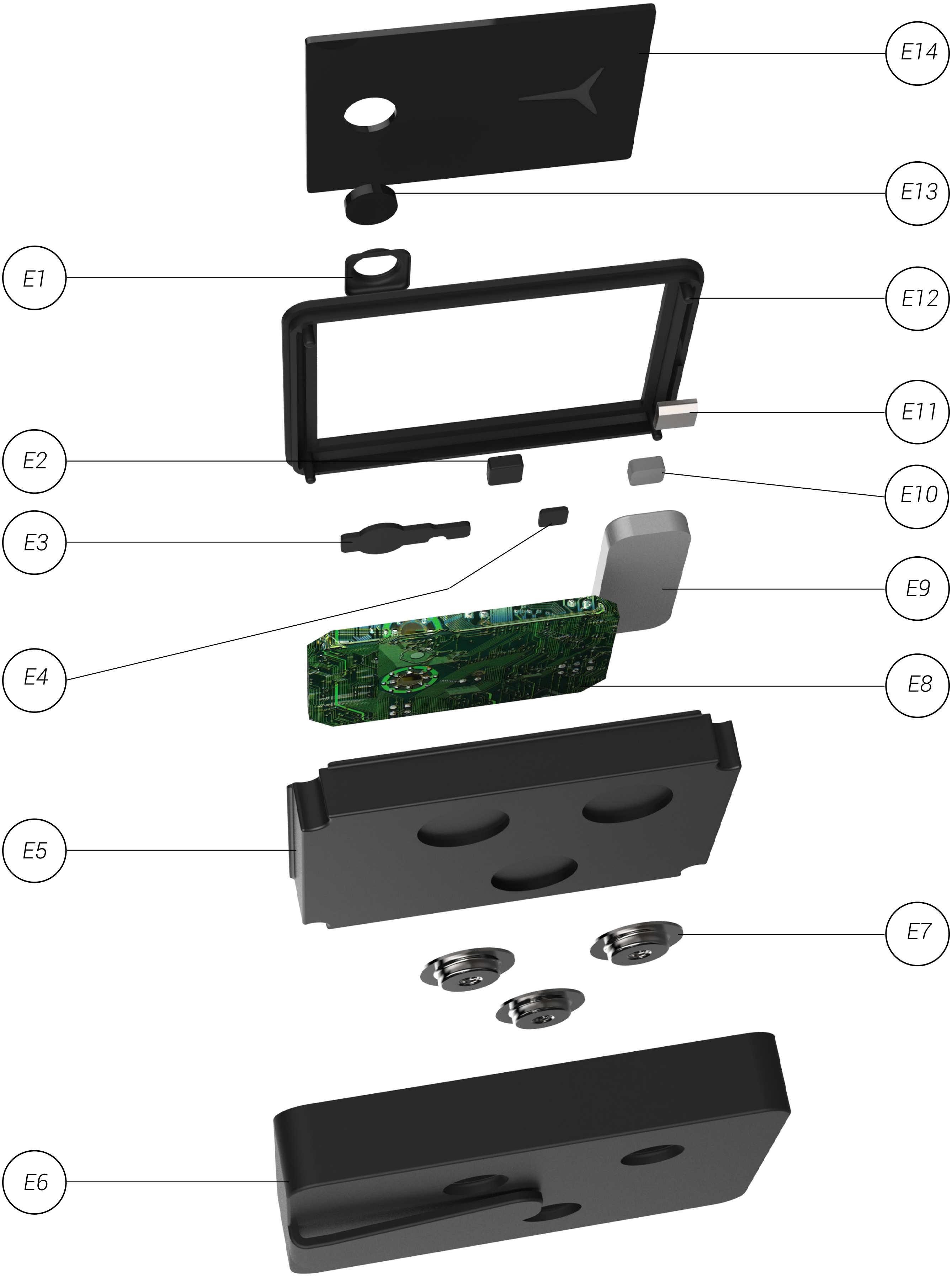
The conductive fabric is Circuitex, chosen for its lightness and the ability to create a specific fabric as needed. The physical properties of this fabric are only indicative, the company in fact produces the fabric following the customer's demands for an optimal result.
Circuitex fabrics are available in a range of conductive and construction options. Circuitex Filament yarns are continuous filaments. They can be monofilament or multifilament.
Clip buttons, conductive fabric and buy components like electrodes are sewn into the stocking fabric.

Electrostimulator

For components E2, E5 and E6, project constraint and target analysis highlighted the need to choose a shock resistant material, minimizing weight and cost.

FUNCTION	Contain the electrostimulator components
CONSTRAINS	Shock resistance Stifness Corrosion resistance
GOALS	Good aesthetic finitures Lightness Minimize cost
VARIABLES	Material choise Geometry

Tab. 20


E14
E13
E1
E12
E11
E2
E10
E3
E9
E4
E8
E5
E7
E6

Again, PP-H showed a good relationship between mechanical properties, cost, lightness, and injection molding ease.

The top component, however, has the main constraint on design to ensure transparency, which is why PC was made choosen.

6.2 Costs

After choosing the materials, an estimate of the costs was made assuming a production of 1000 pieces.
This fairly low quantity affects the final price because molds are needed for making some components.
Many parts required a geometry with organic shapes to fit the shape of the leg, in these cases the chosen procedures were casting for aluminum and injection molding for polimers.
Whenever possible, the components are designed to be manufactured with processes that do not require machine ammunition or expensive tools.
The **back shell of the electro stimulator** is made with SLA technology (3D print).
Since the geometry has a big undercut, a comparison among 3 different possible solutions was made:

- Injection molding with a mobile mold
- Split the geometry in 2 mold and than attach them with wlding process
- **3D technology**

In this case, mostly thanks to the relative small batch size of the production, SLA technology seems to have the best compromise between aesthetic result and cost.

MATERIALS, PROCESSES AND EQUIPMENT DETAILS *Batch size : 1.000 pc*	COST per PIECE **€**
Piezo top hook	
Al 7075 T6 --> 3€/kg --> 3€ x 0,003kg	0,009
Bending --> 24€/h --> 30sec	0,2
Welding --> 32€/h --> 60 sec	0,53
	TOT. 0,75 €
Back shell	
3D print (SLA technology) with PA12	**TOT. 11€**
Inner shell	
PP-H --> 1,7€/kg --> 1,7 x 0,003kg	0,005
Injectiom molding	
mold cost : 2.800€	2,8€
molding cost (20 sec. 55T)	0,1€
	TOT. 3€
Upper shell	
PP-H --> 1,7€/kg --> 1,7 x 0,003kg	0,005
Injectiom molding	
mold cost : 3.000€	3 €
molding cost (20 sec. 55T)	0,1€
	TOT. 3,2€
Upper strip renforced part	
PU expanded --> 3,2 €/kg --> 0,018x3,2	0,05
Injectiom molding	
mold cost : 2.800€	2,8€
molding cost (30 sec. 80T)	0,1€
	TOT. 2,95€
Lower strip renforced part	
PU expanded --> 3,2 €/kg --> 0,012x3,2	0,03
Injectiom molding	
mold cost : 2.800€	2,8€
molding cost (30 sec. 80T)	0,1€
	TOT. 2,90€

Tab. 21

MATERIALS, PROCESSES AND EQUIPMENT DETAILS *Batch size : 1.000 pc*	COST per PIECE **€**
Piezo bottom hook half1	
PA6 fb30 --> 3,8€/kg --> 3€ x 0,001kg	0,004
Injectiom molding	
mold cost : 2.400€	2,4
molding cost (20 sec. 55T)	0,1
	TOT. 2,5 €
Piezo bottom hook half1	
PA6 fb30 --> 3,8€/kg --> 3€ x 0,001kg	0,004
Injectiom molding	
mold cost : 2.400€	2,4
molding cost (20 sec. 55T)	0,1
	TOT. 2,5 €
Closure cap	
PP-H --> 1,7€/kg --> 1,7 x 0,001kg	0,002
Injectiom molding	
mold cost : 2.100€	2,1
molding cost (20 sec. 55T)	0,1
	TOT. 2,2 €
Upper support	
PU exp.--> 3,2 €/kg --> 3,2 x 0,047kg	0,15
Injectiom molding	
mold cost : 7.500€	7,5
molding cost (30 sec. 80T)	0,15€
	TOT. 7,8€
Lower support	
PU exp.--> 3,2 €/kg --> 3,2 x 0,066kg	0,21
Injectiom molding	
mold cost : 7.500€	7,5
molding cost (30 sec. 80T)	0,15€
	TOT. 7,86€

Tab. 22

MATERIALS, PROCESSES AND EQUIPMENT DETAILS *Batch size : 1.000 pc*	COST per PIECE **€**
Guide (dx e sx) x2	
PA6 fb30 --> 3,8€/kg --> 3€ x 0,002kg	0,008
Injectiom molding	
mold cost : 4.200€	4,2
molding cost (20 sec. 55T)	0,1
	TOT. 4,4 €
Piezo limiter	
PA6 fb30 --> 3,8€/kg --> 3€ x 0,001kg	0,004
Injectiom molding	
mold cost : 5.200€	5,2
molding cost (20 sec. 55T)	0,1
	TOT. 5,3€
Pivot bar pin	
PP-H --> 1,7€/kg --> 1,7 x 0,001kg	0,001
Injectiom molding	
mold cost : 1.100€	1,1
molding cost (20 sec. 55T)	0,1
	TOT. 1,2 €
Pivot bar	
Al 6061 -->bar diam. 3mm --> 20€/m	0,7
Milling 80€/h --> 30/40 sec.	0,8
	TOT. 1,5€
Rubber piezo cover	
polybutadiene->1,5€/kg ---> 1,5x0,001kg	0,001
Injectiom molding	
mold cost : 3.800€	3.8
molding cost (30 sec. 80T)	0,15€
	TOT. 3,95€

Tab. 23

MATERIALS, PROCESSES AND EQUIPMENT DETAILS *Batch size : 1.000 pc*	COST per PIECE **€**
Low central support	
Al 7075 A6 --> 3€/kg --> 3€ x 0,054kg	0,15
Casting	
material waste = 50% material	0,075
mold cost --> 3.500€	3,5
T process --> 30€/h --> 8 min.	4
Anodizing -->5€/m2	0,7
Drilling --> 50€/h --> 30 sec.	0,4
	TOT. 8,8 €
Cap	
Al 7075 A6 --> 3€/kg --> 3€ x 0,007kg	0,02
Casting	
material waste = 50% material	0,001
mold cost --> 2.000€	2
T process --> 30€/h --> 7 min.	3,5
Anodizing -->5€/m2	0,1
	TOT. 5,6 €
Transmission	
Al 7075 A6 --> 3€/kg --> 3€ x 0,003 kg	0,01
Casting	
material waste = 50% material	0,005
mold cost --> 2.000€	2
T process --> 30€/h --> 7 min.	3,5
Anodizing -->5€/m2	0,1
Bar -->50cmx10€	1,15
Milling --> 80€/h	0,7
Welding --> 32€/h --> 30sec.	0,3€
	TOT. 7,8€

Tab. 24

MATERIALS, PROCESSES AND EQUIPMENT DETAILS *Batch size : 1.000 pc*	COST per PIECE **€**
Terminal transmission	
Al 7075 A6 --> 3€/kg --> 3€ x 0,003 kg	0,01
Casting	
material waste = 50% material	0,005
mold cost --> 2.000€	2
T process --> 30€/h --> 7 min.	3,5
	0,1
	TOT. 5,7€
Electro stimulator top cover	
PC sheet --> 122x122x0,2 cm --> 68€	0,13
Laser cutting --> 50€/h , 6m/min	0,04
Spray coating --> 30€/m2	0,08
	TOT. 0,25 €
Buttonhole	
Stainless steel beam --> 5€x0,6m	0,8
Spray coating --> 30€/m2	0,02
	TOT. 0,82€
Upper central support	
Al 7075 A6 pipe --> 6€x1m	0,2
Al 7075 A6 --> 1x1m 71€	0,35
Anodizing -->5€/m2	0,7
Drilling --> 50€/h --> 1 min.	0,85
	TOT. 2,20€
Velcro upper strip	
velcro --> 50x1000mm -->50x207mm	**TOT. 2,20€**
Velcro lower strip	
velcro --> 50x1000mm -->50x145mm	**TOT. 1,6€**
Velcro (mechanism) x2	
velcro --> 50x1000mm -->50x60mm	**0,7€**

Tab. 25

Final considerations

At the end of the design process it's appropriate to make some general considerations about the project.
Looking at the E-knee concept it is possible to see how every stage of the research has contributed to making improvements and new interesting aspects in a particular industry such as the electrostimulation.
The general degree of complexity of the project has allowed me to handle various aspects of design, from the most technical and engineering aspect to semiotics, visual elements and aesthetic choices.
All of these phases have been developed, always taking in consideration the holistic vision of the project, coherent with the goals I wanted to achieve.
The use of piezoelectric materials to establish a link between body motion and battery charging has proved to be the hardest problem I have faced in my design path.
I have been able to deepen my knowledge of piezoelectric materials, understanding their future potential especially in the wearable environment.
While seems to be true that these technologies will be able to feed small systems with low energy consumption, it is equally true that the use of a piezoelectric material to fully charge a battery of an electrostimulator is currently difficult because of the high energy consumption these therapies require.
After these considerations, I decided to deal with the difficulties and apparent limitations, transforming them into project opportunities that could have given value to my project.
For this reason, I decided to use a piezoelectric material that could carry both battery and sensor recharge function in order to monitor physical activity.
The physical properties of the chosen piezoelectric material have influenced the design of the mechanism that manages both to control and limit the flexion of the knee

and to create a slight spring effect (effect caused by the plastic deformation of the piezoelectric plate) which can motivate the user by helping him in the first stages of leg extension thanks to a return of energy.
I am sure that in the future, thanks to the advancement of technology and new studies on piezoelectric materials, it will be possible to obtain more efficient systems that can fully charge the batteries of an electrostimulator, and devices such as smartphones and PCs.
This will not only save money and reduce the impact on the environment, but will also increase motivation in carrying out physical activity, with obvious improvements in people's health and lifestyle.

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fig. 143 *https://cdn5.kicksonfire.com/wp-content/uploads/2017/07/CLOT-x-Nike-Air-VaporMax.jpg?x77385,*

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fig. 145 *https://cdn5.kicksonfire.com/wp-content/uploads/2017/07/CLOT-x-Nike-Air-VaporMax.jpg?x77385,*

fig. 146 *http://sds.parsons.edu/designmanagement/files/2013/10/3019090-poster-1280-nike.jpg,*

fig. 147 *made by Stefano Morazzoni*

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fig. 151 *https://i.pinimg.com/564x/7e/37/1c/7e371c0a17a2aef3ae86d844854c1799.jpg,*

fig. 152 *https://i.pinimg.com/originals/37/0f/bd/370fbd842c-208c5c3878624313b6bdf1.jpg,*

fig. 153 *https://cdn.shopify.com/s/files/1/0214/7974/products/Jordan_Pants_Black-Gym_red-2.jpg?*

fig. 154 *https://s3.amazonaws.com/nikeinc/assets/50160/SP16_BSTY_Tights_Speed-Tight_Detail1_07_original.jpg?1447944255,*

fig. 155 *https://i.pinimg.com/736x/09/60/cf/0960cfeb9d17dc062e889fd1dd9e2319--nike-running-jacket-running-pants-women.jpg,*

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fig. 161 *https://stockx.imgix.net/Nike-Air-VaporMax-Dark-Grey.png?fit=fill&b-g=FFFFFF&w=1400&h=1000&auto=format&trim=color,*

fig. 162 *https://i.pinimg.com/736x/e6/a8/a6/e6a8a6a9b1ae008c56127a458120fb51.jpg,*

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fig. 164 *https://s3.amazonaws.com/nikeinc/assets/50158/SP16_BSTY_Tights_Nike-Pro_HypercoolMax_Detail3_03_original.jpg?1447944222,*

fig. 165 *http://brain-images.cdn.dixons.com/2/2/10133822/l_10133822_002.jpg,*

fig. 166 *https://www.mistertennis.com/images/dunlop/623525_C.jpg,*

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fig. 184 *https://images.solecollector.com/complex/image/upload/t_cmplx_featured_cover/sole-collector-macro-sneaker-materials_ah_26_grlfkp,*

fig. 185 *made by Stefano Morazzoni*

Tables

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tab. 2 *made by Stefano Morazzoni*

tab. 3 *made by Stefano Morazzoni*

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tab. 24 *made by Stefano Morazzoni*

tab. 25 *made by Stefano Morazzoni*

Schemes

1. *made by Stefano Morazzoni*

2. *http://wewatt.com/wp-content/uploads/2015/03/WeWatt-Kiosk-round-setup-3.jpg,*

3. *https://i.ytimg.com/vi/XI7FfrlTchM/maxresdefault.jpg,*

4. *http://wewatt.com/wp-content/uploads/2015/03/WeWatt-Kiosk-round-setup-3.jpg,*

5. *http://sds.parsons.edu/designmanagement/files/2013/10/3019090-poster-1280-nike.jpg,*

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7. *made by Stefano Morazzoni*

8. *made by Stefano Morazzoni*

9. *http://www.ptonline.it/media/k2/items/cache/4b9f9da50cf2f358abdcd4a4321104f9_XL.jpg,*

10. *made by Stefano Morazzoni*

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20. *https://i.ytimg.com/vi/z0A0FtVxS4Y/maxresdefault.jpg,*

21. *made by Stefano Morazzoni*

22. *http://cdn.nocamels.com/wp-content/uploads/2014/07/Ray-coverImage1-runner.jpg,*

23. *http://www.uluvassu.it/grafici/*

24. *made by Stefano Morazzoni*

25. *https://s-media-cache-ak0.pinimg.com/originals/de/dd/9e/*

26. *https://images.solecollector.com/complex/image/upload/t_cmplx_featured_cover/sole-collector-macro-sneaker-materials_ah_26_grlfkp,*

27. *http://media.tio.ch/files/images/4bhj/45wt.jpg?v=1,*

28. *made by Stefano Morazzoni*

29. *https://www.rm-style.com/armocromia-analisi-del-colore/*

Thanks

I would like to thank my thesis rapporteur, Professor Matteo Ingaramo, who led me during the drafting of this thesis project with valuable criticisms and advice.
Special thanks to my co-rapporteur, Professor Giuseppe Andreoni, who with patience and kindness helped me throughout the design phase on various technical aspects and not only.
I also thank Professor Giacomo Claudio Ghiringhelli of the Physics Department (Politecnico di Milano) for the help during the definition of some project's technical aspects. A great thank goes to Professor Mario Bisson, not only for the precious thesis advice, but because even after the bachelor degree he has always been available to give me very useful advice for my professional and personal growth.

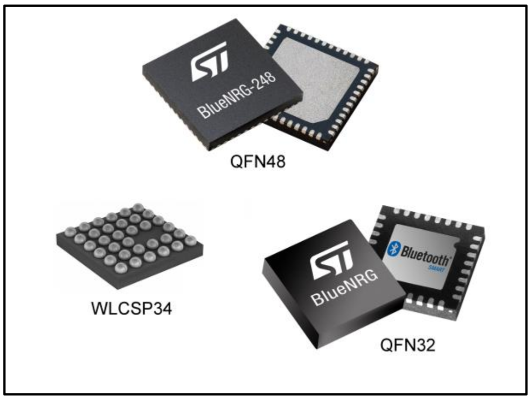
At the end my greatest thanks goes to my family who has always supported and encouraged me during these years. I dedicate to them the achievement of this goal and this thesis, because with their love I have taught values much more important than any kind of academic title.

Technical documents

BlueNRG-2

Bluetooth® low energy wireless system-on-chip

Datasheet - production data



Features

- Bluetooth low energy single mode system-on-chip compliant with Bluetooth 4.2 specification:
  - master, slave and multiple simultaneous roles
  - LE Data Packet Length Extension
- Operating supply voltage: from 1.7 to 3.6 V
- Integrated linear regulator and DC-DC step-down converter
- Operating temperature range: -40 °C to 105 °C
- High performance, ultra-low power Cortex-M0 32-bit based architecture core
- Programmable 256 KB Flash
- 24 KB RAM with retention (two 12 KB banks)
- 1 x UART interface
- 1 x SPI interface
- 2 x I²C interface
- 14, 15 or 26 GPIOs
- 2 x multifunction timer
- 10-bit ADC
- Watchdog & RTC
- DMA controller
- PDM stream processor
- 16 or 32 MHz crystal oscillator
- 32 kHz crystal oscillator
- 32 kHz ring oscillator
- Battery voltage monitor and temperature sensor
- Up to +8 dBm available output power (at antenna connector)
- Excellent RF link budget (up to 96 dB)
- Accurate RSSI to allow power control
- 8.3 mA TX current (@ -2 dBm, 3.0 V)
- Down to 1 µA current consumption with active BLE stack (sleep mode)
- Suitable for building applications compliant with the following radio frequency regulations: ETSI EN 300 328, EN 300 440, FCC CFR47 Part 15, ARIB STD-T66
- Pre-programmed bootloader via UART
- QFN32, QFN48 and WCSP34 package options

Applications

- Watches
- Fitness, wellness and sports
- Consumer medical
- Security/proximity
- Remote control
- Home and industrial automation
- Assisted living
- Mobile phone peripherals
- Lighting
- PC peripherals

Table 1: Device summary table

Order code	Package	Packing
BlueNRG-232	QFN32 (5 x 5 mm)	Tape and reel
BlueNRG-248	QFN48 (6 x 6 mm)	Tape and reel
BlueNRG-234	WLCSP34	Tape and reel

This is information on a product in full production.

CREE

PRODUCT FAMILY DATA SHEET

CLD-DS32 REV 6F

Cree® XLamp® MX-3S LEDs

PRODUCT DESCRIPTION

The Cree XLamp® MX-3S LED provides the proven lighting-class performance and reliability of Cree XLamp LEDs in a high-voltage, PLCC configuration. All members of the MX-family of LEDs have a wide viewing angle, uniform light output without secondary optics, unlimited floor life and electrically neutral thermal path.

The XLamp MX-3S LED brings high performance and quality of light to a range of lighting applications that require near-line-voltage configuration, including LED light bulbs, fluorescent retrofits and retail-display lighting.

FEATURES

- Available in white (2600 K to 8300 K CCT)
- Wide viewing angle: 120°
- 10.7 VDC nominal with voltage binning available
- Electrically neutral thermal path
- Qualification at maximum drive current
- RoHS and REACh compliant
- UL® recognized component (E349212)

TABLE OF CONTENTS

Cree, Inc.
4600 Silicon Drive
Durham, NC 27703
USA Tel: +1.919.313.5300

CHARACTERISTICS

Characteristics	Unit	Minimum	Typical	Maximum
Thermal resistance, junction to solder point	°C/W		11	
Viewing angle (FWHM)	degrees		120	
Temperature coefficient of voltage	mV/°C		-13	
ESD withstand voltage (HBM per Mil-Std-883D)	V			8000
DC forward current	mA			175
Reverse voltage	V			-5
Reverse current	mA			-0.1
Forward voltage (@ 115 mA)	V		10.7	12.0
LED junction temperature	°C			150

FLUX CHARACTERISTICS (T_J = 25 °C)

The following table provides several base order codes for XLamp MX-3S LEDs. It is important to note that the base order codes listed here are a subset of the total available order codes for the product family. For more order codes, as well as a complete description of the order-code nomenclature, please consult the XLamp MX LED Family Binning and Labeling document.

Color	CCT Range		Minimum Luminous Flux (lm) @ 115 mA		Order Code
	Minimum	Maximum	Group	Flux (lm)	
Cool White	5000 K	8300 K	R2	114	MX3SWT-A1-0000-000E51
			Q5	107	MX3SWT-A1-0000-000D51
Warm White	3700 K	4300 K	Q4	100	MX3SWT-A1-0000-000CE5
			Q3	93.9	MX3SWT-A1-0000-000BE5
	2600 K	3700 K	Q3	93.9	MX3SWT-A1-0000-000BE7
			Q3	87.4	MX3SWT-A1-0000-000AE7

Notes:

- Cree maintains a tolerance of ±7% on flux and power measurements, ±0.005 on chromaticity (CCx, CCy) measurements and ±2 on CRI measurements. See the Measurements section (page 7).
- Typical CRI for Cool White (4300 K – 8300 K CCT) is 75.
- Typical CRI for Warm White (2600 K – 4300 K CCT) is 80.

SPECIFICATIONS	RCM6700	RCM6710	RCM6750	RCM6760
FEATURES				
MICROPROCESSOR	Rabbit® 6000 up to 200 MHz			
NETWORK INTERFACE	10/100Base-T (Ethernet signals only)	10/100Base-T RJ-45 connector	10/100Base-T (Ethernet signals only)	10/100Base-T RJ-45 connector
FLASH MEMORY (CODE AND FILE SYSTEM)	1 MB serial Flash		4 MB serial Flash	
INTERNAL SRAM (CODE AND DATA)	1 MB			
BATTERY-BACKABLE SRAM	32 KB (Internal)		32 KB (Internal), 1 MB (External)	
FLEXIBLE INTERFACE MODULE(FIM)	400 MHz DRPIC165X CPU 1k program/192 bytes data RAM			
MASS STORAGE	On-board serial Flash			
GENERAL-PURPOSE I/O	Up to 32 parallel digital I/O			
SERIAL PORTS	6 high-speed, CMOS compatible ports, 4 configureable as clocked serial (SPI)			
SERIAL RATE	Maximum asynchronous baud rate = CLK/8			
REAL-TIME CLOCK	Yes			
TIMERS	Ten 8-bit timers (6 cascadable from the first) , one 10-bit timer with 2 match registers			
WATCHDOG/SUPERVISOR	Yes			
PULSE WIDTH MODULATORS	4 channels synchronized PWM with 10-bit counter ; 4 channels variable-phase or synchronized PWM with 16-bit counter			
I^2C	1 channel, standard (100 Kbits/s) and (400 Kbits/s) clock modes			
QUADRATURE DECODER	2-channel quadrature decoder accepts inputs from external incremental encoder modules			
INPUT CAPTURE	2-channel input capture can be used to time input signals from various port pins			
POWER - WITH ETHERNET	210 mA @ 3.3V	250 mA @ 3.3V	250 mA @ 3.3V	260 mA @ 3.3V
POWER - WITHOUT ETHERNET	120 mA @ 3.3V	130 mA @ 3.3V	130 mA @ 3.3V	140 mA @ 3.3V
OPERATING TEMPERATURE	-40° C to +85° C			
SUPPORTED PROTOCOLS	HTTP, HTTPS, SSLv3, DHCP, UDP, TCP, SNMP, Telnet, FTP, TFTP, SMTP, POP3			
HUMIDITY	5% to 95%, non-condensing			
CONNECTORS - HEADERS	52-pin Mini PCI Express	52-pin Mini PCI Express RJ-45 10/100Base-T connector	52-pin Mini PCI Express	52-pin Mini PCI Express RJ-45 10/100Base-T connector
BOARD SIZE	1.20” x 2.00” x 0.12” (30 mm x 51 mm x 3 mm)	1.20” x 2.00” x 0.70” (30 mm x 51 mm x 18 mm)	1.20” x 2.00” x 0.27” (30 mm x 51 mm x 7 mm)	1.20” x 2.00” x 0.73” (30 mm x 51 mm x 19 mm)

PART NUMBERS	DESCRIPTION
20-101-1318	RCM6700
20-101-1319	RCM6710
20-101-1320	RCM6750
20-101-1321	RCM6760
101-1326	RCM6700 Deluxe Development Kit
101-1327	RCM6700 Standard Development Kit

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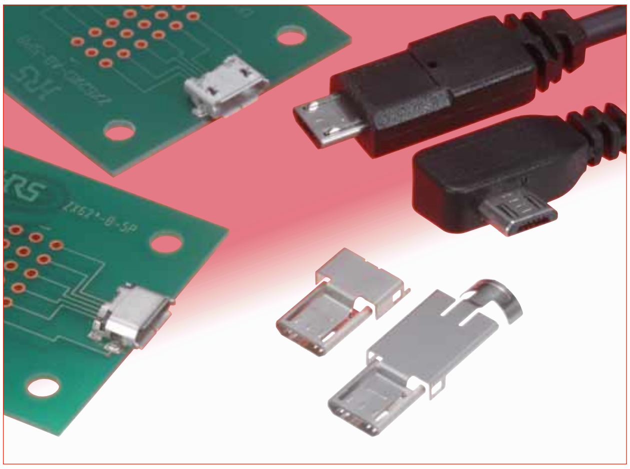
Micro-USB connectors meeting USB 2.0 Standard

ZX Series



Note: Contact us to ascertain whether a TID number has been acquired for an individual product.

Fig.1

■Overview

Extremely small highly reliable connectors complying with physical, electrical and environmental requirements of Micro-USB standard (USB 2.0).
Receptacles and plugs are available in a wide variety of mounting and termination styles, allowing their use in various applications.

■Features

1. Size reduction

Compared with the standard Mini-USB connectors, the size of ZX connectors is reduced by approximately 60% while still allowing a high-speed data transfer of 480 Mbps, specified in USB 2.0.

2. Receptacle styles

Two interface configurations: Micro-B and Micro-AB in standard, mid-mount and reverse mounting styles.
SMT and through-hole (shell) PC board terminations.

3. Plug styles

Corresponding to the receptacle styles, two interface configurations: Micro-A and Micro-B, with direct wire or PCB wire soldering.
Several plug styles can be used for data transmission, earphone or charging applications.

4. Smooth mating and unmating

A smooth mating and unmating operation results in less wear and a longer product life. The unique Hirose active latch mechanism produces a reliable and durable connector.
Even after repeated use, the user will experience a smooth click sensation when mating the connectors.
Note: The statement above only applies when using both plug and receptacles made by Hirose Electric.

5. Hirose was the first company to obtain a Micro-USB certification (TID number).

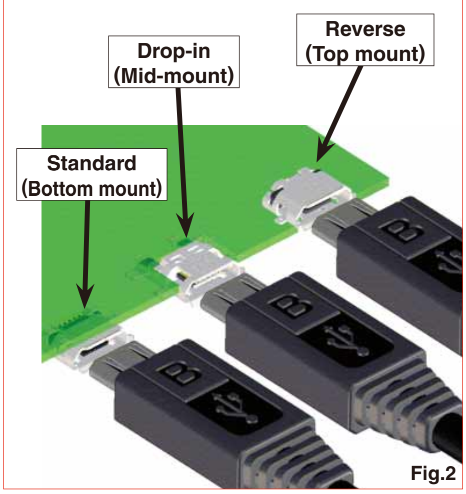


Fig.2

USB 2.0 Hi-Speed (480 Mbps)

Eye diagram measurement results:
Measured with 2.4 m long USB 2.0 cable

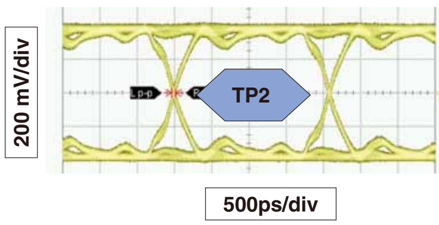
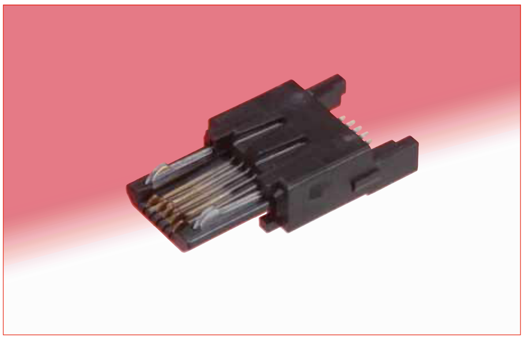


Fig.3

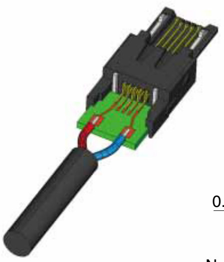
■Plugs

●Micro B - Assembly (insulator/contacts/lock) - Right angle SMT

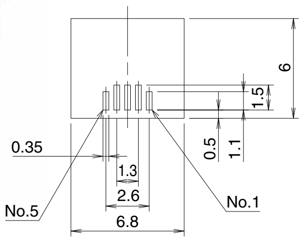


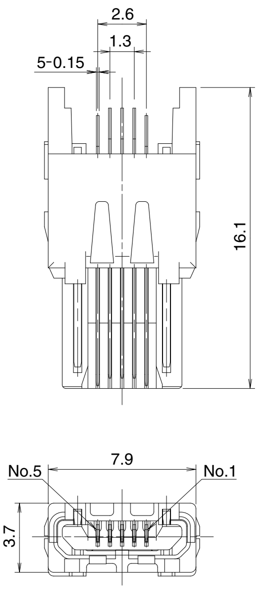
Part No.	HRS No.	Packaging
ZX64-B-5S-UNIT(31)	242-0009-3 31	1 piece

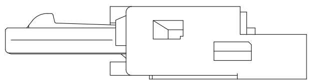
Contact HRS for Cable Termination Procedure Manual.



PCB mounting pattern
∗PCB required (not supplied)
Max. thickness: 1.0mm

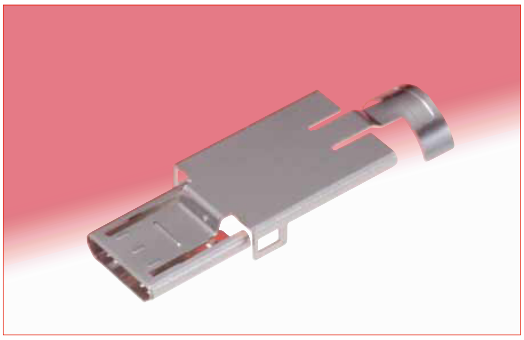




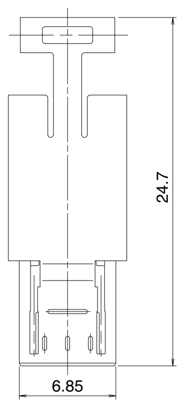


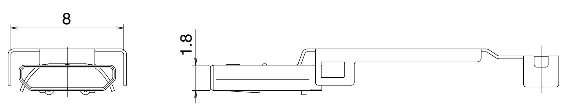
All dimensions : mm

●Micro B - Component, Cover-top – Right angle SMT



Part No.	HRS No.	Packaging
ZX64-B-SLDA	242-0013-0	4,000 pcs/reel

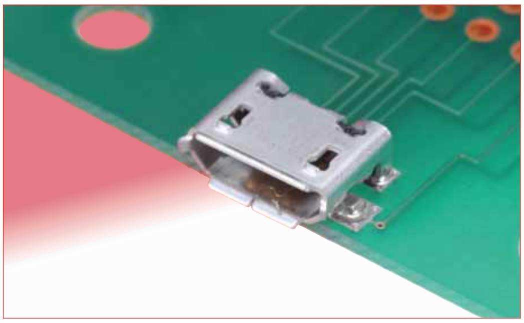




All dimensions : mm

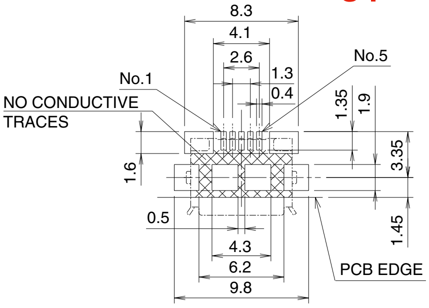
■Receptacles

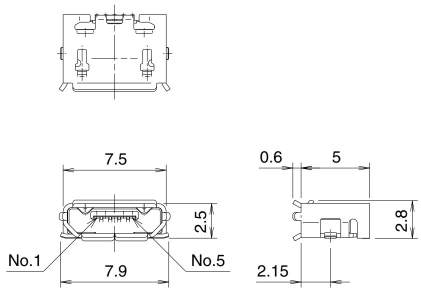
●Micro B - Standard (Bottom mount), Shell SMT



Part No.	HRS No.	Packaging
ZX62-B-5PA(33)	242-0033-8 33	3,500pcs/reel

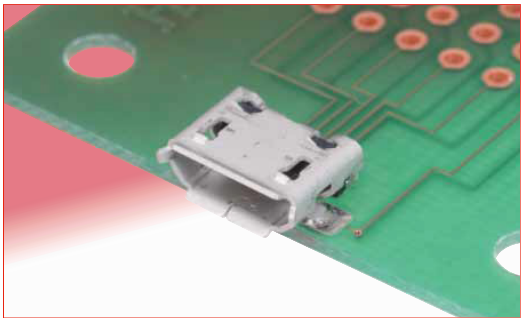
◆Recommended PCB mounting pattern





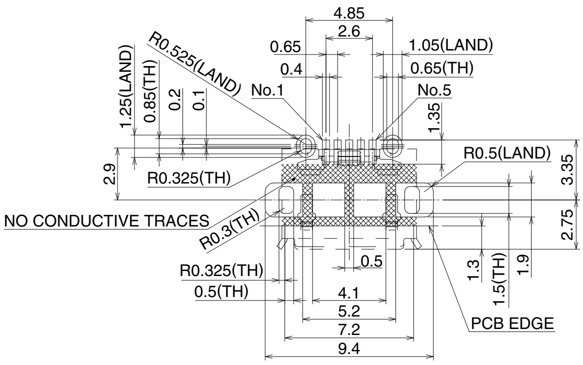
All dimensions : mm

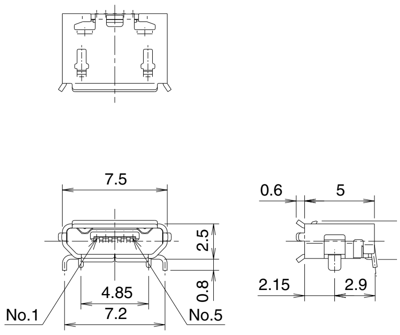
●Micro B - Standard (Bottom mount), Shell through hole



Part No.	HRS No.	Packaging
ZX62D-B-5PA8(30)	242-0056-3 30	2,000pcs/reel

◆Recommended PCB mounting pattern

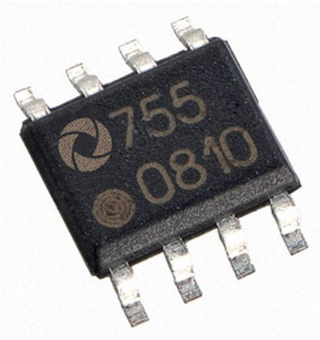




All dimensions : mm

Transducer

Sensitec magnetic transducer AFF755BHA-AD, Analog, 1 MHz switching frequency, voltage 1,2 to 9 V



Product Details

Magnetic Resistive Field Sensors AFF755
AFF775 Sensitec low-noise magnetic field sensors are based on the AMR effect (anisotropic magnetoresistant effect) and are equipped with a Wheatstone bridge. It also includes a mobile reel for offset correction.
The AFF775 magnetic field sensors are ideal for detecting weak magnetic fields, including the planet Earth.

Features and Benefits

- Extreme sensitivity
- Wide range of magnetic field intensity
- Low power consumption
- Low coil resistance
- Good signal-to-noise ratio

Battery

Producer: Samsung SDI

Type: flat cell

Code: PCF441435

Dimensions (mm): 4.4x14x35 mm

Charge density: 210 mAh

Site: http://www.samsungsdi.com/lithium-ion-battery/it-devices/wearable-device.html

Home key set (camble + button)

Manufacturer / Retailer: 0365Italia

Name: Key Home Iphone Button Spare Parts

Part code: IT_GSM004091

Dimensions (mm): 11 * 9 * 0.6 mm

Weight (g): 15 tot.

Quantity: 1

Price: 2,2 €

Site: http://www.0365italia.com/

Aukru USB wall charger, Micro USB cable

Input: AC 100-240V 0.3 a, 50/60 Hz

Output: DC 5V, 2000mA

Compatible with all smartphones (Samsung, Sony, Nokia, LG, HTC, Blackberry etc.) cameras and other USB tablet devices requiring 2A charge current; Apple Charger Cable Required for Apple Device: iPhone 5 / 5S / 6 / 6s / 6 Plus, iPad Air, Mini iPad

Steel clip buttons (50 pieces)

Cost: 3€ (x 50 pieces)

Dimensions: 9,5 mm diameter

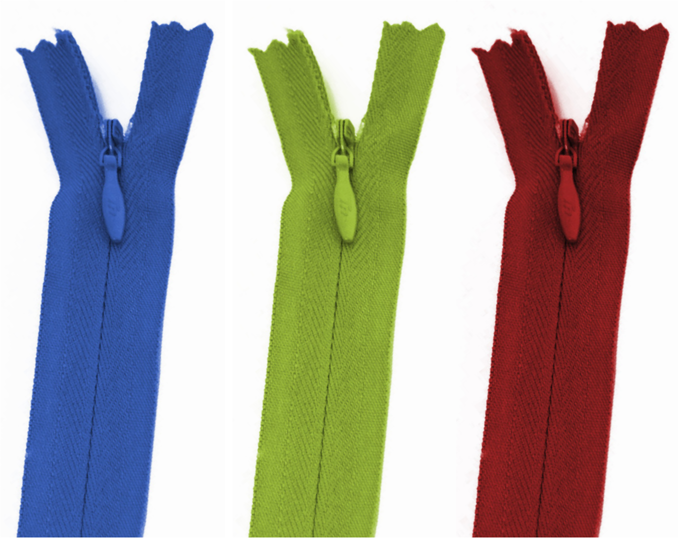
ZIP

Producer: janus

Dimensions (mm): 20 mm x 5m

Cost: 6,99€

Site: http://www.merceriaonline.eu



Electrodes

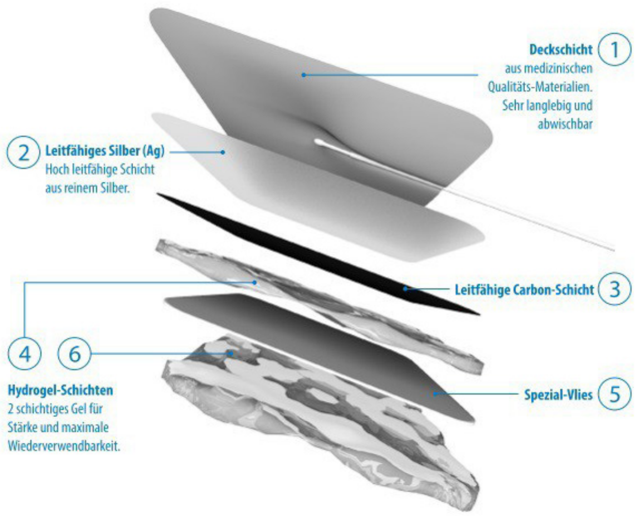
Producer: Gima

Code: 28366

Dimensions (mm): 40 x 60 mm

Cost: 23 € x 10 pc

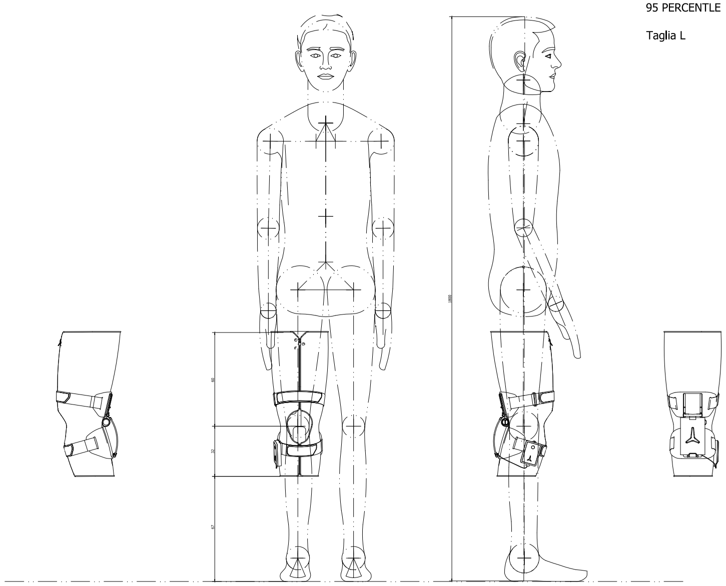
Site: http://www.ebay.it/itm/Gima-28366



Riferimenti antropometrie: HDFS Chapter 14 Ed. 2009

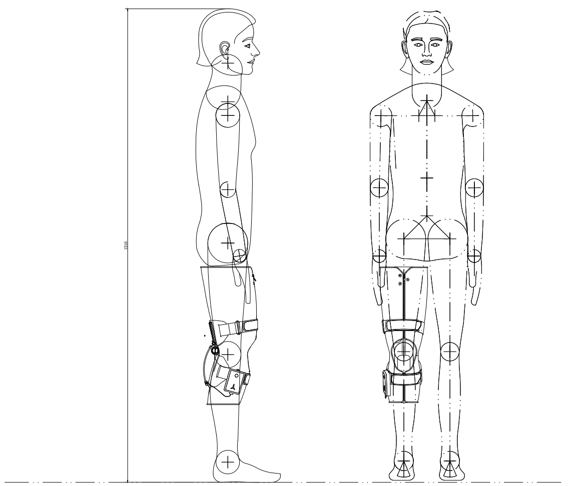
95 PERCENTLE

Taglia L



5 PERCENTLE

Taglia S



	circonferenza coscia (cm)	circonferenza polpaccio (cm)	altezza (cm)
Taglia S	124	49	555
Taglia M	143	54	585
Taglia L	178	57	615

	0000xx	Xxxxxxxx	Xxxxxxxxxxxxx Xxxxxx	x,xx	
NUMERO DI PEZZI	CODICE Part number	DENOMINAZIONE Part name	MATERIALE - DATI TECNICI Technical data, designation	PESO UN. Unit Wt., kg	NOTE Notes

TIPO DI DOCUMENTO Document type: Antropometria

AUTORE Created by: Morazzoni Stefano

VERIFICATO DA Approved by

DATA DI EDIZIONE Date of issues: 2017.10.04

PROGETTO Project: E-Knee

RELATORE: Matteo Oreste Ingaramo

CORRELATORE: Giuseppe Andreoni

STUDENTE: Morazzoni Stefano

INSIEME Assembly: Xxxxxxxx

GRUPPO Sub-assembly drawing: Xxxxxxxx

PARTICOLARE Part: Xxxxxxxx

Rev | App'd | Date: 01, 02, 03, 04

CODICE - Part number: 000xxx

SCALA Scale: 1:5

Logo

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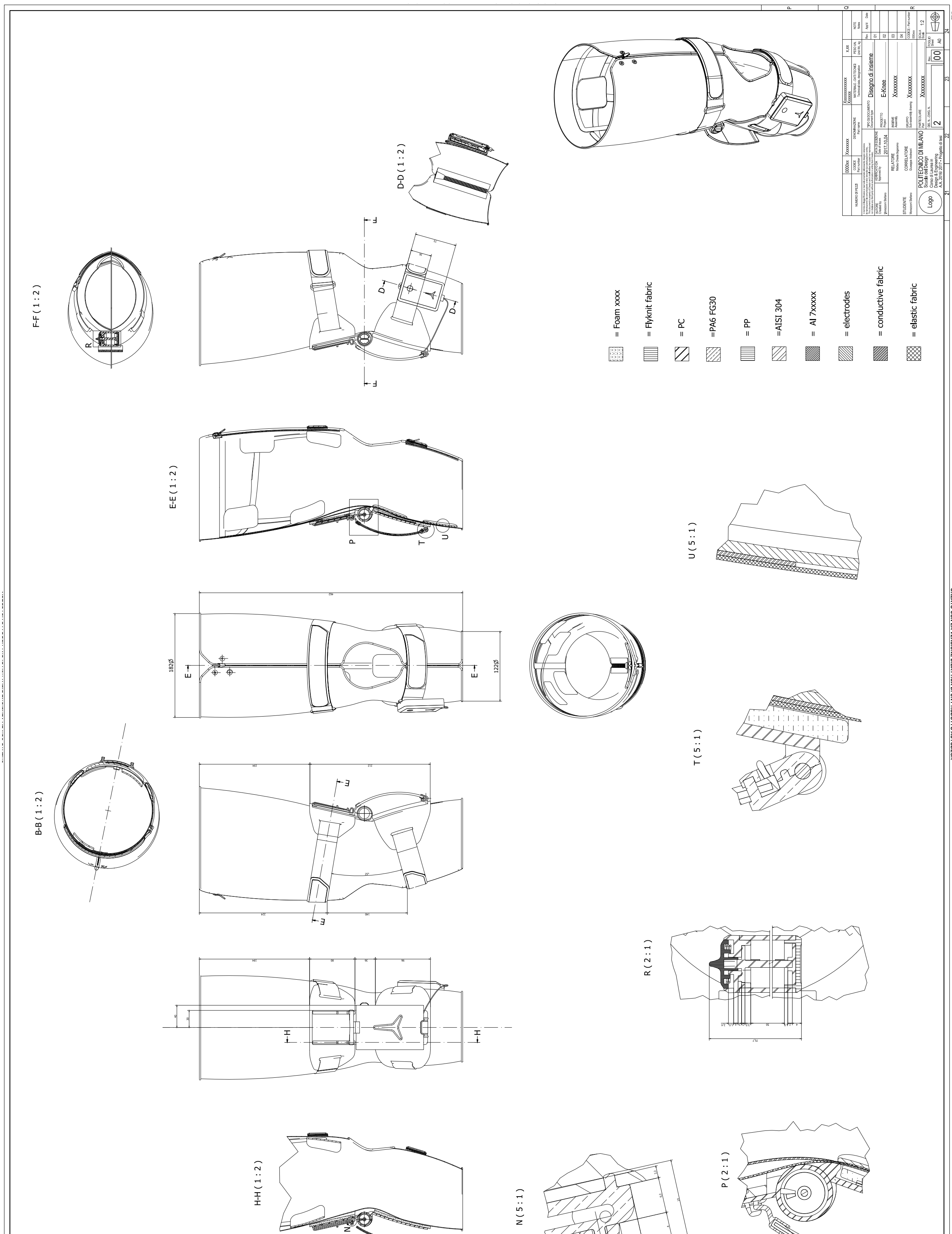
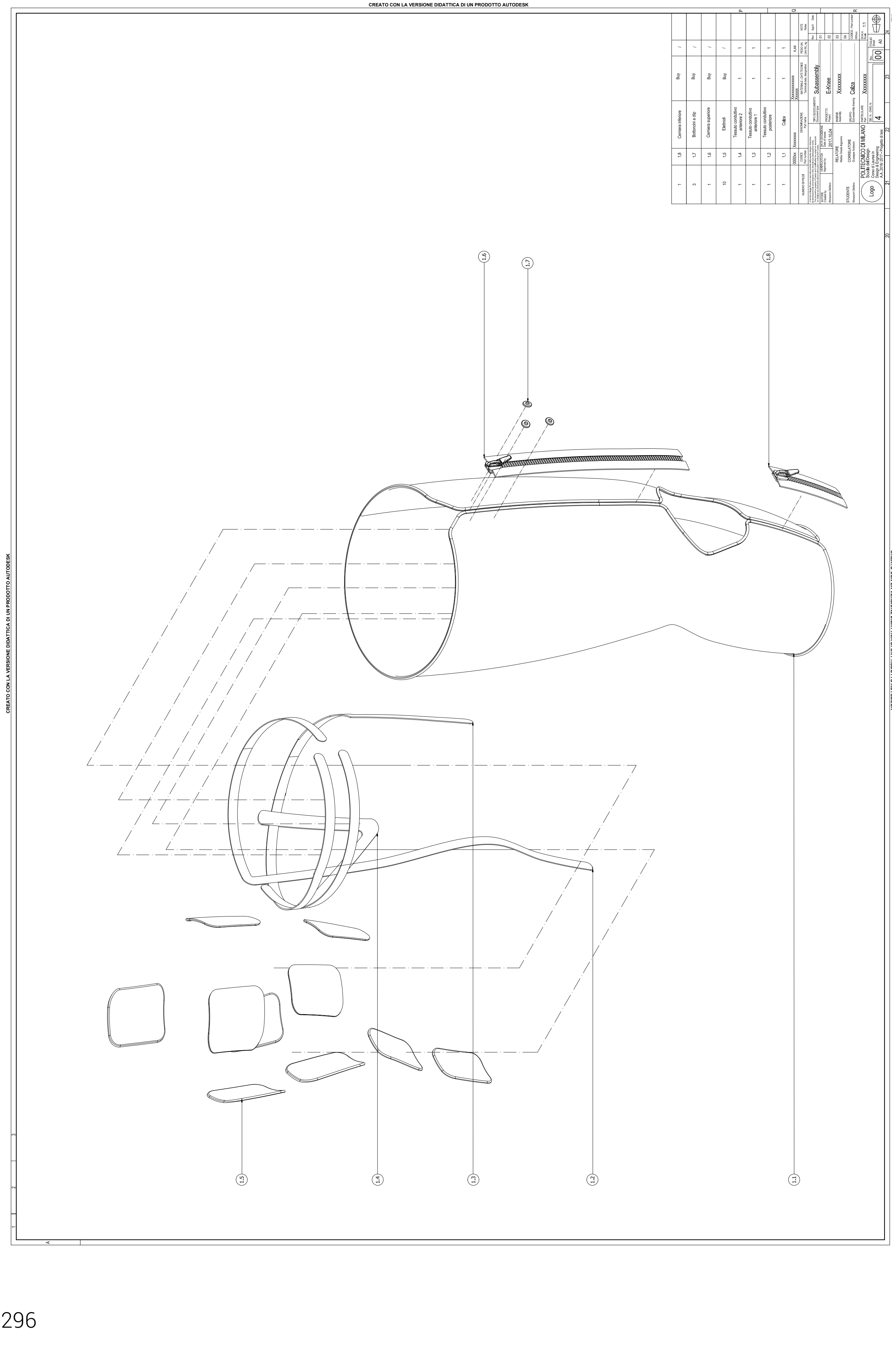
A.A. 2016/ 2017 - Progetto di tesi

DIS. N. - DWG. N.: 1

Rev.: 00

FOGLIO Sheet: A0


F-F (1 : 2)
D-D (1 : 2)
E-E (1 : 2)
B-B (1 : 2)
H-H (1 : 2)
N (5 : 1)
P (2 : 1)
R (2 : 1)
T (5 : 1)
U (5 : 1)
= Foam xxxx
= Flyknit fabric
= PC
=PA6 FG30
= PP
=AISI 304
= Al 7xxxxx
= electrodes
= conductive fabric
= elastic fabric
Disegno di insieme
E-Knee
POLITECNICO DI MILANO
Scuola del Design
Logo
CREATO CON LA VERSIONE DIDATTICA DI UN PRODOTTO AUTODESK


CREATO CON LA VERSIONE DIDATTICA DI UN PRODOTTO AUTODESK
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1 1.8 Cerniera inferiore Buy /
3 1.7 Bottoncini a clip Buy /
1 1.6 Cerniera superiore Buy /
10 1.5 Elettrodi Buy /
1 1.4 Tessuto conduttivo anteriore 2 1 1
1 1.3 Tessuto conduttivo anteriore 1 1 1
1 1.2 Tessuto conduttivo posteriore 1 1
1 1.1 Calza 1 1
0000xx Xxxxxxxx Xxxxxxxxxxxxx Xxxxxx x,xx
NUMERO DI PEZZI
CODICE Part number
DENOMINAZIONE Part name
MATERIALE - DATI TECNICI Technical data, designation
PESO UN. Unit Wt., kg
NOTE Notes
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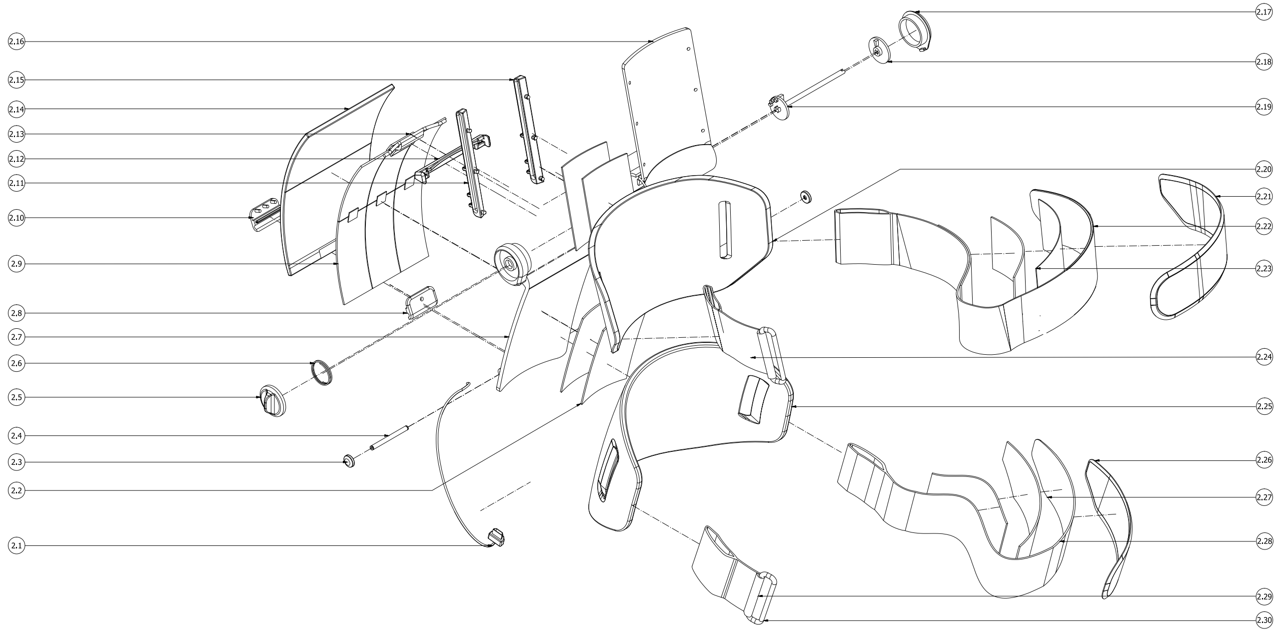
TIPO DI DOCUMENTO Document type Subassembly
Rev App'd Date
01
02
03
04
AUTORE Created by Morazzoni Stefano
VERIFICATO DA Approved by
DATA DI EDIZIONE Date of issues 2017.10.04
PROGETTO Project E-Knee
RELATORE Matteo Oreste Ingaramo
INSIEME Assembly Xxxxxxxx
STUDENTE Morazzoni Stefano
CORRELATORE Giuseppe Andreoni
GRUPPO Sub-assembly drawing Calza
CODICE - Part number 000xxx
POLITECNICO DI MILANO
Scuola del Design
Corso di Laurea in Design & Engineering
A.A. 2016/ 2017 - Progetto di tesi
Logo
PARTICOLARE Part Xxxxxxxx
SCALA Scale 1:1
DIS. N. - DWG. N. 4
Rev. 00
FOGLIO Sheet A0
ISO A0



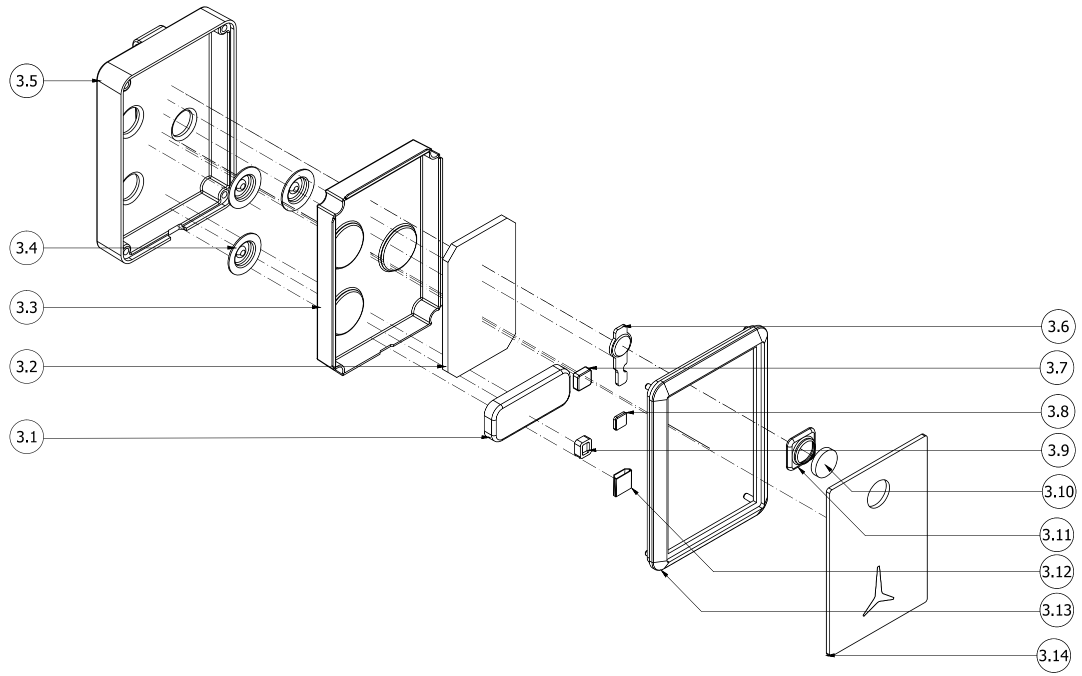
NUMERO DI PEZZI	CODICE Part number	DENOMINAZIONE Part name	MATERIALE - DATI TECNICI Technical data, designation	PESO UN. Unit Wt., kg	NOTE Notes
2	2.30	asola acciaio	AISI 304 pigatura / saldatura		
1	2.29	fettuccia inferiore 2	tessuto Fly-Knit		
1	2.28	fettuccia inferiore 1	tessuto Fly-Knit		
1	2.27	velcro fettuccia inf.	/		
1	2.26	rinforzo fettuccia inf.	PU espanso	0,01	
1	2.25	gomma inferiore	PU espanso	0,02	
1	2.24	fettuccia superiore 2	tessuto Fly-Knit		
1	2.23	velcro fettuccia sup.	/		
1	2.22	fettuccia superiore 1	tessuto Fly-Knit		
1	2.21	rinforzo fettuccia sup.	PU espanso	0,01	
1	2.20	gomma superiore	PU espanso	0,02	
1	2.19	trasmissione	Al 7075 T6 Colata / saldatura/ CNC	0,002	
1	2.18	terminale trasmisione	Al 7075 T6 Colata in conchiglia	0,0015	
1	2.17	tappo cilindro	PP-H Iniezione	0,001	
1	2.16	cilindro centrale	Al 7075 T6 piegatura / saldatura	0,05	
1	2.15	guida sx	PA6 fb30 Iniezione	0,002	
1	2.14	rivestimento piezoelettrico	1	1	
1	2.13	attacco superiore piezo	Al 7075 T6 piegatura / saldatura	0,003	
1	2.12	staffa di bloccaggio	PA6 fb30 Iniezione	0,001	
1	2.11	guida sx	PA6 fb30 Iniezione	0,002	
1	2.10	fissaggio piezo metà2	PA6 fb30 Iniezione	0,001	
1	2.9	Piezoelettrico	Buy		
1	2.8	fissaggio piezo metà1	PA6 fb30 Iniezione	0,001	
1	2.7	barra centrale	Al 7075 T6 Colata in conchiglia	0,06	
1	2.6	Molla multiwave	Buy		
1	2.5	regolatore	PP-H Iniezione	0,001	
1	2.4	perno	Al 7075 T6 estrusione / tornio	1	
2	2.3	tappo perno	PP-H Iniezione	0.0005	
2	2.2	velcro posteriore	/		
1	2.1	cavetto micro USB	Buy	/	
	0000xx	Xxxxxxxx	Xxxxxxxxxxxxx Xxxxxx	x,xx	

AUTORE Created by: Morazzoni Stefano	VERIFICATO DA Approved by	DATA DI EDIZIONE Date of issues: 2017.10.04	TIPO DI DOCUMENTO Document type: Subassembly	Rev / App'd / Date
STUDENTE: Morazzoni Stefano	RELATORE: Matteo Oreste Ingaramo	CORRELATORE: Giuseppe Andreoni	PROGETTO Project: E-Knee	01
			INSIEME Assembly: Xxxxxxxx	02
			GRUPPO Sub-assembly drawing: Meccanismo	03
			PARTICOLARE Part: Xxxxxxxx	04
Logo	POLITECNICO DI MILANO Scuola del Design Corso di Laurea in Design & Engineering A.A. 2016/ 2017 - Progetto di tesi		DIS. N. - DWG. N.: 5	CODICE - Part number: 000xxx
			Rev.: 00	SCALA Scale: 1:1
			FOGLIO Sheet: A0	

21 22 23 24

ISO A0

CREATO CON LA VERSIONE DIDATTICA DI UN PRODOTTO AUTODESK
CREATO CON LA VERSIONE DIDATTICA DI UN PRODOTTO AUTODESK
CREATO CON LA VERSIONE DIDATTICA DI UN PRODOTTO AUTODESK



NUMERO DI PEZZI	CODICE Part number	DENOMINAZIONE Part name	MATERIALE - DATI TECNICI Technical data, designation	PESO UN. Unit Wt., kg	NOTE Notes
1	3.14	cover	PC taglio laser	0,005	
1	3.13	scocca superiore	PP-H Iniezione	0,003	
1	3.12	ingresso microUSB	Buy	/	
1	3.11	supporto tasto	Buy	/	
1	3.10	tasto	Buy	/	
1	3.9	LED	Buy	/	
1	3.8	trasduttore elettrico	Buy	/	
1	3.7	modulo bluetooth	Buy	/	
1	3.6	base tasto	Buy	/	
1	3.5	scocca posteriore	PA 12 3D print Sla extreme	0,004	
1	3.4	bottoncini a clip	Buy	/	
1	3.3	scocca interna	PP-H Iniezione	0,003	
1	3.2	micro processore	Buy	/	
1	3.1	batteria	Buy	/	
	0000xx	Xxxxxxxx	Xxxxxxxxxxxxx Xxxxxx	x,xx	

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AUTORE Created by: Morazzoni Stefano	VERIFICATO DA Approved by	DATA DI EDIZIONE Date of issues: 2017.10.04
STUDENTE: Morazzoni Stefano	RELATORE: Matteo Oreste Ingaramo	CORRELATORE: Giuseppe Andreoni

TIPO DI DOCUMENTO Document type	Subassembly
PROGETTO Project	E-Knee
INSIEME Assembly	Xxxxxxxx
GRUPPO Sub-assembly drawing	Elettrostimolatore
PARTICOLARE Part	Xxxxxxxx
DIS. N. - DWG. N.	6
Rev.	00

Rev	App'd	Date
01		
02		
03		
04		

CODICE - Part number: 000xxx
SCALA Scale: 1:1
FOGLIO Sheet: A2

Logo
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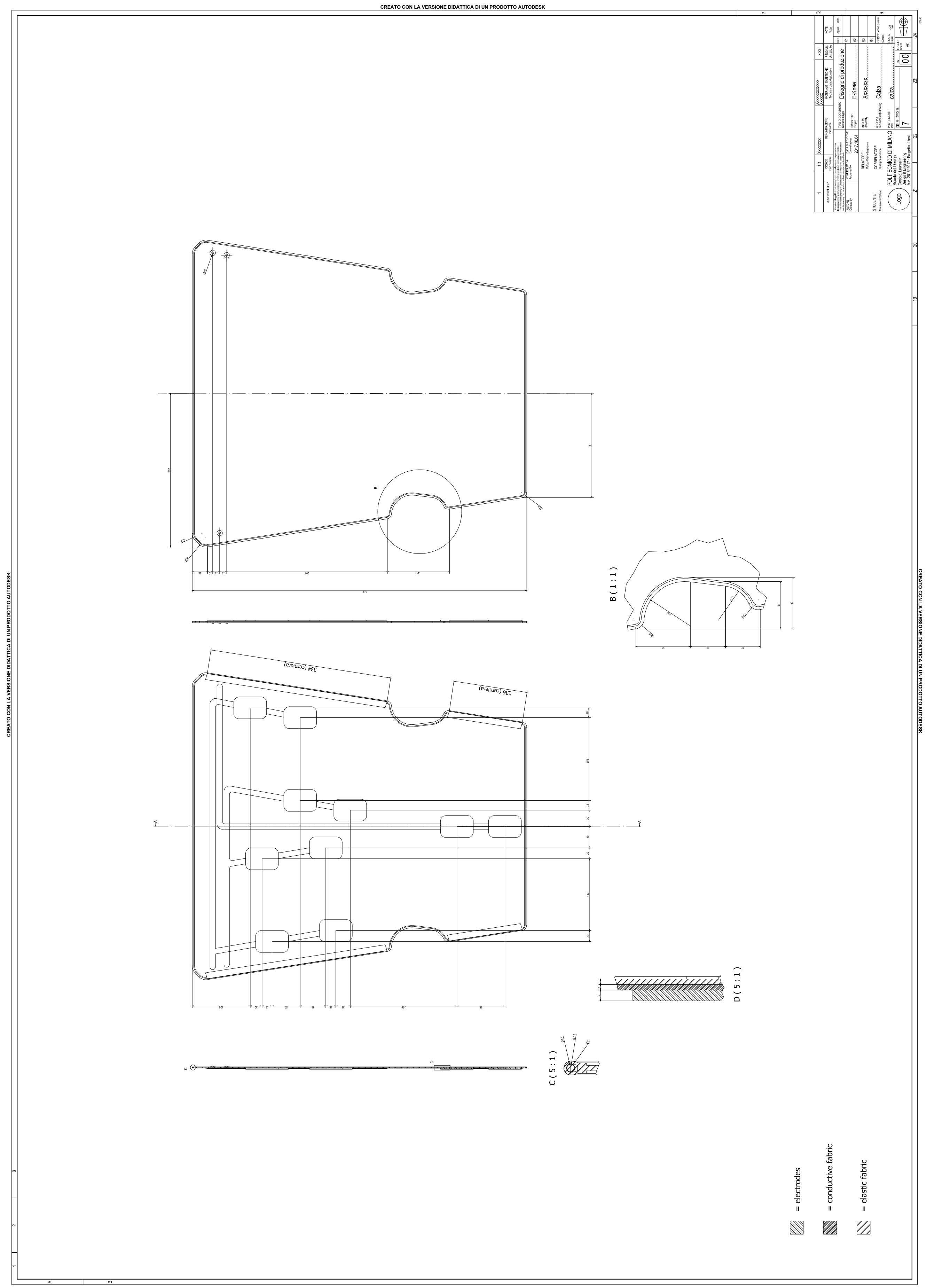
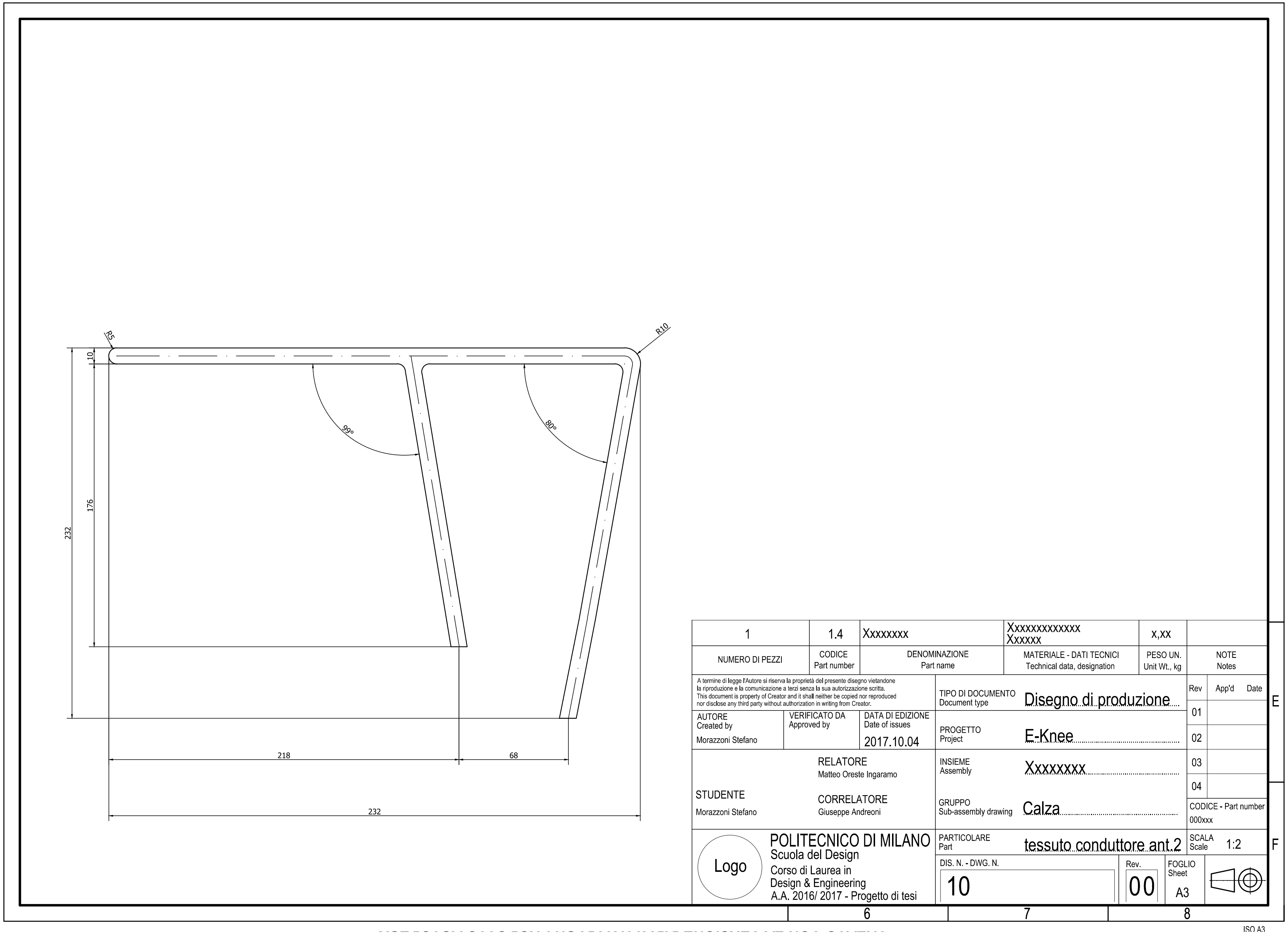
A.A. 2016/ 2017 - Progetto di tesi


CREATO CON LA VERSIONE DIDATTICA DI UN PRODOTTO AUTODESK
B (1 : 1)
C (5 : 1)
D (5 : 1)
334 (cerniera)
136 (cerniera)
= electrodes
= conductive fabric
= elastic fabric
POLITECNICO DI MILANO
Disegno di produzione
E-Knee
Calza



R5
R10
10
176
232
99°
80°
218
68
232
1
1.4
Xxxxxxxx
Xxxxxxxxxxxxx Xxxxxx
x,xx
NUMERO DI PEZZI
CODICE Part number
DENOMINAZIONE Part name
MATERIALE - DATI TECNICI Technical data, designation
PESO UN. Unit Wt., kg
NOTE Notes
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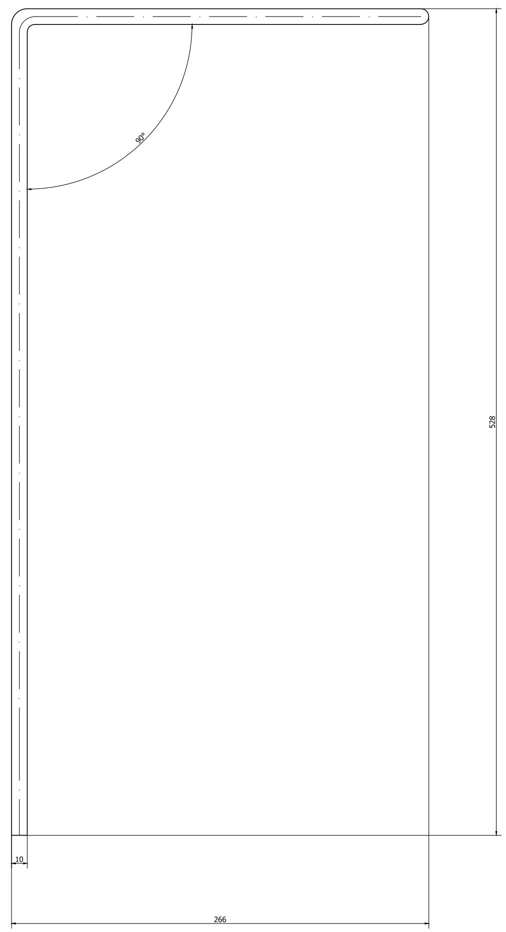
TIPO DI DOCUMENTO Document type
Disegno di produzione
AUTORE Created by
Morazzoni Stefano
VERIFICATO DA Approved by
DATA DI EDIZIONE Date of issues
2017.10.04
PROGETTO Project
E-Knee
RELATORE
Matteo Oreste Ingaramo
INSIEME Assembly
Xxxxxxxx
STUDENTE
Morazzoni Stefano
CORRELATORE
Giuseppe Andreoni
GRUPPO Sub-assembly drawing
Calza
Rev
App'd
Date
01
02
03
04
CODICE - Part number
000xxx
Logo
POLITECNICO DI MILANO
Scuola del Design
Corso di Laurea in
Design & Engineering
A.A. 2016/ 2017 - Progetto di tesi
PARTICOLARE Part
tessuto conduttore ant.2
SCALA Scale
1:2
DIS. N. - DWG. N.
10
Rev.
00
FOGLIO Sheet
A3
E
F
6
7
8
ISO A3



1	1.2	Xxxxxxxx	Xxxxxxxxxxxxx Xxxxxx	x,xx	
NUMERO DI PEZZI	CODICE Part number	DENOMINAZIONE Part name	MATERIALE - DATI TECNICI Technical data, designation	PESO UN. Unit Wt., kg	NOTE Notes

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AUTORE Created by: Morazzoni Stefano
VERIFICATO DA Approved by
DATA DI EDIZIONE Date of issues: 2017.10.04

TIPO DI DOCUMENTO Document type: Disegno di produzione
PROGETTO Project: E-Knee
INSIEME Assembly: Xxxxxxxx
GRUPPO Sub-assembly drawing: Calza
PARTICOLARE Part: tessuto conduttore post.

STUDENTE: Morazzoni Stefano
RELATORE: Matteo Oreste Ingaramo
CORRELATORE: Giuseppe Andreoni

Rev	App'd	Date
01		
02		
03		
04		

CODICE - Part number: 000xxx
SCALA Scale: 1:2

Logo
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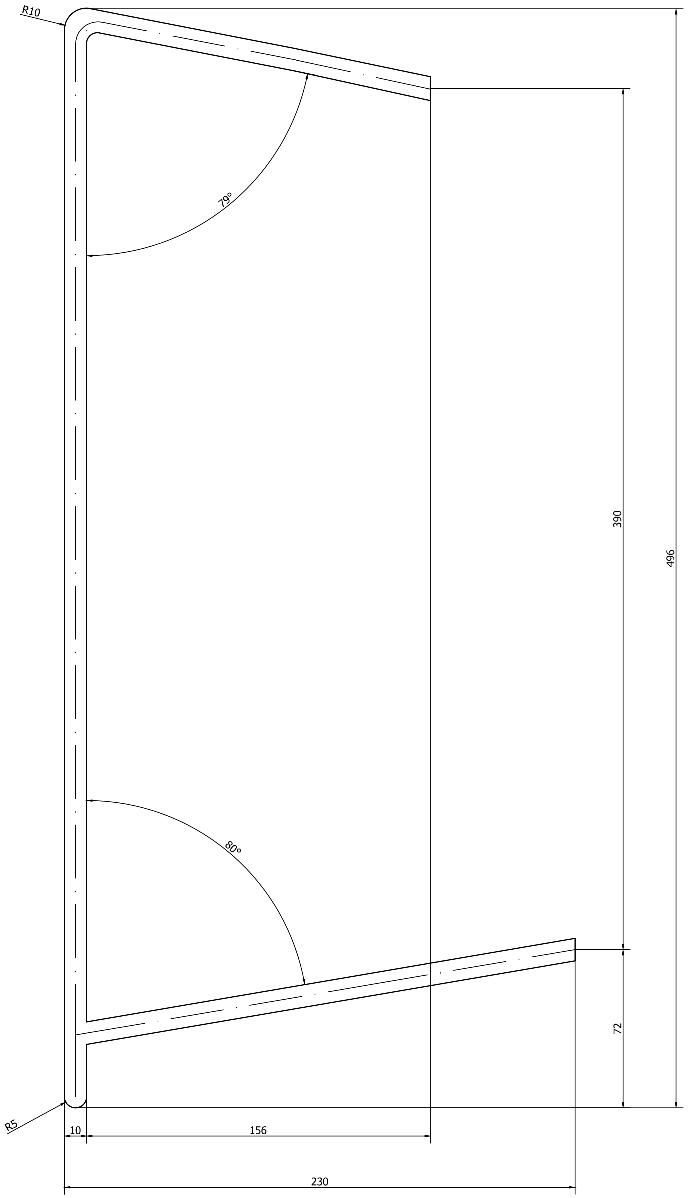
A.A. 2016/ 2017 - Progetto di tesi

DIS. N. - DWG. N.: 8
Rev.: 00
FOGLIO Sheet: A2

1 9 10 11 12 G H



1	1.3	Xxxxxxxx	Xxxxxxxxxxxxx Xxxxxx	x,xx	
NUMERO DI PEZZI	CODICE Part number	DENOMINAZIONE Part name	MATERIALE - DATI TECNICI Technical data, designation	PESO UN. Unit Wt., kg	NOTE Notes

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.		2017.10.04

STUDENTE
Morazzoni Stefano

RELATORE
Matteo Oreste Ingaramo

CORRELATORE
Giuseppe Andreoni

TIPO DI DOCUMENTO Document type	Disegno di produzione
PROGETTO Project	E-Knee
INSIEME Assembly	Xxxxxxxx
GRUPPO Sub-assembly drawing	Calza
PARTICOLARE Part	tessuto conduttore ant.1

Rev	App'd	Date
01		
02		
03		
04		

CODICE - Part number
000xxx

SCALA Scale 1:2

Logo

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Design & Engineering
A.A. 2016/ 2017 - Progetto di tesi

DIS. N. - DWG. N.	Rev.	FOGLIO Sheet
9	00	A3

E
F
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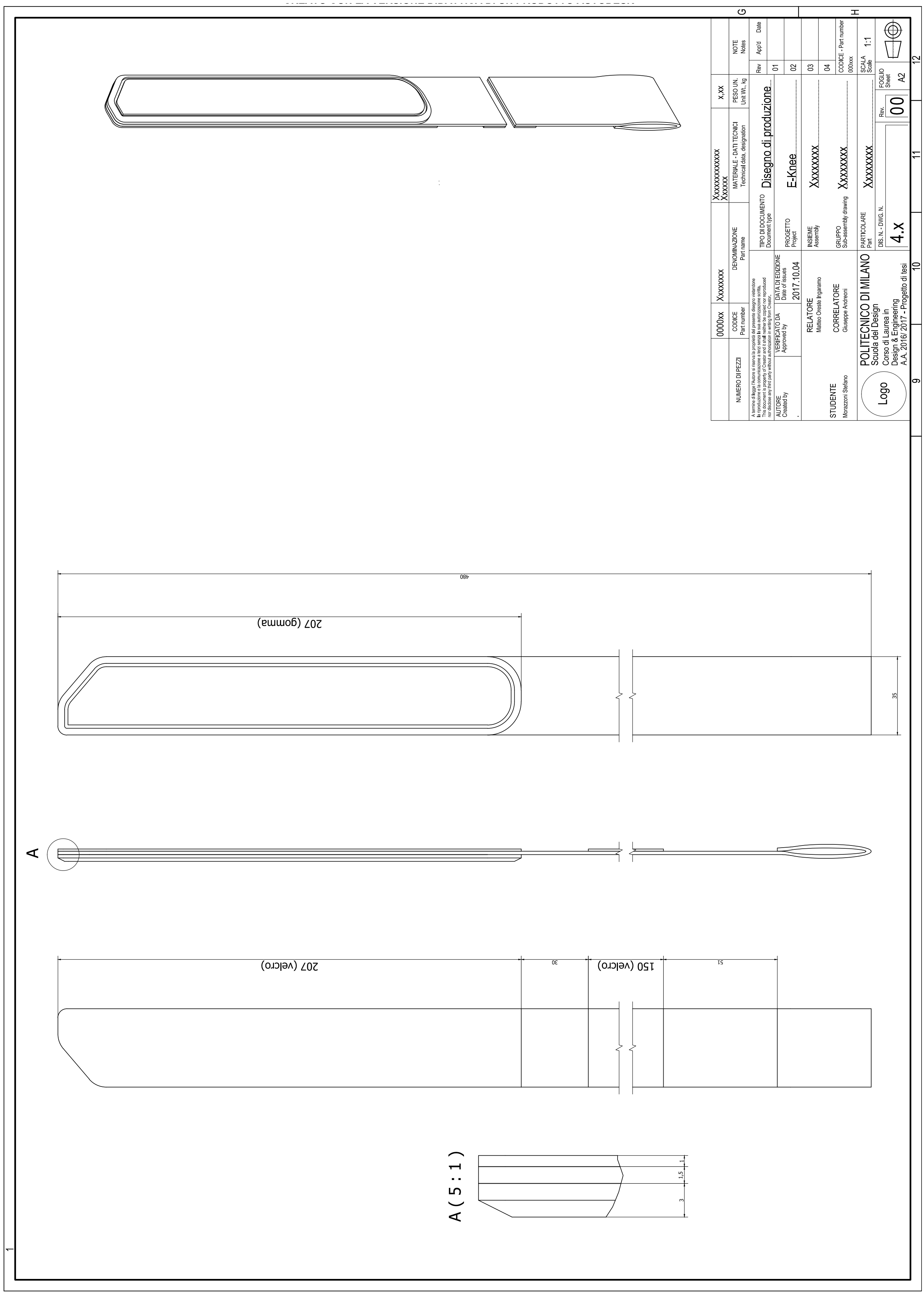
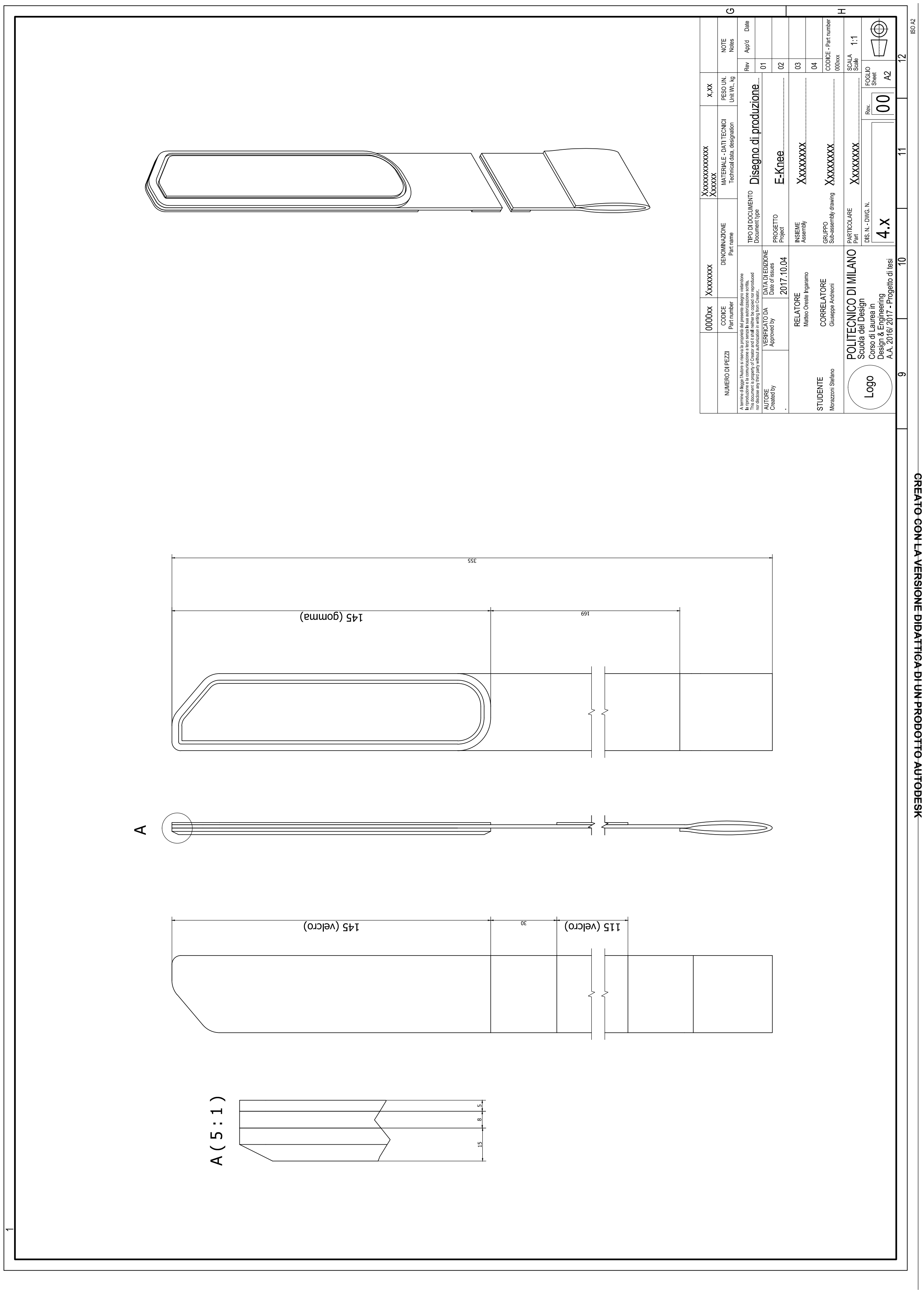
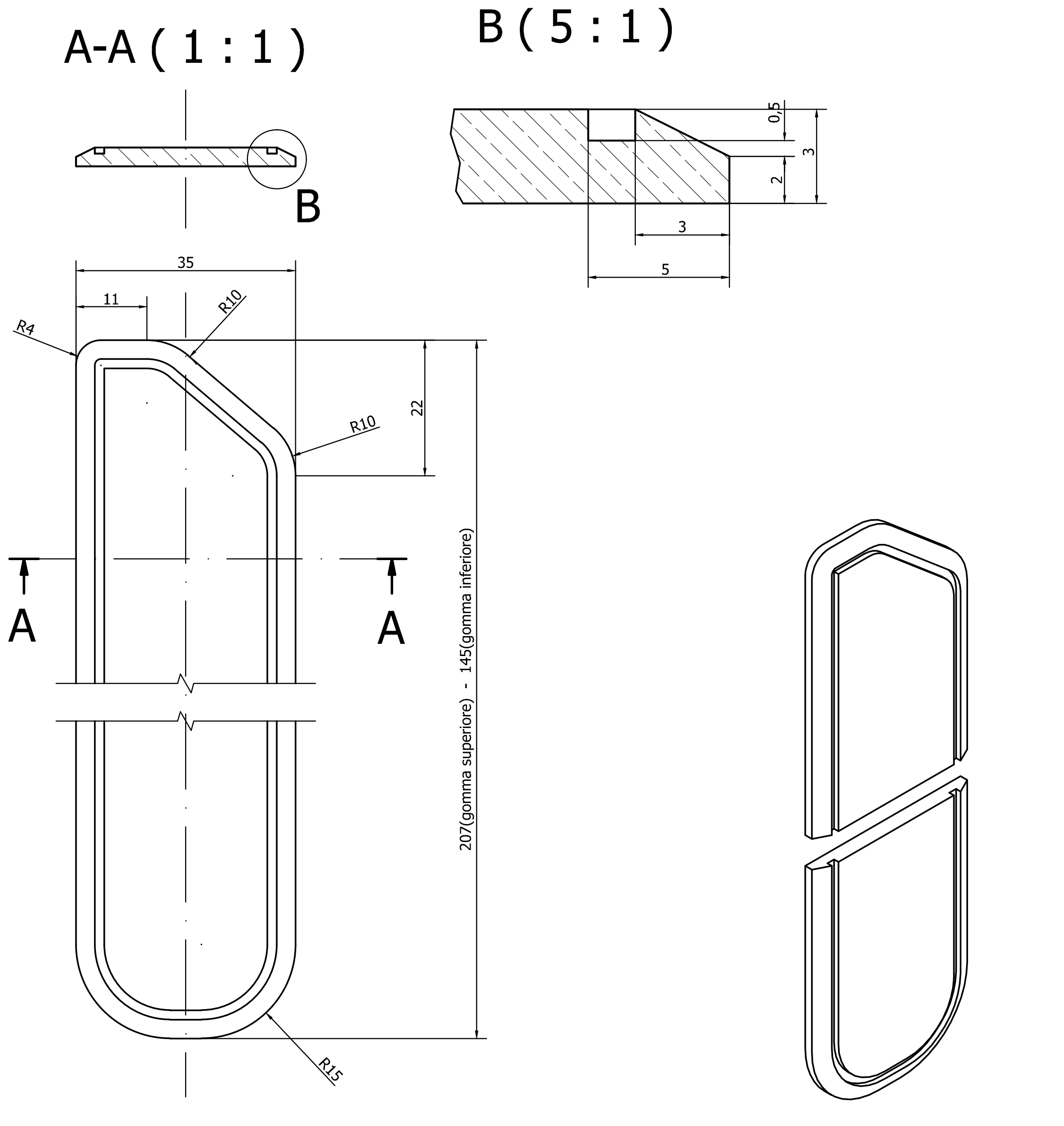

207 (gomma)
480
35
A
207 (velcro)
30
150 (velcro)
51
A (5 : 1)
1
1,5
3
NUMERO DI PEZZI
0000xx
CODICE
Part number
Xxxxxxxx
DENOMINAZIONE
Part name
Xxxxxxxxxxxxx
Xxxxxx
MATERIALE - DATI TECNICI
Technical data, designation
x,xx
PESO UN.
Unit Wt., kg
NOTE
Notes
AUTORE
Created by
VERIFICATO DA
Approved by
DATA DI EDIZIONE
Date of issues
2017.10.04
TIPO DI DOCUMENTO
Document type
Disegno di produzione
PROGETTO
Project
E-Knee
STUDENTE
Morazzoni Stefano
RELATORE
Matteo Oreste Ingaramo
CORRELATORE
Giuseppe Andreoni
INSIEME
Assembly
Xxxxxxxx
GRUPPO
Sub-assembly drawing
Xxxxxxxx
PARTICOLARE
Part
Xxxxxxxx
Logo
POLITECNICO DI MILANO
Scuola del Design
Corso di Laurea in
Design & Engineering
A.A. 2016/ 2017 - Progetto di tesi
DIS. N. - DWG. N.
4.x
Rev.
00
Rev
App'd
Date
01
02
03
04
CODICE - Part number
000xxx
SCALA
Scale
1:1
FOGLIO
Sheet
A2
G
H
9
10
11
12
1


CREATO CON LA VERSIONE DIDATTICA DI UN PRODOTTO AUTODESK
NUMERO DI PEZZI
CODICE
Part number
0000xx
Xxxxxxxx
DENOMINAZIONE
Part name
Xxxxxxxxxxxxx
Xxxxxx
MATERIALE - DATI TECNICI
Technical data, designation
x,xx
PESO UN.
Unit Wt., kg
NOTE
Notes
AUTORE
Created by
VERIFICATO DA
Approved by
DATA DI EDIZIONE
Date of issues
2017.10.04
TIPO DI DOCUMENTO
Document type
Disegno di produzione
PROGETTO
Project
E-Knee
Rev
App'd
Date
01
02
03
04
RELATORE
Matteo Oreste Ingaramo
INSIEME
Assembly
Xxxxxxxx
STUDENTE
Morazzoni Stefano
CORRELATORE
Giuseppe Andreoni
GRUPPO
Sub-assembly drawing
Xxxxxxxx
CODICE - Part number
000xxx
Logo
POLITECNICO DI MILANO
Scuola del Design
Corso di Laurea in
Design & Engineering
A.A. 2016/ 2017 - Progetto di tesi
PARTICOLARE
Part
Xxxxxxxx
SCALA
Scale
1:1
DIS. N. - DWG. N.
4.x
Rev.
00
FOGLIO
Sheet
A2
ISO A2
355
169
145 (gomma)
A
145 (velcro)
30
115 (velcro)
A (5 : 1)
5
8
15



NUMERO DI PEZZI	CODICE Part number	DENOMINAZIONE Part name	MATERIALE - DATI TECNICI Technical data, designation	PESO UN. Unit Wt., kg	NOTE Notes
	0000xx	Xxxxxxxx	Xxxxxxxxxxxxx Xxxxxx	x,xx	

TIPO DI DOCUMENTO Document type: Disegno di produzione

Rev	App'd	Date
01		
02		
03		
04		

AUTORE Created by: .

VERIFICATO DA Approved by:

DATA DI EDIZIONE Date of issues: 2017.10.04

PROGETTO Project: E-Knee

RELATORE
Matteo Oreste Ingaramo

STUDENTE
Morazzoni Stefano

CORRELATORE
Giuseppe Andreoni

INSIEME Assembly: Xxxxxxxx

GRUPPO Sub-assembly drawing: Xxxxxxxx

CODICE - Part number: 000xxx

Logo

POLITECNICO DI MILANO
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Design & Engineering
A.A. 2016/ 2017 - Progetto di tesi

PARTICOLARE Part: Xxxxxxxx

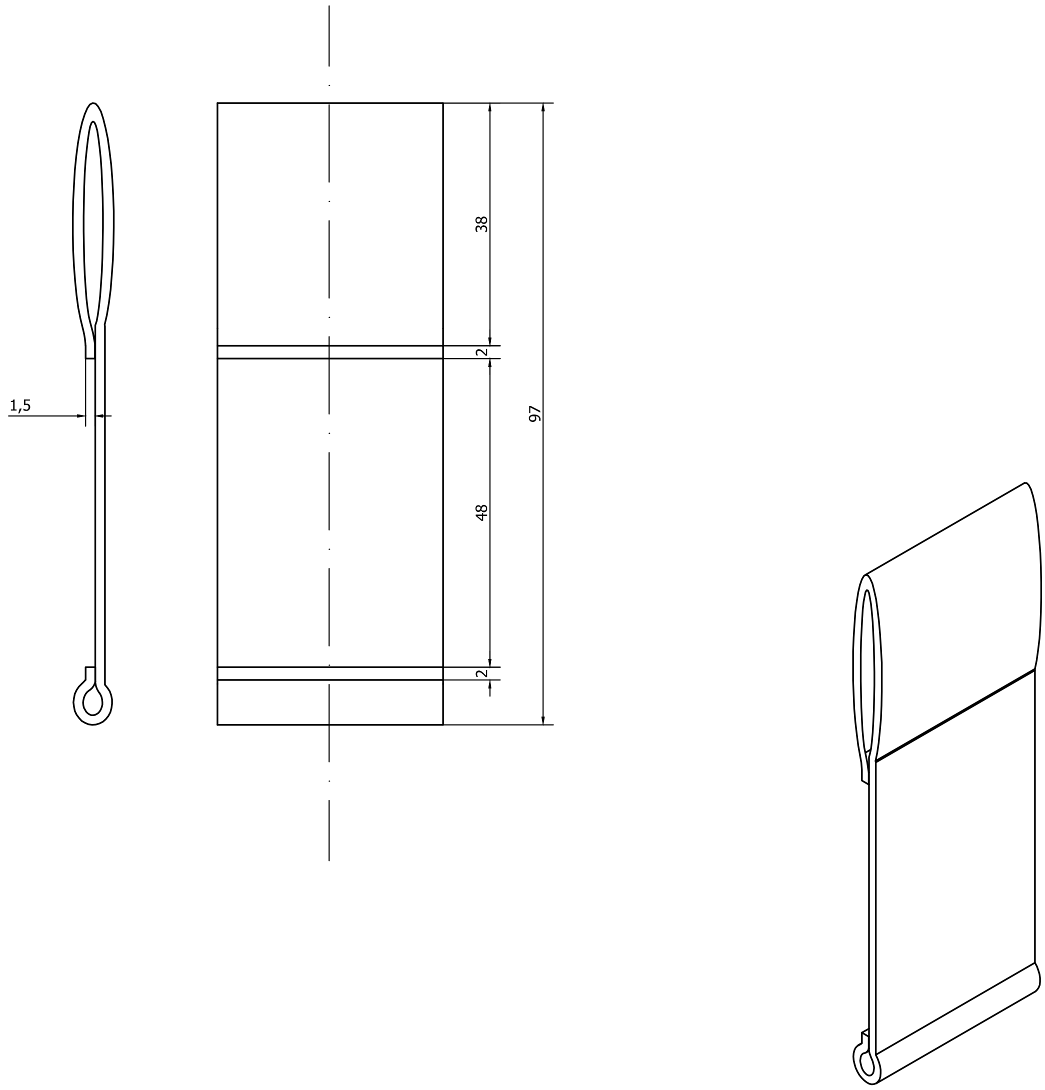
SCALA Scale: 1:1

F

DIS. N. - DWG. N.: 4.x

Rev.: 00

FOGLIO Sheet: A4



	0000xx	Xxxxxxxx	Xxxxxxxxxxxxx Xxxxxx	x,xx	
NUMERO DI PEZZI	CODICE Part number	DENOMINAZIONE Part name	MATERIALE - DATI TECNICI Technical data, designation	PESO UN. Unit Wt., kg	NOTE Notes

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TIPO DI DOCUMENTO Document type: Disegno di produzione

Rev	App'd	Date
01		
02		
03		
04		

E

AUTORE Created by: .
VERIFICATO DA Approved by:
DATA DI EDIZIONE Date of issues: 2017.10.04

PROGETTO Project: E-Knee

RELATORE
Matteo Oreste Ingaramo

INSIEME Assembly: Xxxxxxxx

STUDENTE
Morazzoni Stefano

CORRELATORE
Giuseppe Andreoni

GRUPPO Sub-assembly drawing: Xxxxxxxx

CODICE - Part number
000xxx

Logo

POLITECNICO DI MILANO
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Design & Engineering
A.A. 2016/ 2017 - Progetto di tesi

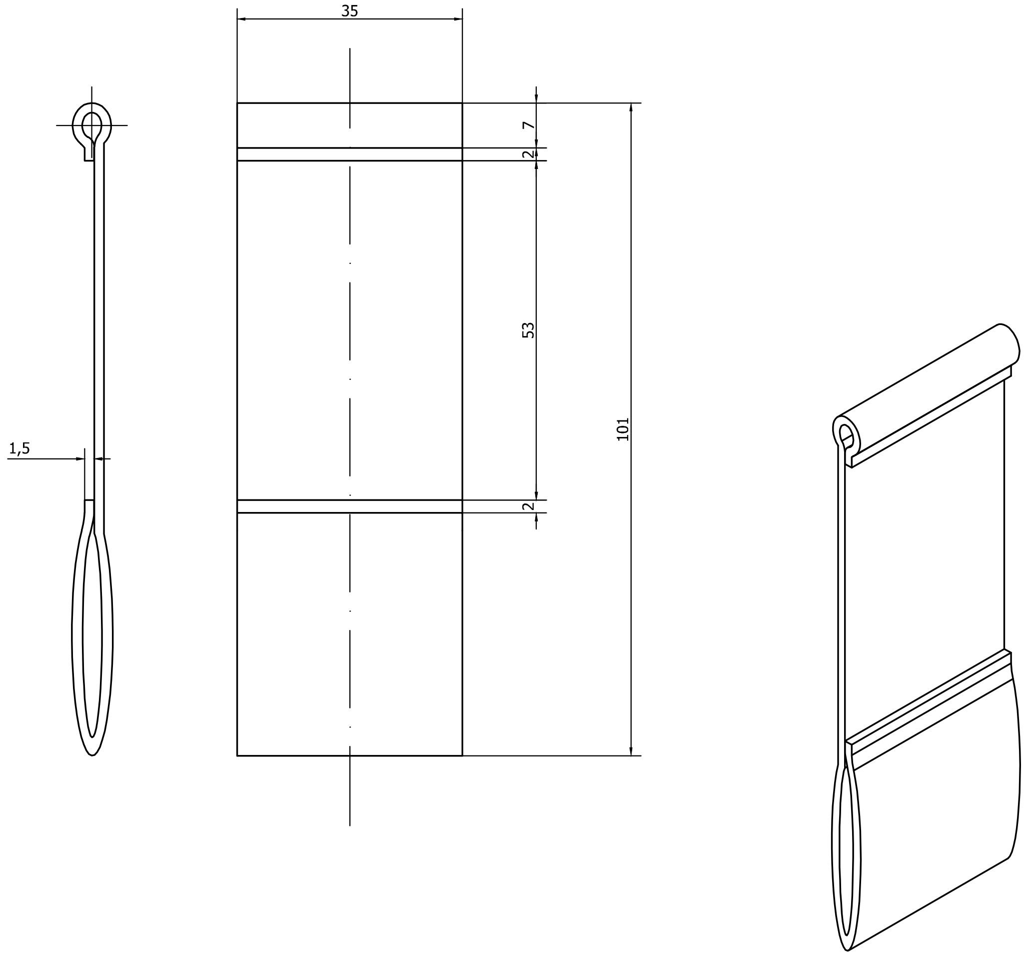
PARTICOLARE Part: Xxxxxxxx

SCALA Scale: 1:1

F

DIS. N. - DWG. N.: 4.x
Rev.: 00
FOGLIO Sheet: A4

CREATO CON LA VERSIONE DIDATTICA DI UN PRODOTTO AUTODESK



	0000xx	Xxxxxxxx	Xxxxxxxxxxxxx Xxxxxx	x,xx	
NUMERO DI PEZZI	CODICE Part number	DENOMINAZIONE Part name	MATERIALE - DATI TECNICI Technical data, designation	PESO UN. Unit Wt., kg	NOTE Notes

TIPO DI DOCUMENTO Document type: Disegno di produzione

Rev	App'd	Date
01		
02		
03		
04		

AUTORE Created by: .
VERIFICATO DA Approved by:
DATA DI EDIZIONE Date of issues: 2017.10.04

PROGETTO Project: E-Knee

RELATORE
Matteo Oreste Ingaramo

STUDENTE
Morazzoni Stefano

CORRELATORE
Giuseppe Andreoni

INSIEME Assembly: Xxxxxxxx

GRUPPO Sub-assembly drawing: Xxxxxxxx

CODICE - Part number: 000xxx

Logo

POLITECNICO DI MILANO
Scuola del Design
Corso di Laurea in
Design & Engineering
A.A. 2016/ 2017 - Progetto di tesi

PARTICOLARE Part: Xxxxxxxx

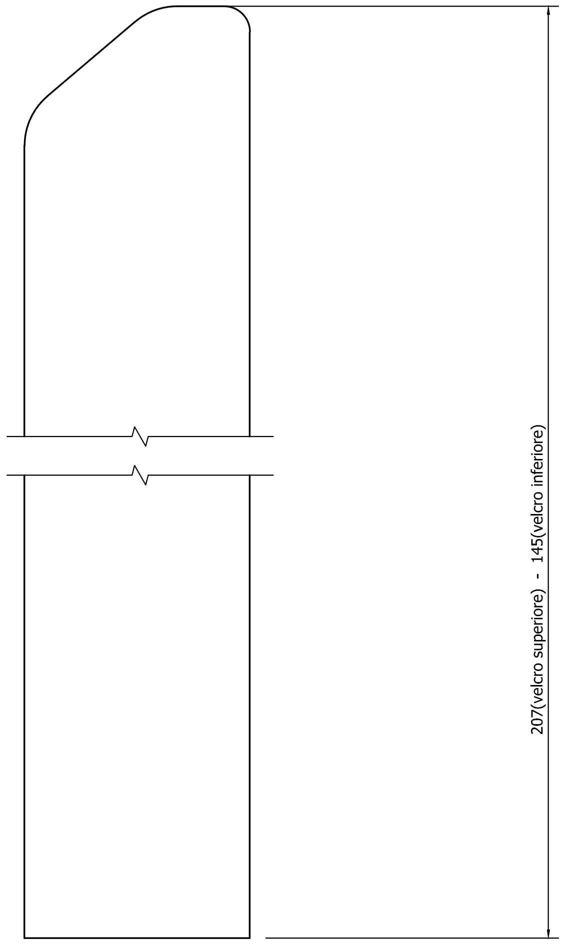
SCALA Scale: 1:1

F

DIS. N. - DWG. N.: 4.x

Rev.: 00

FOGLIO Sheet: A4



2	2.2	Xxxxxxxx	Xxxxxxxxxxxxx Xxxxxx	x,xx	
NUMERO DI PEZZI	CODICE Part number	DENOMINAZIONE Part name	MATERIALE - DATI TECNICI Technical data, designation	PESO UN. Unit Wt., kg	NOTE Notes

TIPO DI DOCUMENTO Document type: Disegno di produzione

AUTORE Created by	VERIFICATO DA Approved by	DATA DI EDIZIONE Date of issues
.		2017.10.04

PROGETTO Project: E-Knee

Rev	App'd	Date
01		
02		
03		
04		

RELATORE
Matteo Oreste Ingaramo

STUDENTE
Morazzoni Stefano

CORRELATORE
Giuseppe Andreoni

INSIEME Assembly: Xxxxxxxx

GRUPPO Sub-assembly drawing: Meccanismo

CODICE - Part number: 000xxx

Logo

POLITECNICO DI MILANO
Scuola del Design
Corso di Laurea in
Design & Engineering
A.A. 2016/ 2017 - Progetto di tesi

PARTICOLARE Part: velcro posteriore

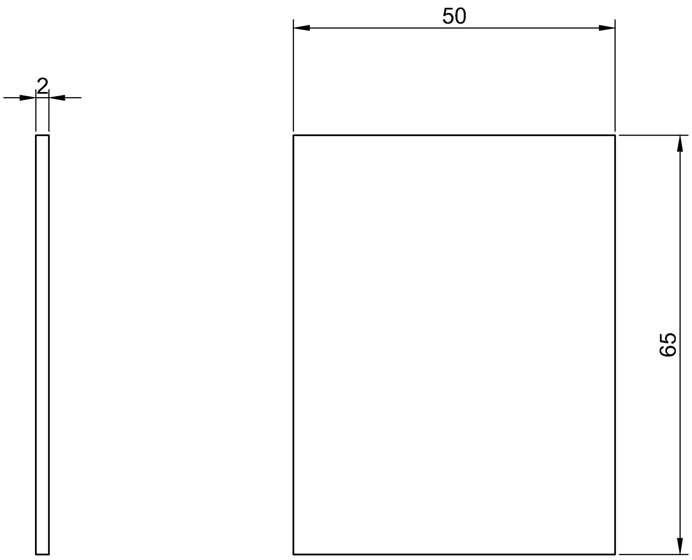
SCALA Scale: 1:1

F

DIS. N. - DWG. N.: 11

Rev.: 00

FOGLIO Sheet: A4



NUMERO DI PEZZI	CODICE Part number	DENOMINAZIONE Part name	MATERIALE - DATI TECNICI Technical data, designation	PESO UN. Unit Wt., kg	NOTE Notes
2	2.2	Xxxxxxxx	Xxxxxxxxxxxxx Xxxxxx	x,xx	

TIPO DI DOCUMENTO / Document type: Disegno di produzione

AUTORE / Created by: .
VERIFICATO DA / Approved by:
DATA DI EDIZIONE / Date of issues: 2017.10.04

PROGETTO / Project: E-Knee

INSIEME / Assembly: Xxxxxxxx

GRUPPO / Sub-assembly drawing: Meccanismo

RELATORE
Matteo Oreste Ingaramo

STUDENTE
Morazzoni Stefano

CORRELATORE
Giuseppe Andreoni

Rev	App'd	Date
01		
02		
03		
04		

CODICE - Part number: 000xxx

Logo

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Design & Engineering
A.A. 2016/ 2017 - Progetto di tesi

PARTICOLARE / Part: velcro posteriore

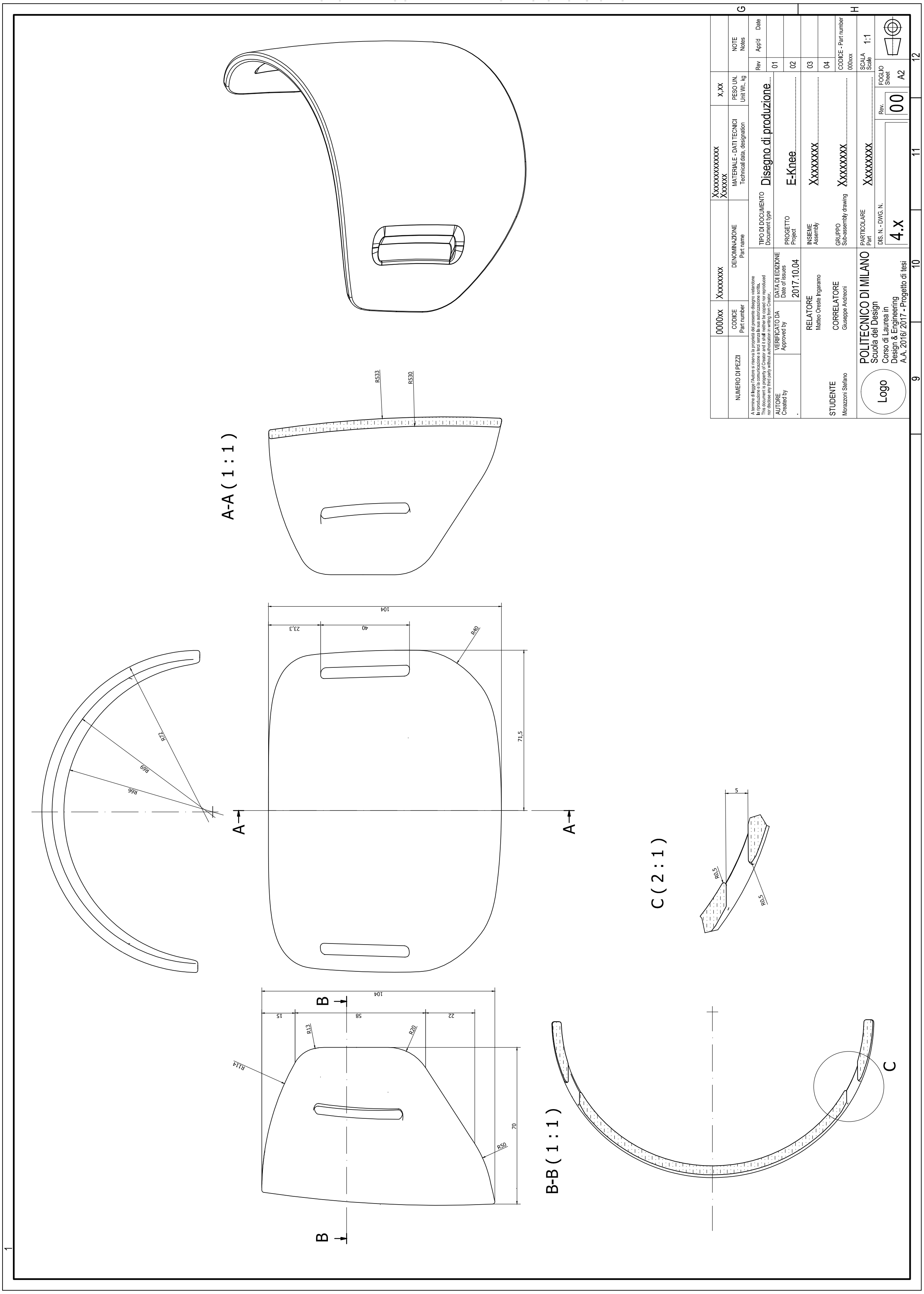
SCALA / Scale: 1:1

DIS. N. - DWG. N.: 11

Rev.: 00

FOGLIO / Sheet: A4

F


A-A (1 : 1)
B-B (1 : 1)
C (2 : 1)
NUMERO DI PEZZI
0000xx
CODICE
Part number
Xxxxxxxx
DENOMINAZIONE
Part name
Xxxxxxxxxxxxx
Xxxxxx
MATERIALE - DATI TECNICI
Technical data, designation
x,xx
PESO UN.
Unit Wt., kg
NOTE
Notes
AUTORE
Created by
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Approved by
DATA DI EDIZIONE
Date of issues
2017.10.04
TIPO DI DOCUMENTO
Document type
Disegno di produzione
PROGETTO
Project
E-Knee
RELATORE
Matteo Oreste Ingaramo
INSIEME
Assembly
Xxxxxxxx
CORRELATORE
Giuseppe Andreoni
GRUPPO
Sub-assembly drawing
Xxxxxxxx
STUDENTE
Morazzoni Stefano
POLITECNICO DI MILANO
Scuola del Design
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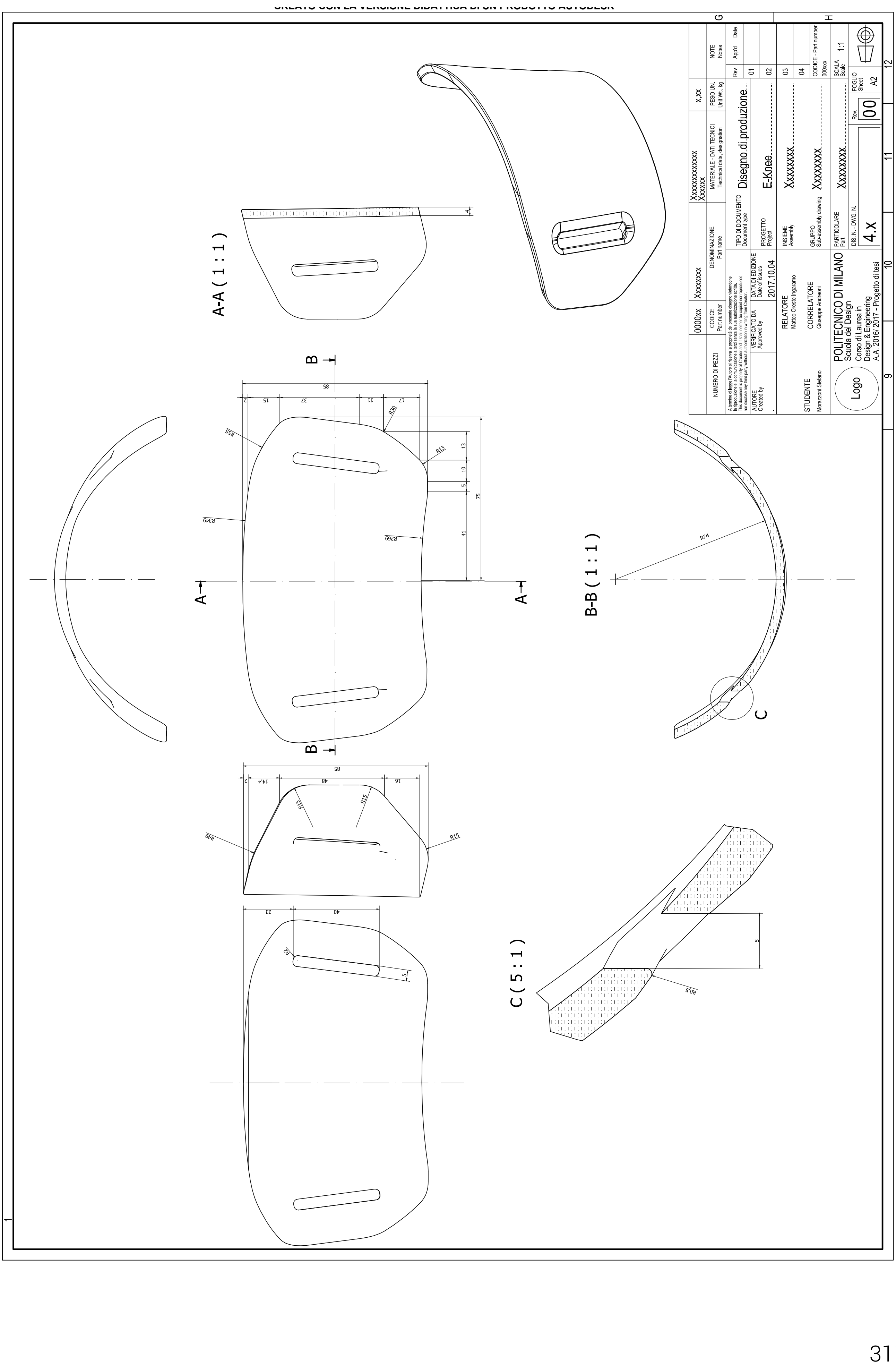
Design & Engineering
A.A. 2016/ 2017 - Progetto di tesi
PARTICOLARE
Part
Xxxxxxxx
DIS. N. - DWG. N.
4.x
Rev.
00
CODICE - Part number
000xxx
SCALA
Scale
1:1
FOGLIO
Sheet
A2
Logo



A-A (1 : 1)
B-B (1 : 1)
C (5 : 1)
NUMERO DI PEZZI
0000xx
CODICE
Part number
Xxxxxxxx
DENOMINAZIONE
Part name
Xxxxxxxxxxxxx
Xxxxxx
MATERIALE - DATI TECNICI
Technical data, designation
x,xx
PESO UN.
Unit Wt., kg
NOTE
Notes
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Document type
Disegno di produzione
PROGETTO
Project
E-Knee
INSIEME
Assembly
Xxxxxxxx
GRUPPO
Sub-assembly drawing
Xxxxxxxx
PARTICOLARE
Part
Xxxxxxxx
STUDENTE
Morazzoni Stefano
RELATORE
Matteo Oreste Ingaramo
CORRELATORE
Giuseppe Andreoni
Logo
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A.A. 2016/ 2017 - Progetto di tesi
DIS. N. - DWG. N.
4.X
Rev.
00
FOGLIO
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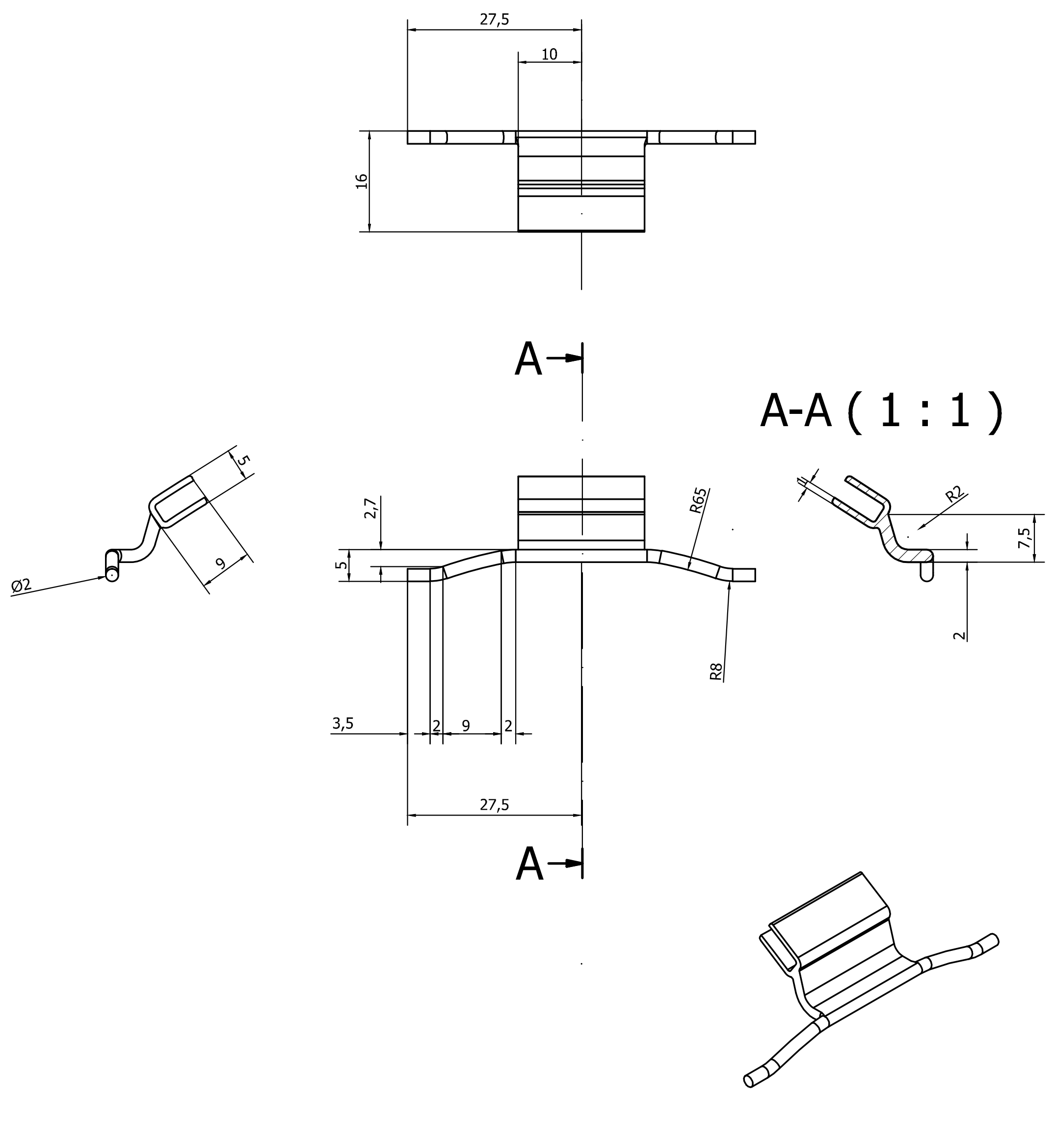
A2
SCALA
Scale
1:1
CODICE - Part number
000xxx
Rev
App'd
Date
01
02
03
04



NUMERO DI PEZZI	CODICE Part number	DENOMINAZIONE Part name	MATERIALE - DATI TECNICI Technical data, designation	PESO UN. Unit Wt., kg	NOTE Notes
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TIPO DI DOCUMENTO Document type: Disegno di produzione

Rev	App'd	Date
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04		

E

AUTORE Created by: Morazzoni Stefano
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PROGETTO Project: E-Knee

RELATORE: Matteo Oreste Ingaramo
STUDENTE: Morazzoni Stefano
CORRELATORE: Giuseppe Andreoni

INSIEME Assembly: Xxxxxxxx
GRUPPO Sub-assembly drawing: Meccanismo

CODICE - Part number: 000xxx

Logo

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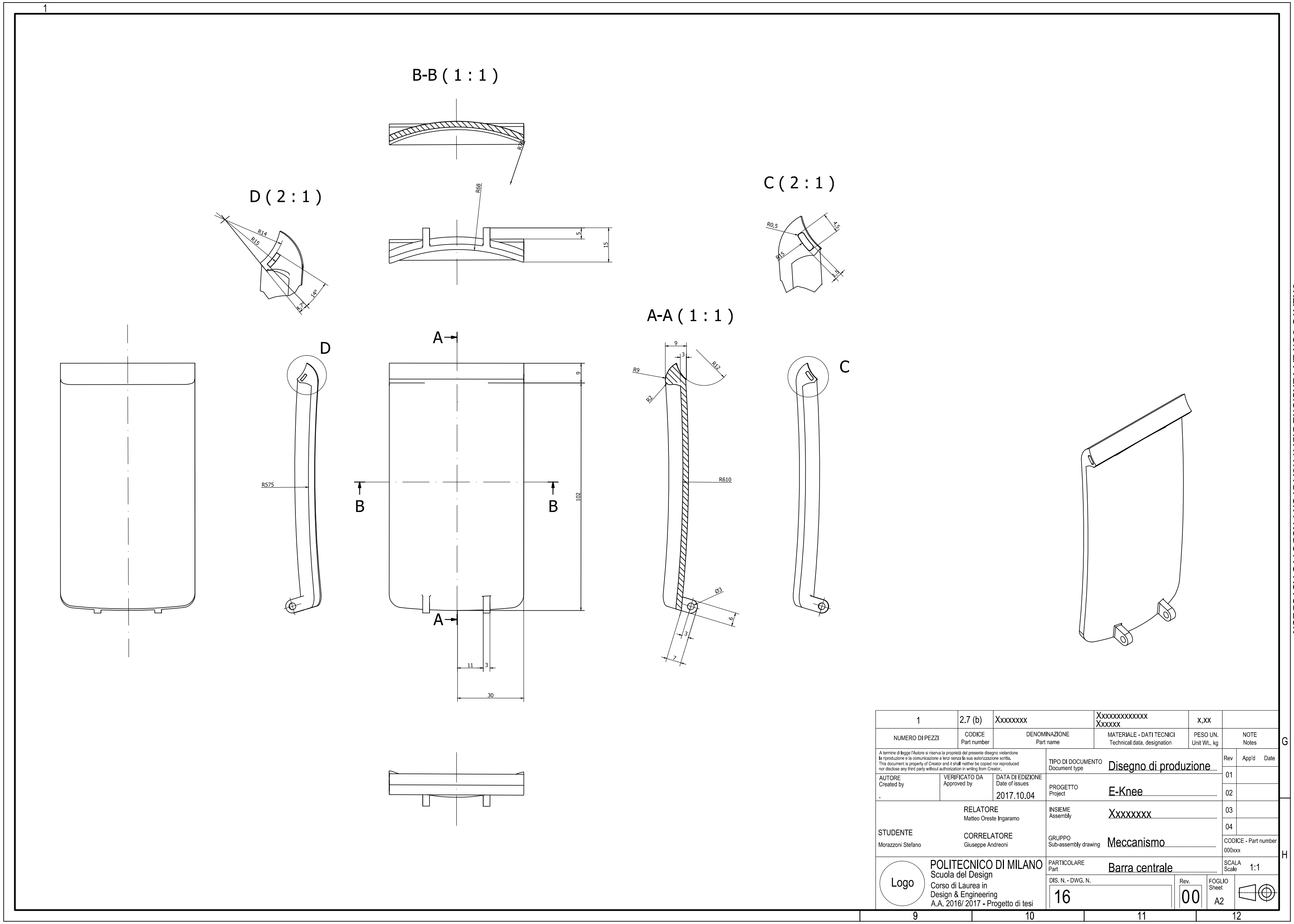
PARTICOLARE Part: attacco superiore piezo
SCALA Scale: 1:1

F

DIS. N. - DWG. N.: 21
Rev.: 00
FOGLIO Sheet: A4


B-B (1 : 1)
D (2 : 1)
C (2 : 1)
A-A (1 : 1)
1
2.7 (b)
Xxxxxxxx
Xxxxxxxxxxxxx Xxxxxx
x,xx
NUMERO DI PEZZI
CODICE Part number
DENOMINAZIONE Part name
MATERIALE - DATI TECNICI Technical data, designation
PESO UN. Unit Wt., kg
NOTE Notes
TIPO DI DOCUMENTO Document type
Disegno di produzione
AUTORE Created by
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DATA DI EDIZIONE Date of issues
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PROGETTO Project
E-Knee
RELATORE
Matteo Oreste Ingaramo
INSIEME Assembly
Xxxxxxxx
STUDENTE
Morazzoni Stefano
CORRELATORE
Giuseppe Andreoni
GRUPPO Sub-assembly drawing
Meccanismo
Logo
POLITECNICO DI MILANO
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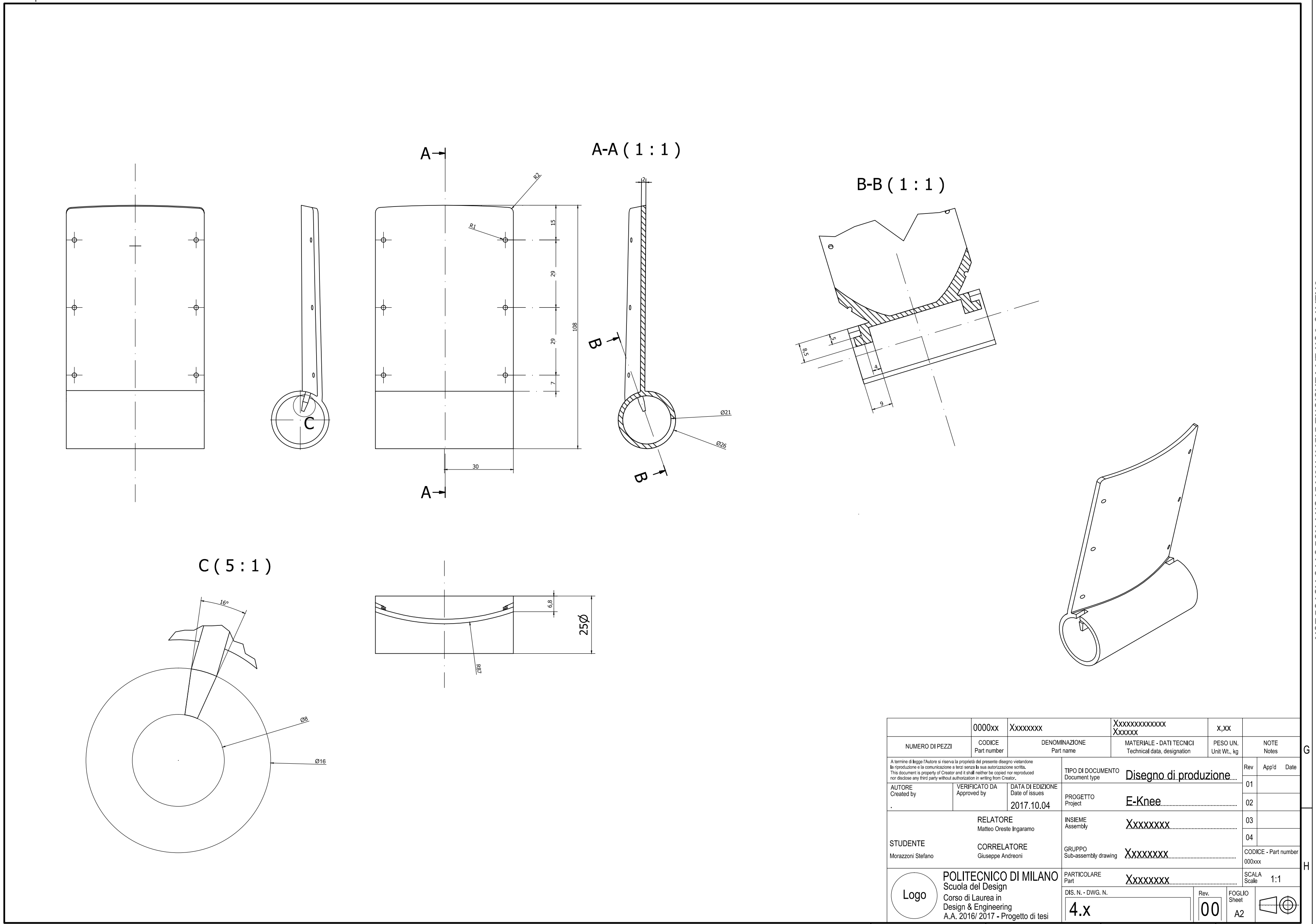
PARTICOLARE Part
Barra centrale
DIS. N. - DWG. N.
16
Rev.
00
CODICE - Part number
000xxx
SCALA Scale
1:1
FOGLIO Sheet
A2


A-A (1 : 1)
B-B (1 : 1)
C (5 : 1)
0000xx
Xxxxxxxx
Xxxxxxxxxxxxx
Xxxxxx
x,xx
NUMERO DI PEZZI
CODICE Part number
DENOMINAZIONE Part name
MATERIALE - DATI TECNICI Technical data, designation
PESO UN. Unit Wt., kg
NOTE Notes
TIPO DI DOCUMENTO Document type
Disegno di produzione
AUTORE Created by
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DATA DI EDIZIONE Date of issues
2017.10.04
PROGETTO Project
E-Knee
RELATORE
Matteo Oreste Ingaramo
INSIEME Assembly
Xxxxxxxx
STUDENTE
Morazzoni Stefano
CORRELATORE
Giuseppe Andreoni
GRUPPO Sub-assembly drawing
Xxxxxxxx
PARTICOLARE Part
Xxxxxxxx
POLITECNICO DI MILANO
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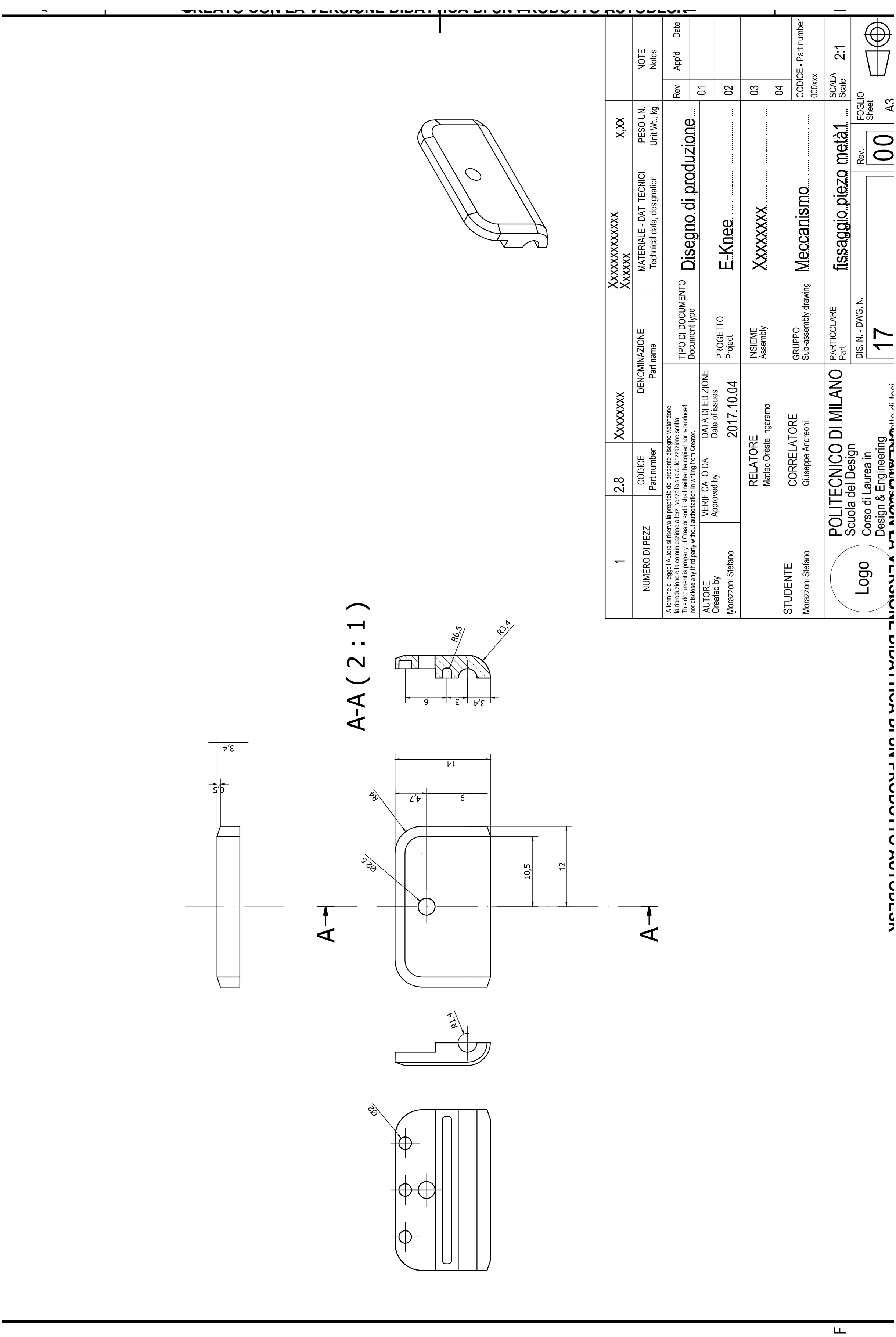
A.A. 2016/ 2017 - Progetto di tesi
Logo
DIS. N. - DWG. N.
4.x
Rev.
00
FOGLIO Sheet
A2
SCALA Scale
1:1
CODICE - Part number
000xxx


A-A (2 : 1)
A
A
NUMERO DI PEZZI
1
CODICE Part number
2.8
Xxxxxxxx
DENOMINAZIONE Part name
Xxxxxxxxxxxxx Xxxxxx
MATERIALE - DATI TECNICI Technical data, designation
PESO UN. Unit Wt., kg
x,xx
NOTE Notes
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DATA DI EDIZIONE Date of issues
2017.10.04
TIPO DI DOCUMENTO Document type
Disegno di produzione
PROGETTO Project
E-Knee
INSIEME Assembly
Xxxxxxxx
GRUPPO Sub-assembly drawing
Meccanismo
PARTICOLARE Part
fissaggio piezo metà1
RELATORE
Matteo Oreste Ingaramo
CORRELATORE
Giuseppe Andreoni
STUDENTE
Morazzoni Stefano
Logo
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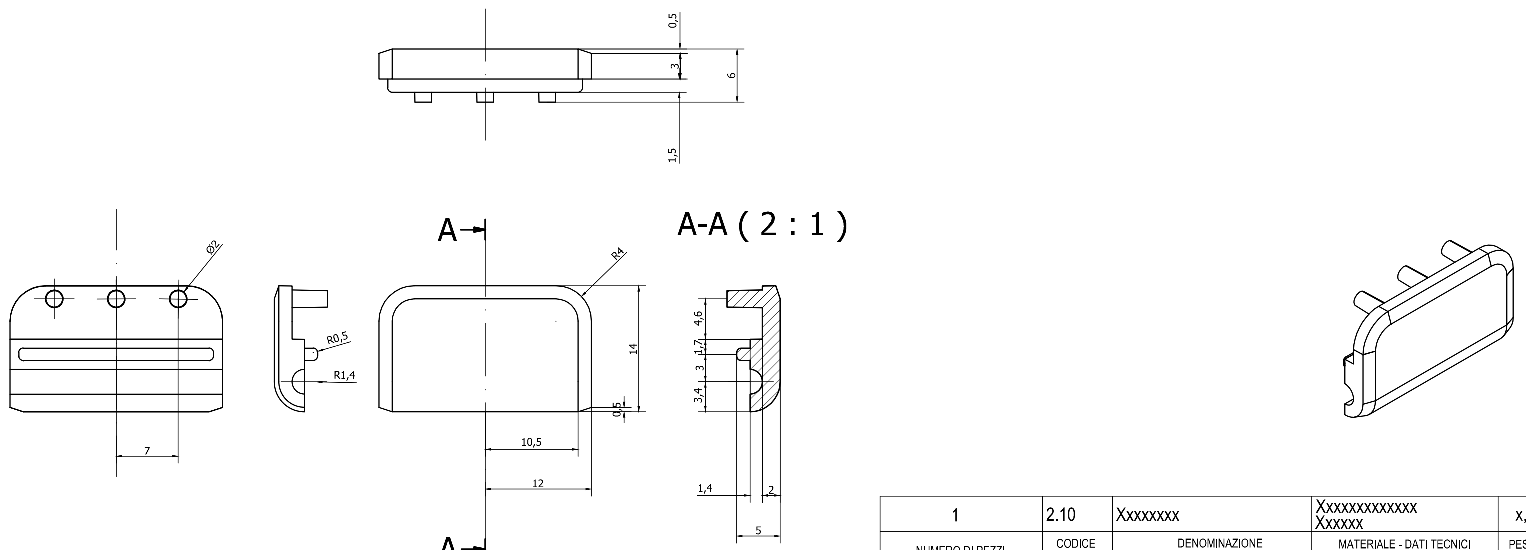
Design & Engineering
DIS. N. - DWG. N.
17
Rev.
00
FOGLIO Sheet
A3
SCALA Scale
2:1
CODICE - Part number
000xxx
Rev
App'd
Date
01
02
03
04



1	2.10	Xxxxxxxx	Xxxxxxxxxxxxx Xxxxxx	x,xx	
NUMERO DI PEZZI	CODICE Part number	DENOMINAZIONE Part name	MATERIALE - DATI TECNICI Technical data, designation	PESO UN. Unit Wt., kg	NOTE Notes

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STUDENTE: Morazzoni Stefano	RELATORE: Matteo Oreste Ingaramo	CORRELATORE: Giuseppe Andreoni

TIPO DI DOCUMENTO Document type	Disegno di produzione
PROGETTO Project	E-Knee
INSIEME Assembly	Xxxxxxxx
GRUPPO Sub-assembly drawing	Meccanismo
PARTICOLARE Part	fissaggio piezo metà2
DIS. N. - DWG. N.	18
Rev.	00
FOGLIO Sheet	A3
SCALA Scale	2:1
CODICE - Part number	000xxx

Rev	App'd	Date
01		
02		
03		
04		

Logo

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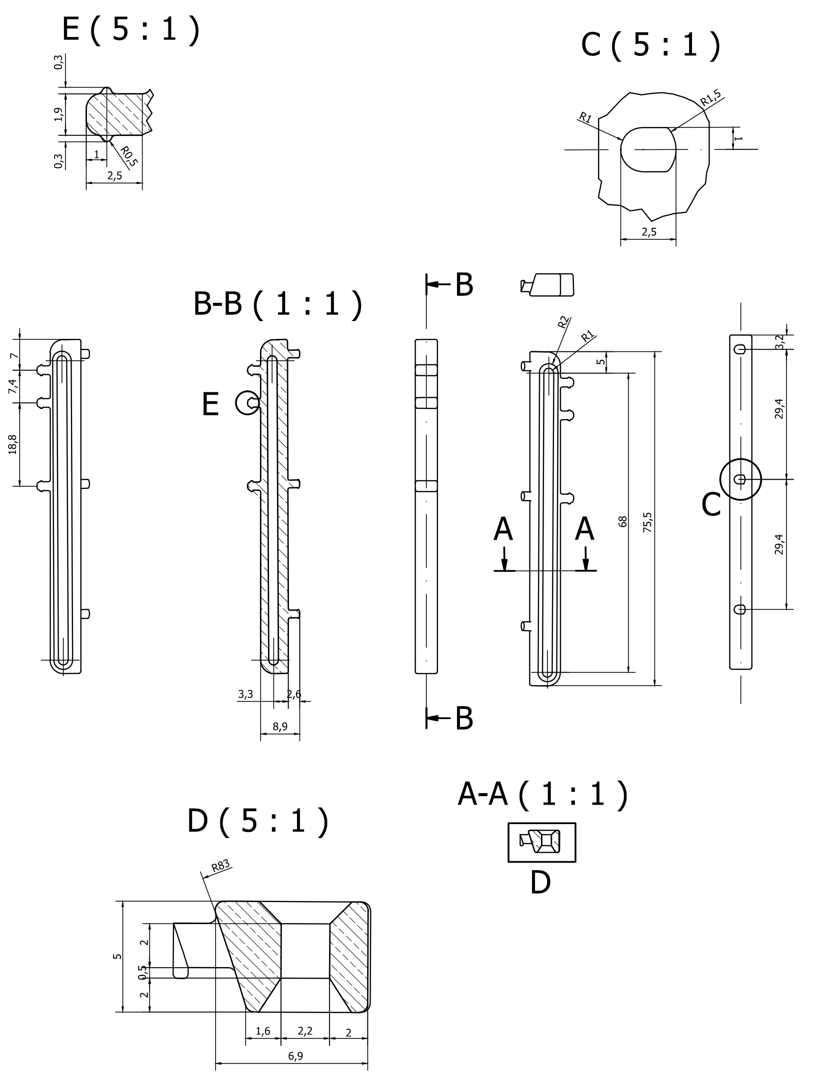
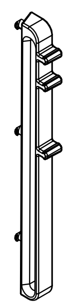
A.A. 2016/ 2017 - Progetto di tesi

6 7 8 E F

ISO A3





0000xx	Xxxxxxxx	Xxxxxxxxxxxxx Xxxxxx	x,xx	
NUMERO DI PEZZI	CODICE Part number	DENOMINAZIONE Part name	MATERIALE - DATI TECNICI Technical data, designation	PESO UN. Unit Wt., kg	NOTE Notes

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TIPO DI DOCUMENTO Document type: Disegno di produzione
PROGETTO Project: E-Knee
INSIEME Assembly: Xxxxxxxx
GRUPPO Sub-assembly drawing: Xxxxxxxx
PARTICOLARE Part: Xxxxxxxx
DIS. N. - DWG. N.: 4.x
Rev.: 00

Rev	App'd	Date
01		
02		
03		
04		

CODICE - Part number: 000xxx
SCALA Scale: 1:1
FOGLIO Sheet: A3

RELATORE
Matteo Oreste Ingaramo
CORRELATORE
Giuseppe Andreoni
STUDENTE
Morazzoni Stefano

Logo
POLITECNICO DI MILANO
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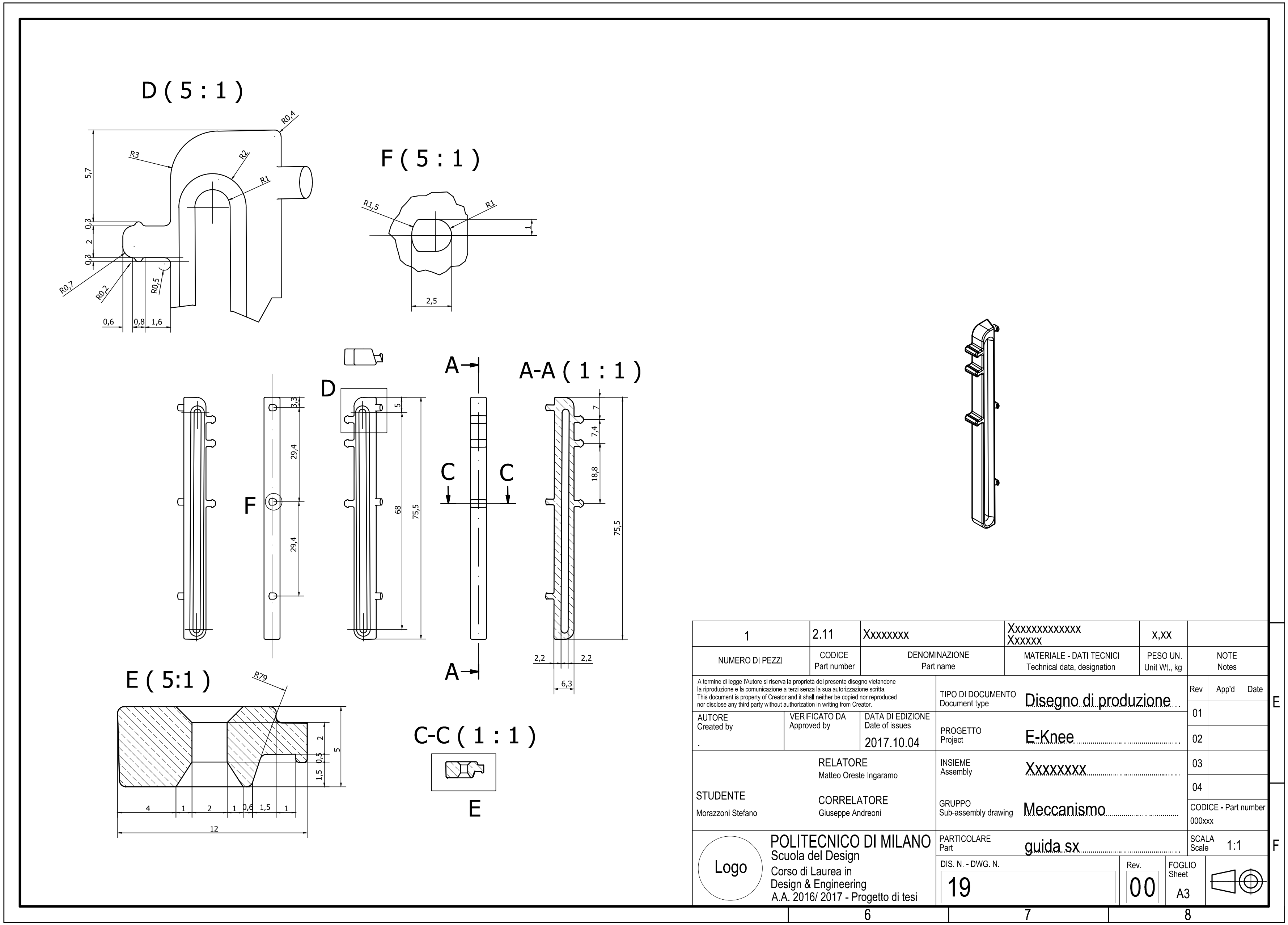
Corso di Laurea in
Design & Engineering
A.A. 2016/ 2017 - Progetto di tesi

6 7 8
E F
ISO A3



D (5 : 1)
F (5 : 1)
A-A (1 : 1)
C-C (1 : 1)
E (5:1)
1
NUMERO DI PEZZI
2.11
CODICE
Part number
Xxxxxxxx
DENOMINAZIONE
Part name
Xxxxxxxxxxxxx
Xxxxxx
MATERIALE - DATI TECNICI
Technical data, designation
x,xx
PESO UN.
Unit Wt., kg
NOTE
Notes
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AUTORE
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Date of issues
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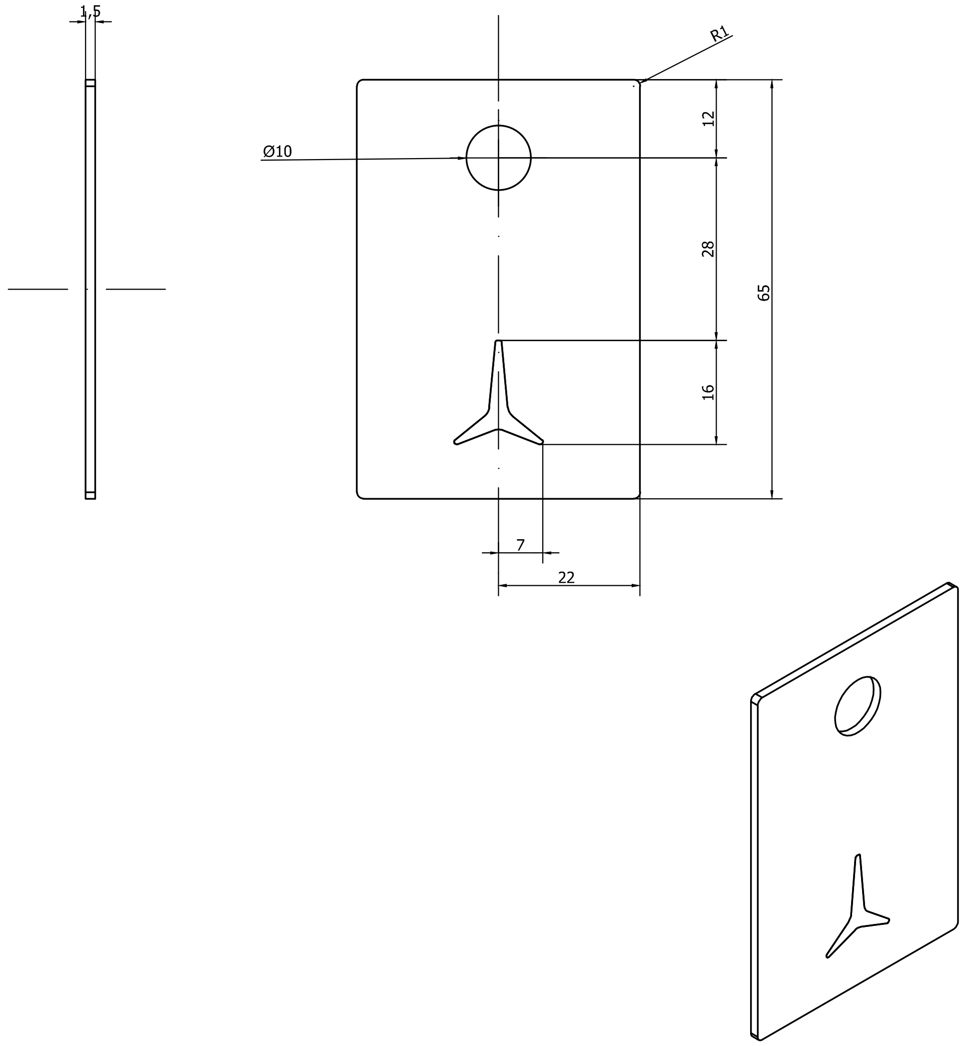
PROGETTO
Project
E-Knee
RELATORE
Matteo Oreste Ingaramo
INSIEME
Assembly
Xxxxxxxx
STUDENTE
Morazzoni Stefano
CORRELATORE
Giuseppe Andreoni
GRUPPO
Sub-assembly drawing
Meccanismo
Rev
App'd
Date
01
02
03
04
CODICE - Part number
000xxx
Logo
POLITECNICO DI MILANO
Scuola del Design
Corso di Laurea in
Design & Engineering
A.A. 2016/ 2017 - Progetto di tesi
PARTICOLARE
Part
guida sx
DIS. N. - DWG. N.
19
Rev.
00
SCALA
Scale
1:1
FOGLIO
Sheet
A3



	0000xx	Xxxxxxxx	Xxxxxxxxxxxxx Xxxxxx	x,xx	
NUMERO DI PEZZI	CODICE Part number	DENOMINAZIONE Part name	MATERIALE - DATI TECNICI Technical data, designation	PESO UN. Unit Wt., kg	NOTE Notes

TIPO DI DOCUMENTO
Document type
Disegno di produzione

Rev	App'd	Date
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04		

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Approved by

DATA DI EDIZIONE
Date of issues
2017.10.04

PROGETTO
Project
E-Knee

RELATORE
Matteo Oreste Ingaramo

STUDENTE
Morazzoni Stefano

CORRELATORE
Giuseppe Andreoni

INSIEME
Assembly
Xxxxxxxx

GRUPPO
Sub-assembly drawing
Xxxxxxxx

CODICE - Part number
000xxx

Logo

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Design & Engineering
A.A. 2016/ 2017 - Progetto di tesi

PARTICOLARE
Part
Xxxxxxxx

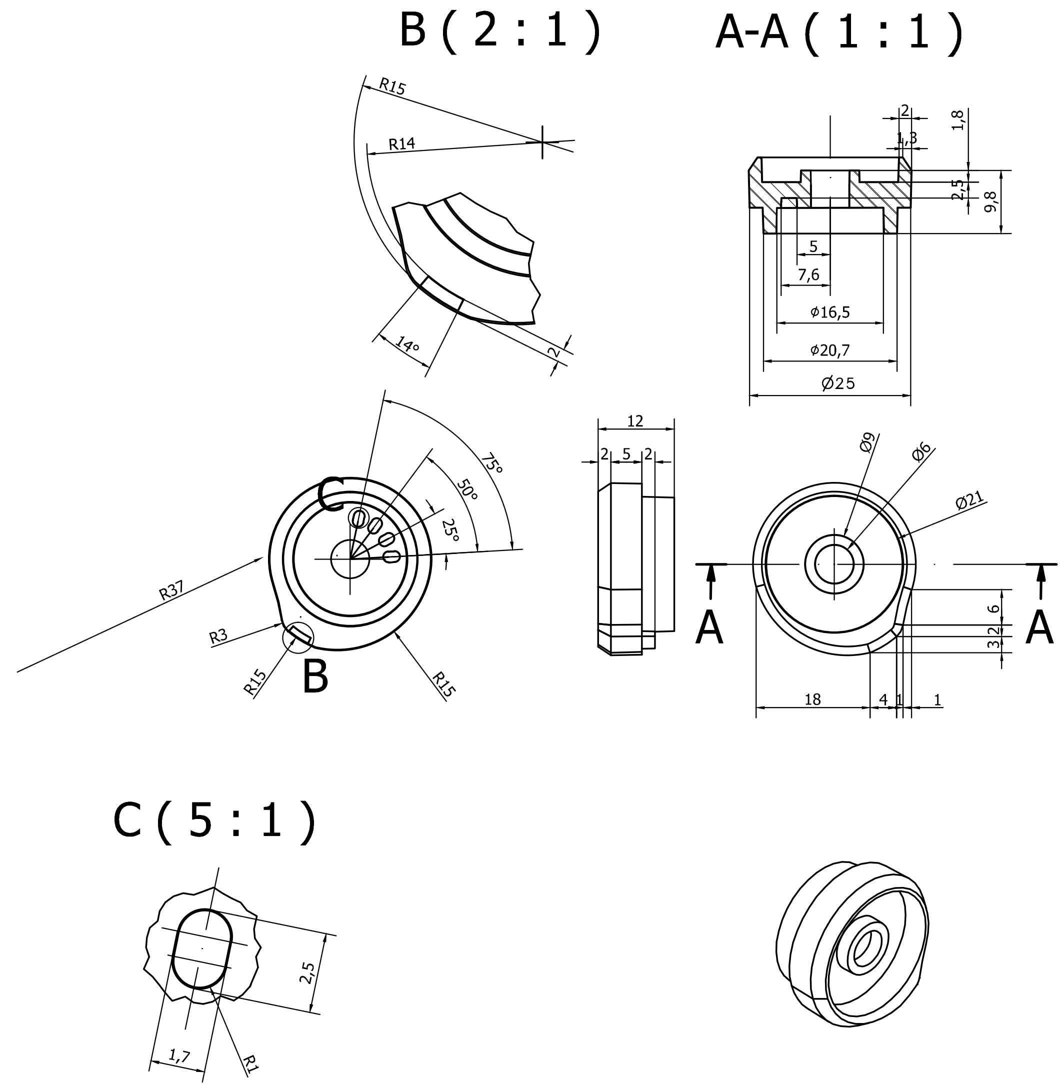
SCALA
Scale
1:1

F

DIS. N. - DWG. N.
4.x

Rev.
00

FOGLIO
Sheet
A4



1	2.7 (a)	Xxxxxxxx	Xxxxxxxxxxxxx Xxxxxx	x,xx	
NUMERO DI PEZZI	CODICE Part number	DENOMINAZIONE Part name	MATERIALE - DATI TECNICI Technical data, designation	PESO UN. Unit Wt., kg	NOTE Notes

TIPO DI DOCUMENTO Document type: Disegno di produzione

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.		2017.10.04

PROGETTO Project: E-Knee

INSIEME Assembly: Xxxxxxxx

GRUPPO Sub-assembly drawing: Meccanismo

PARTICOLARE Part: Barra centrale (tappo)

Rev	App'd	Date
01		
02		
03		
04		

CODICE - Part number: 000xxx

SCALA Scale: 1:1

STUDENTE
Morazzoni Stefano

RELATORE
Matteo Oreste Ingaramo

CORRELATORE
Giuseppe Andreoni

Logo

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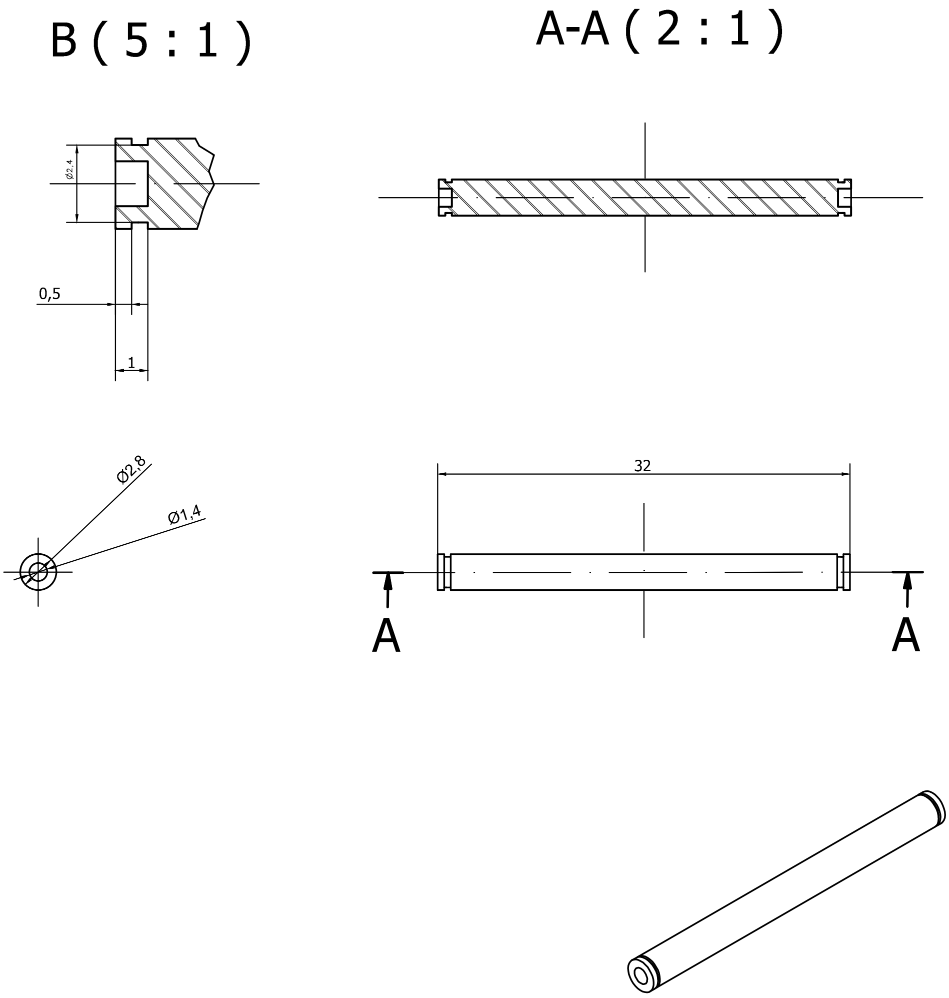
DIS. N. - DWG. N.	Rev.	FOGLIO Sheet
15	00	A4

F



NUMERO DI PEZZI	CODICE Part number	DENOMINAZIONE Part name	MATERIALE - DATI TECNICI Technical data, designation	PESO UN. Unit Wt., kg	NOTE Notes
1	2.4	Xxxxxxxx	Xxxxxxxxxxxxx Xxxxxx	x,xx	

TIPO DI DOCUMENTO Document type: Disegno di produzione

Rev	App'd	Date
01		
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04		

AUTORE Created by: Morazzoni Stefano
VERIFICATO DA Approved by:
DATA DI EDIZIONE Date of issues: 2017.10.04

PROGETTO Project: E-Knee

RELATORE
Matteo Oreste Ingaramo

STUDENTE
Morazzoni Stefano

CORRELATORE
Giuseppe Andreoni

INSIEME Assembly: Xxxxxxxx

GRUPPO Sub-assembly drawing: Meccanismo

CODICE - Part number: 000xxx

Logo

POLITECNICO DI MILANO
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Corso di Laurea in
Design & Engineering
A.A. 2016/ 2017 - Progetto di tesi

PARTICOLARE Part: perno

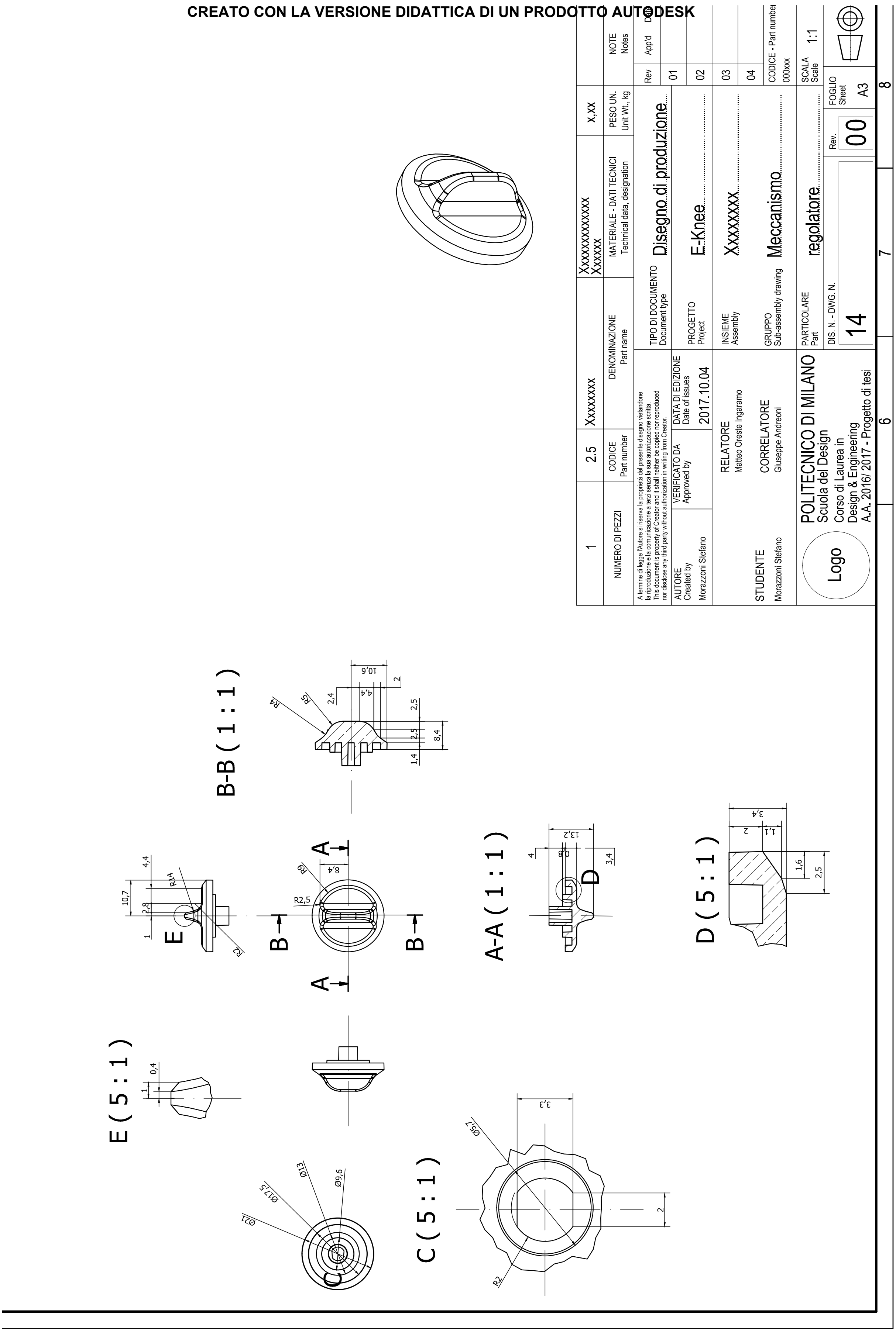
SCALA Scale: 2:1

F

DIS. N. - DWG. N.: 13

Rev.: 00

FOGLIO Sheet: A4


1
NUMERO DI PEZZI
2.5
CODICE
Part number
Xxxxxxxx
DENOMINAZIONE
Part name
Xxxxxxxxxxxxx
Xxxxxx
MATERIALE - DATI TECNICI
Technical data, designation
x,xx
PESO UN.
Unit Wt., kg
NOTE
Notes
AUTORE
Created by
Morazzoni Stefano
VERIFICATO DA
Approved by
DATA DI EDIZIONE
Date of issues
2017.10.04
TIPO DI DOCUMENTO
Document type
Disegno di produzione
PROGETTO
Project
E-Knee
RELATORE
Matteo Oreste Ingaramo
INSIEME
Assembly
Xxxxxxxx
STUDENTE
Morazzoni Stefano
CORRELATORE
Giuseppe Andreoni
GRUPPO
Sub-assembly drawing
Meccanismo
Logo
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Design & Engineering
A.A. 2016/ 2017 - Progetto di tesi
PARTICOLARE
Part
regolatore
DIS. N. - DWG. N.
14
Rev.
00
FOGLIO
Sheet
A3
SCALA
Scale
1:1
CODICE - Part number
000xxx
Rev
App'd
01
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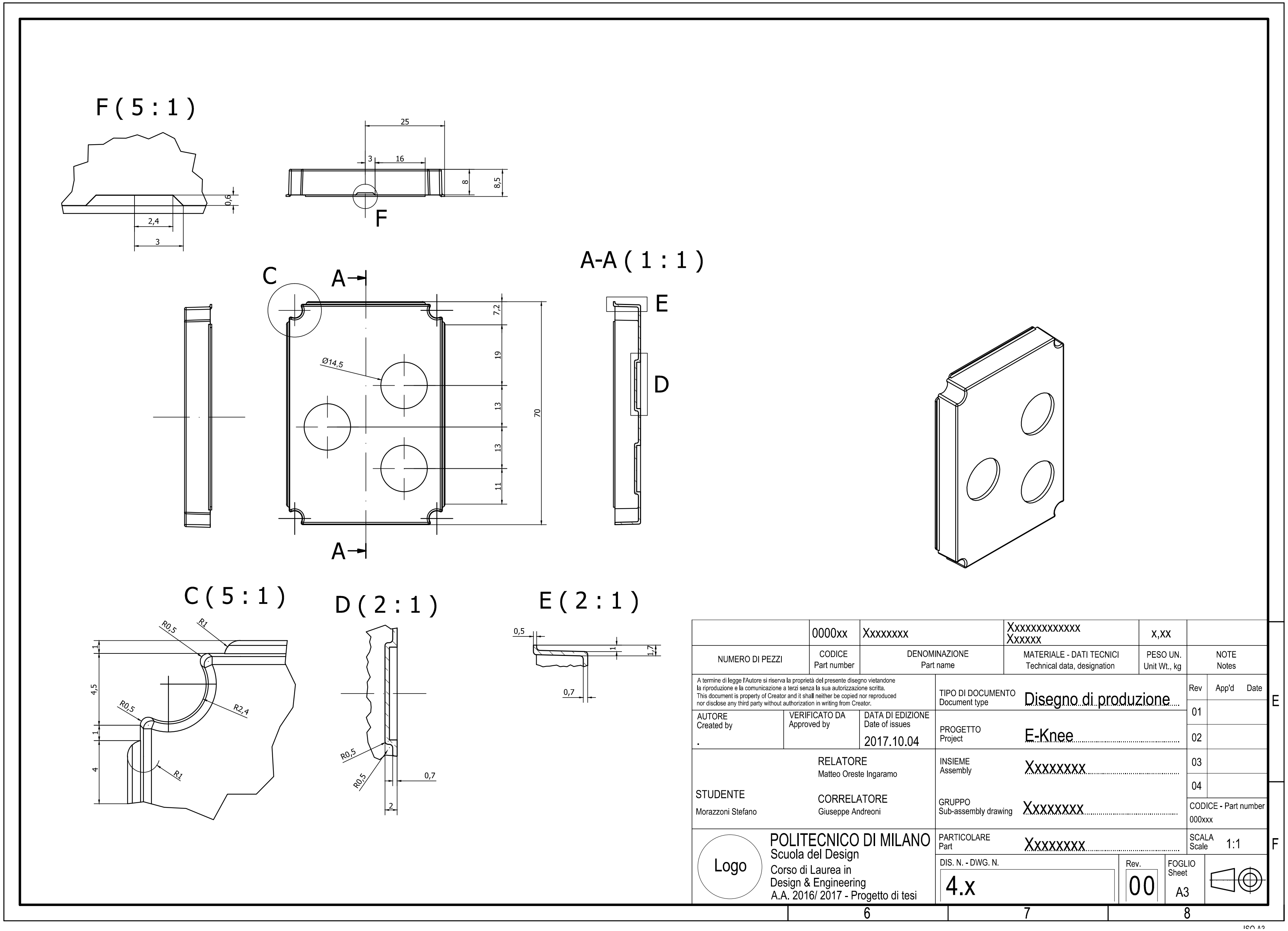
03
04
B-B (1 : 1)
A-A (1 : 1)
D (5 : 1)
E (5 : 1)
C (5 : 1)
6
7
8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C
A
A
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D
Ø14,5
7,2
19
13
13
11
70
C (5 : 1)
D (2 : 1)
E (2 : 1)
R0,5
R1
R0,5
R2,4
R1
4,5
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R0,5
0,7
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1,7
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0000xx
Xxxxxxxx
Xxxxxxxxxxxxx
Xxxxxx
x,xx
NUMERO DI PEZZI
CODICE
Part number
DENOMINAZIONE
Part name
MATERIALE - DATI TECNICI
Technical data, designation
PESO UN.
Unit Wt., kg
NOTE
Notes
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2017.10.04
PROGETTO
Project
E-Knee
01
02
03
04
RELATORE
Matteo Oreste Ingaramo
INSIEME
Assembly
Xxxxxxxx
STUDENTE
Morazzoni Stefano
CORRELATORE
Giuseppe Andreoni
GRUPPO
Sub-assembly drawing
Xxxxxxxx
CODICE - Part number
000xxx
Logo
POLITECNICO DI MILANO
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PARTICOLARE
Part
Xxxxxxxx
SCALA
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4.x
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Sheet
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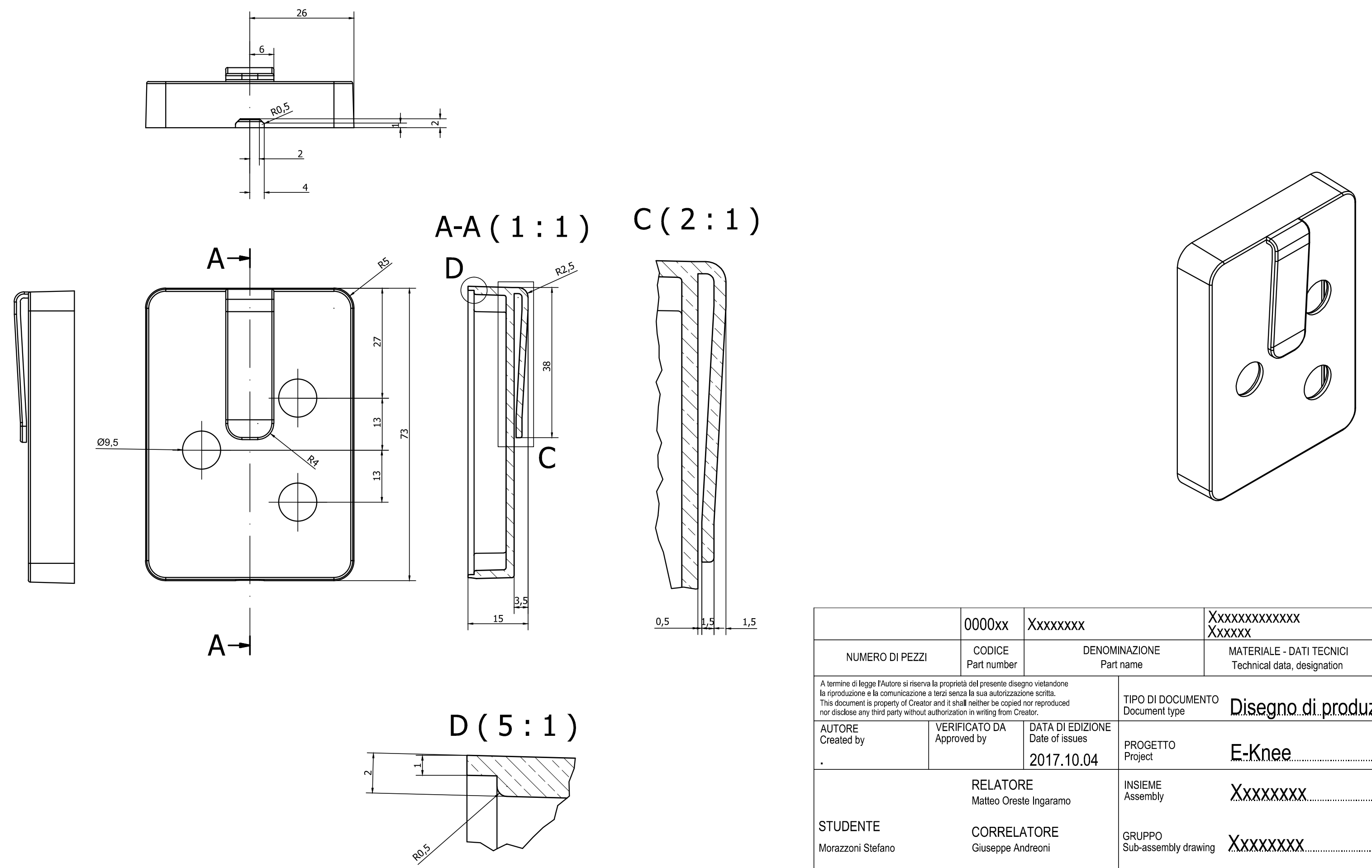

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NUMERO DI PEZZI	CODICE Part number	DENOMINAZIONE Part name	MATERIALE - DATI TECNICI Technical data, designation	PESO UN. Unit Wt., kg	NOTE Notes

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			PROGETTO Project	E-Knee	01
	RELATORE Matteo Oreste Ingaramo		INSIEME Assembly	Xxxxxxxx	02
STUDENTE Morazzoni Stefano	CORRELATORE Giuseppe Andreoni		GRUPPO Sub-assembly drawing	Xxxxxxxx	03
					04
					CODICE - Part number 000xxx
Logo	POLITECNICO DI MILANO Scuola del Design Corso di Laurea in Design & Engineering A.A. 2016/ 2017 - Progetto di tesi		PARTICOLARE Part	Xxxxxxxx	SCALA Scale 1:1
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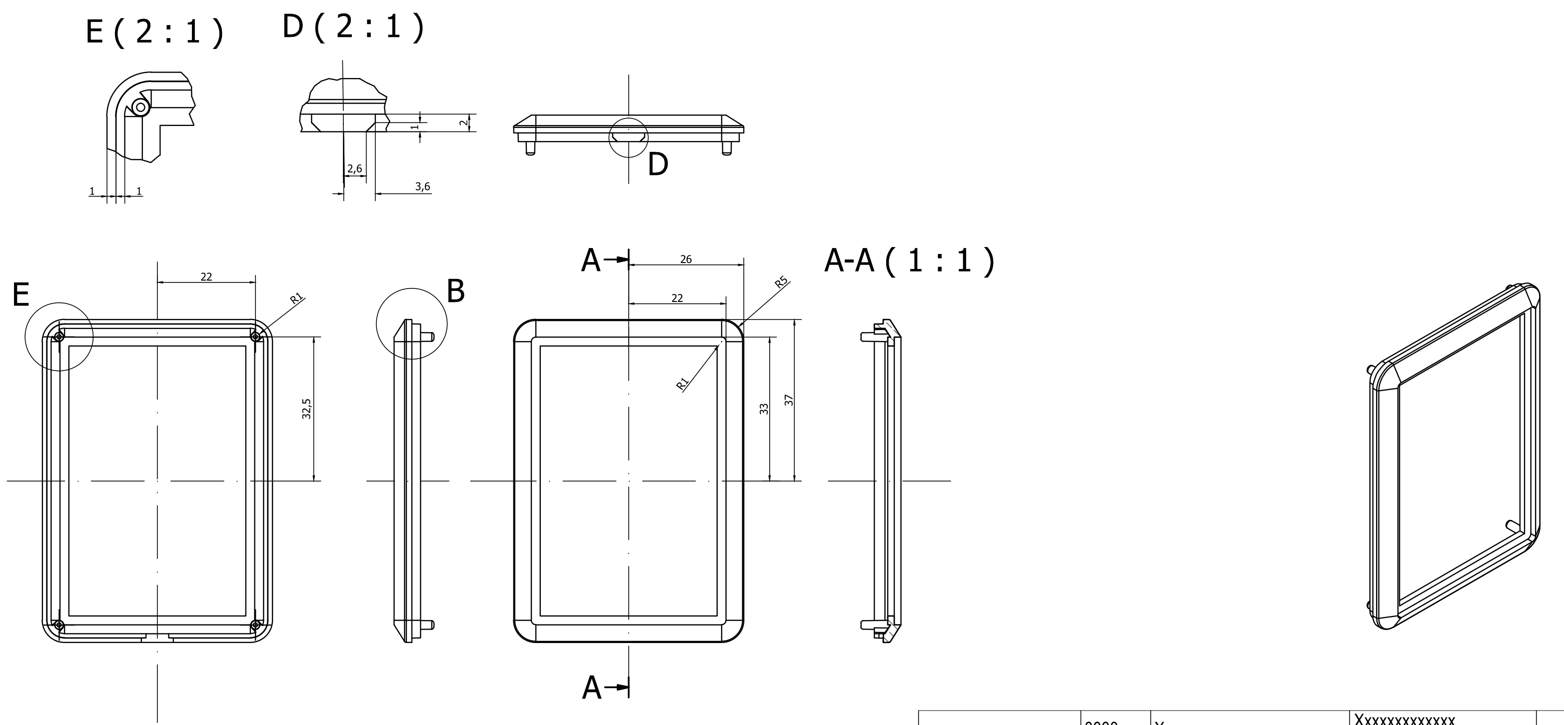

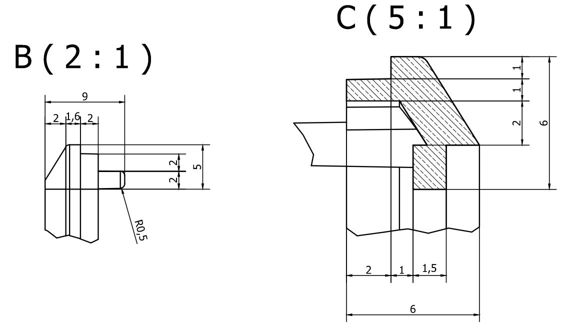

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NUMERO DI PEZZI	CODICE Part number	DENOMINAZIONE Part name	MATERIALE - DATI TECNICI Technical data, designation	PESO UN. Unit Wt., kg	NOTE Notes

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Giuseppe Andreoni

TIPO DI DOCUMENTO Document type	Disegno di produzione
PROGETTO Project	E-Knee
INSIEME Assembly	Xxxxxxxx
GRUPPO Sub-assembly drawing	Xxxxxxxx
PARTICOLARE Part	Xxxxxxxx

Rev	App'd	Date
01		
02		
03		
04		

CODICE - Part number
000xxx

SCALA Scale 1:1

Logo

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Corso di Laurea in
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DIS. N. - DWG. N.	Rev.	FOGLIO Sheet
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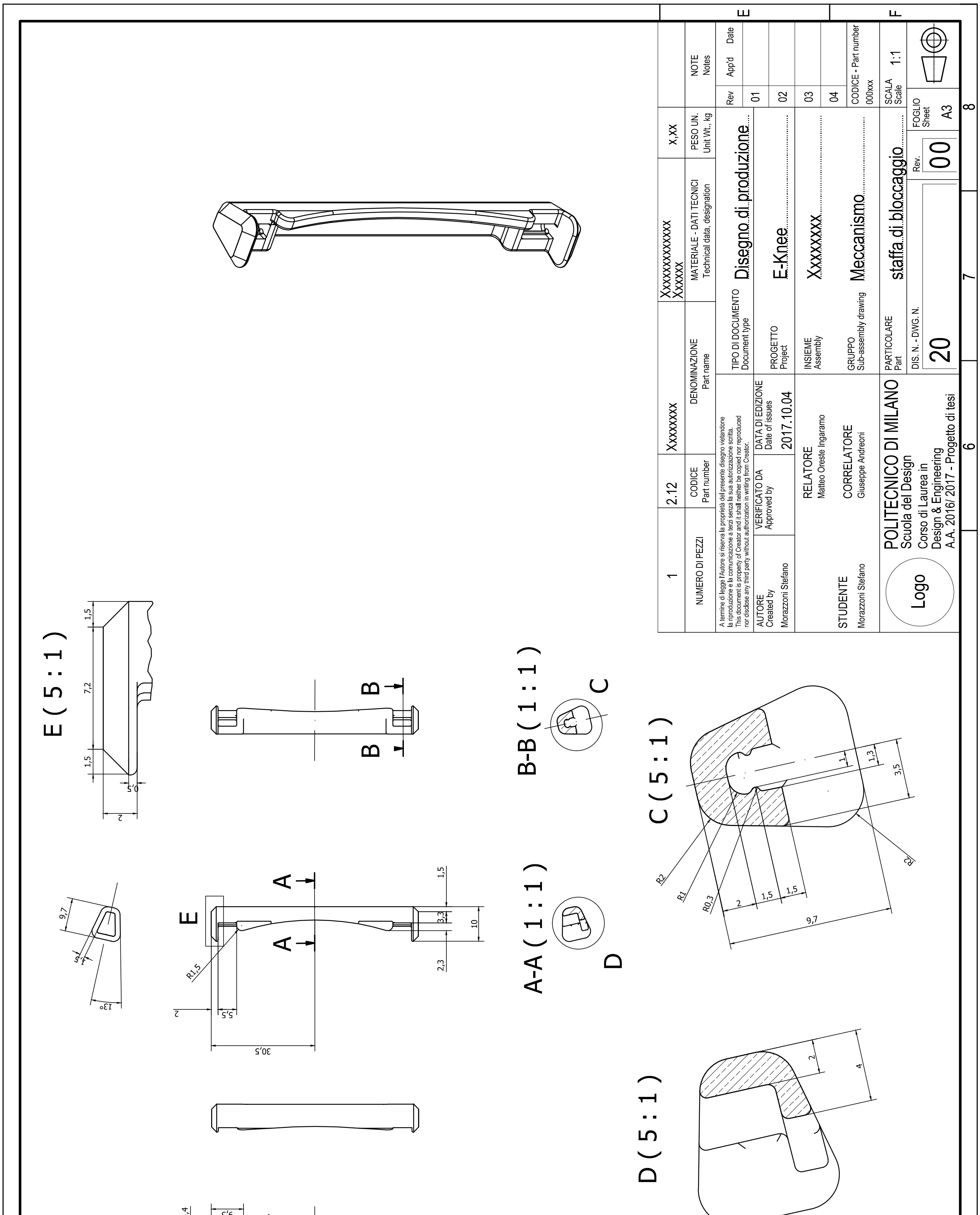

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B-B (1 : 1)
C (5 : 1)
A-A (1 : 1)
D (5 : 1)
NUMERO DI PEZZI
1
CODICE
Part number
2.12
DENOMINAZIONE
Part name
Xxxxxxxx
MATERIALE - DATI TECNICI
Technical data, designation
Xxxxxxxxxxxxxx Xxxxxx
PESO UN.
Unit Wt., kg
x,xx
NOTE
Notes
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Document type
Disegno di produzione
PROGETTO
Project
E-Knee
RELATORE
Matteo Oreste Ingaramo
INSIEME
Assembly
Xxxxxxxx
STUDENTE
Morazzoni Stefano
CORRELATORE
Giuseppe Andreoni
GRUPPO
Sub-assembly drawing
Meccanismo
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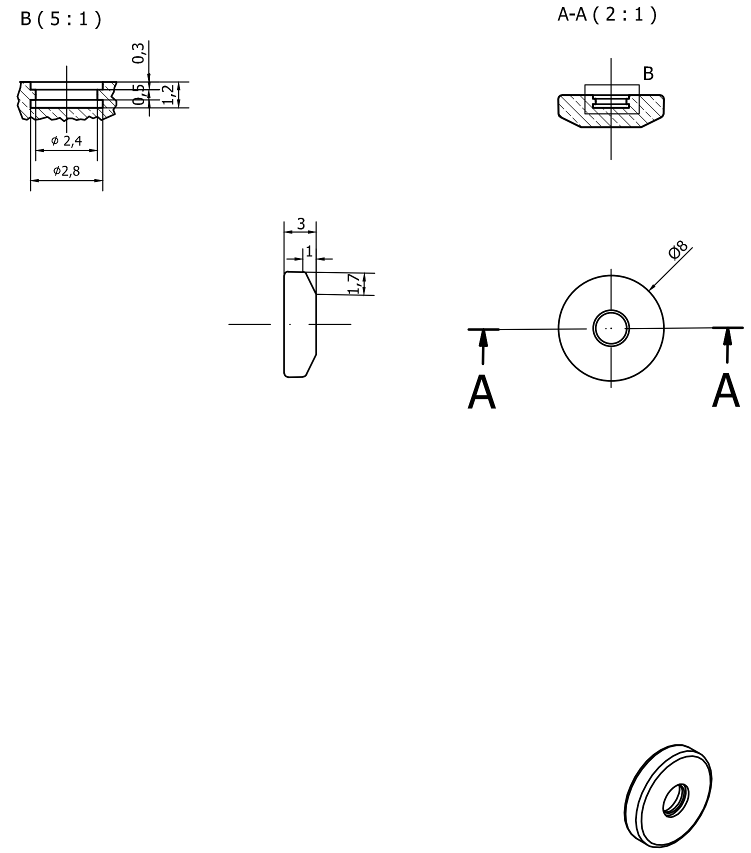
PARTICOLARE
Part
staffa di bloccaggio
DIS. N. - DWG. N.
20
Rev.
00
FOGLIO
Sheet
A3
SCALA
Scale
1:1
CODICE - Part number
000xxx



NUMERO DI PEZZI	CODICE Part number	DENOMINAZIONE Part name	MATERIALE - DATI TECNICI Technical data, designation	PESO UN. Unit Wt., kg	NOTE Notes
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TIPO DI DOCUMENTO Document type: Disegno di produzione

AUTORE Created by: .
VERIFICATO DA Approved by:
DATA DI EDIZIONE Date of issues: 2017.10.04

PROGETTO Project: E-Knee

INSIEME Assembly: Xxxxxxxx

GRUPPO Sub-assembly drawing: Meccanismo

PARTICOLARE Part: tappo perno

Rev	App'd	Date
01		
02		
03		
04		

CODICE - Part number: 000xxx

SCALA Scale: 2:1

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DIS. N. - DWG. N.: 12
Rev.: 00
FOGLIO Sheet: A4

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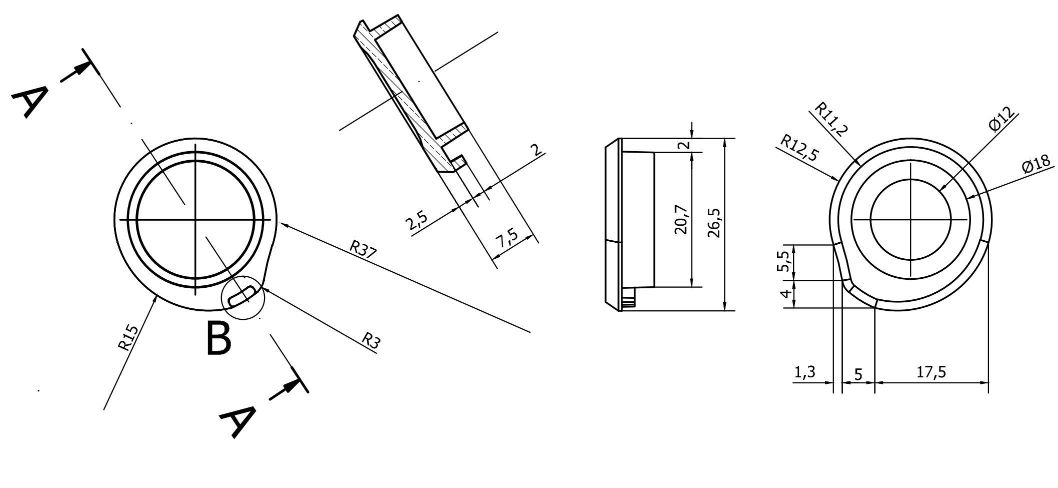

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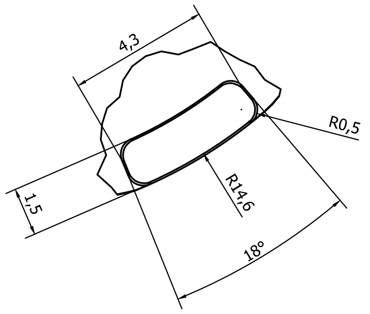

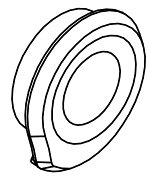

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NUMERO DI PEZZI	CODICE Part number	DENOMINAZIONE Part name	MATERIALE - DATI TECNICI Technical data, designation	PESO UN. Unit Wt., kg	NOTE Notes

TIPO DI DOCUMENTO Document type	Disegno di produzione
PROGETTO Project	E-Knee
INSIEME Assembly	Xxxxxxxx
GRUPPO Sub-assembly drawing	Xxxxxxxx
PARTICOLARE Part	Xxxxxxxx

Rev	App'd	Date
01		
02		
03		
04		

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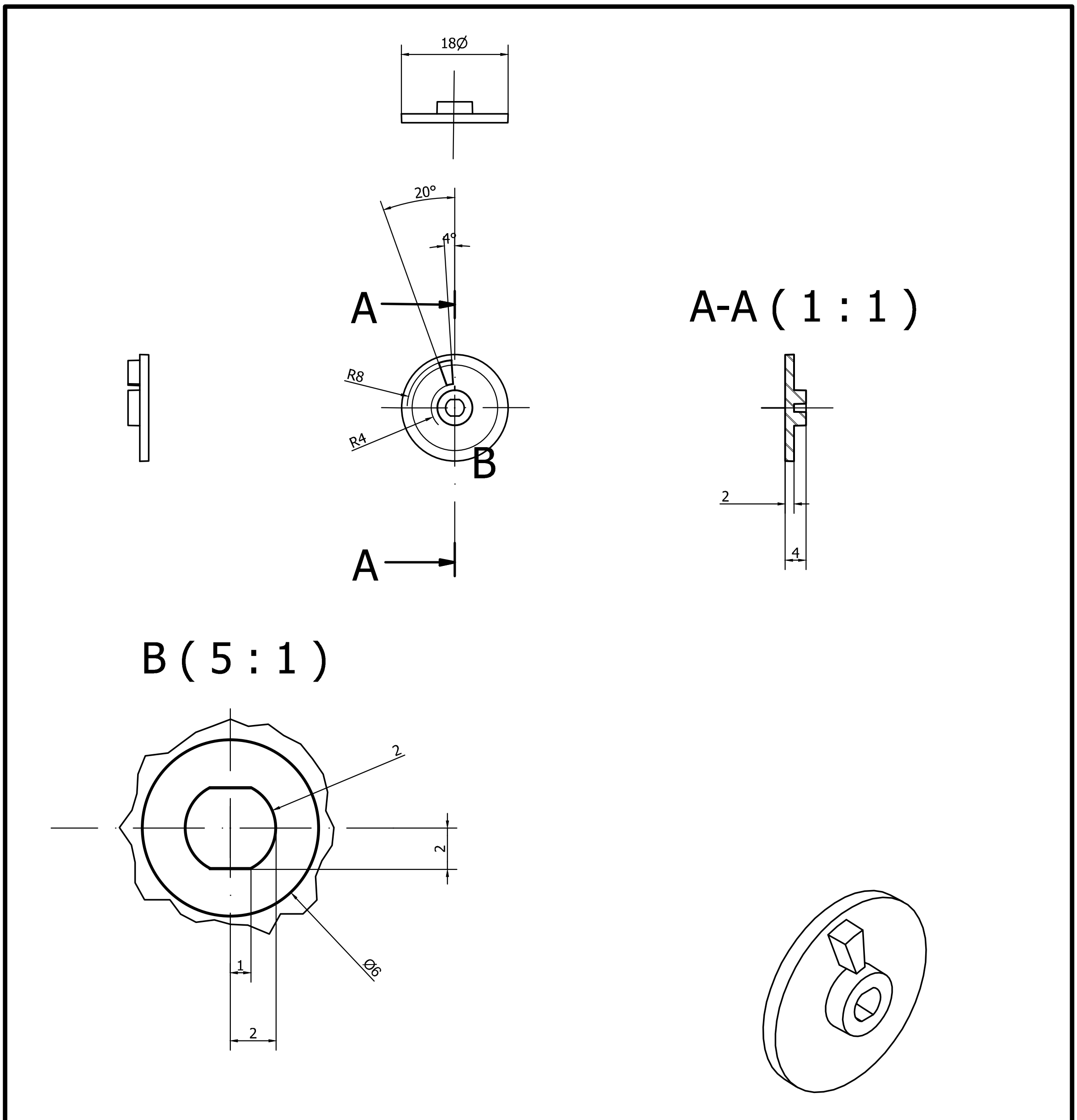
DIS. N. - DWG. N.	Rev.	FOGLIO Sheet
4.x	00	A4



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NUMERO DI PEZZI	CODICE Part number	DENOMINAZIONE Part name	MATERIALE - DATI TECNICI Technical data, designation	PESO UN. Unit Wt., kg	NOTE Notes

TIPO DI DOCUMENTO Document type	Disegno di produzione	Rev	App'd	Date
AUTORE Created by .	VERIFICATO DA Approved by	DATA DI EDIZIONE Date of issues 2017.10.04		
PROGETTO Project	E-Knee	01		
		02		
INSIEME Assembly	Xxxxxxxx	03		
GRUPPO Sub-assembly drawing	Xxxxxxxx	04		
PARTICOLARE Part	Xxxxxxxx	CODICE - Part number 000xxx		
SCALA Scale	1:1			
DIS. N. - DWG. N.	4.x	Rev.	00	
FOGLIO Sheet	A4			

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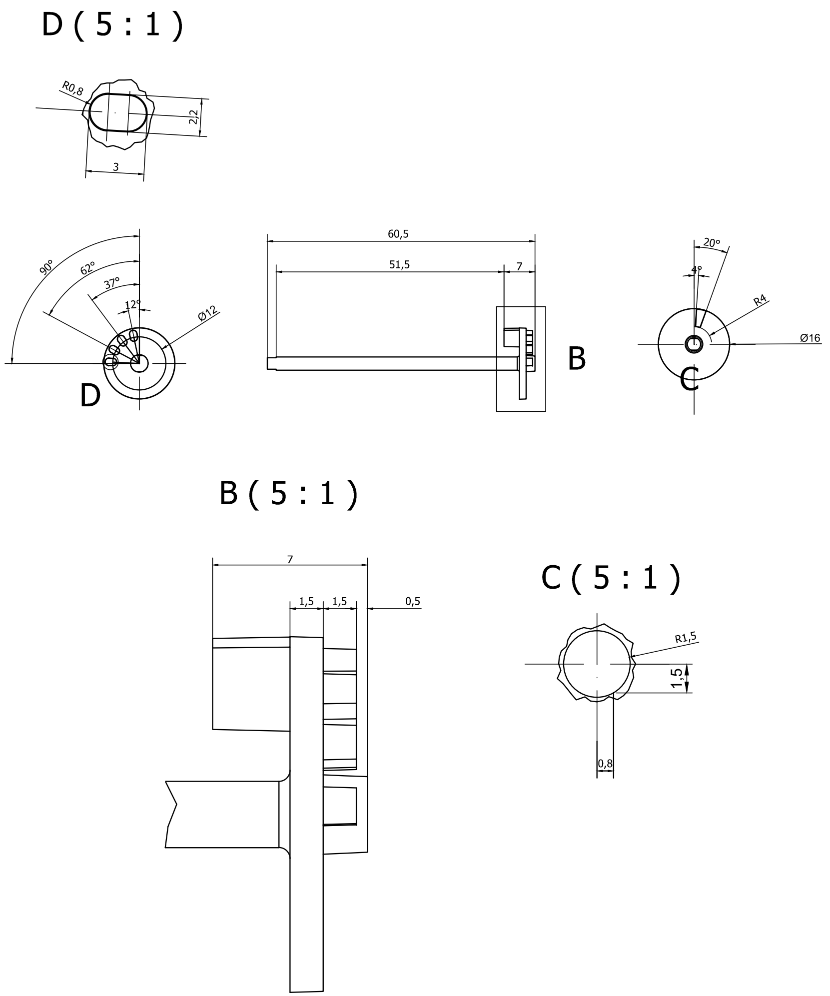

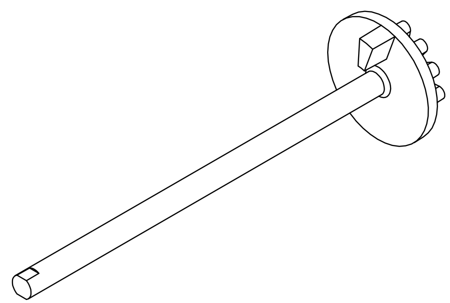

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NUMERO DI PEZZI	CODICE Part number	DENOMINAZIONE Part name	MATERIALE - DATI TECNICI Technical data, designation	PESO UN. Unit Wt., kg	NOTE Notes

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PROGETTO Project	E-Knee
INSIEME Assembly	Xxxxxxxx
GRUPPO Sub-assembly drawing	Xxxxxxxx
PARTICOLARE Part	Xxxxxxxx
DIS. N. - DWG. N.	4.x

RELATORE
Matteo Oreste Ingaramo

STUDENTE
Morazzoni Stefano

CORRELATORE
Giuseppe Andreoni

Rev	App'd	Date
01		
02		
03		
04		

CODICE - Part number
000xxx

SCALA Scale 1:1

Rev. 00

FOGLIO Sheet A3

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Design & Engineering
A.A. 2016/ 2017 - Progetto di tesi

E
F
6
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8