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Wireless Speech Recognition with WIFI Environment Monitor

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Registration Number :........../2019

Dedication

To my great family BELACEL

To my parents, LAMOURI and HOURIYA for their unconditional love, support and care.

To all my sisters and all my brothers for their support and encouragements

To my friends who stood by my side all this time, for their compassion, motivation and for giving me a bit of breathing space.

To all my teachers and professors for their hardworking and inspiration

To everyone who made this work possible.

I dedicate this humble work to You.

KHALIL BELACEL

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First of all, I would like to thank "The Almighty ALLAH" for his continuous help and care.

I would like to express my deepest gratitude to my parents, grandmother, Family, teachers, Friends, and Mates for their encouragement, help and support.

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I' am also delighted to thank all professors and colleagues for their help and advice, specially Dr. METIDJI BRAHIM Who shared his knowledge and passion with me.

Abstract

This report discloses an attempt of creating a complete technical system that based mainly on speech recognition technology and environment monitor which can be used by people with physical disability, using technology that we have today is powerful tool which will allow us to accomplish and construct this system.

The aim of the system is giving a disabled person the ability of controlling some surrounding devices such as lightning, air conditioner and other domestic devices which require some basic body movements which cannot be performed by a person who has special type of injury like quadriplegia or paraplegia, and that ability is given by using speech recognition system, and also an environment monitor which can be used to monitor the environment parameters in the room where the patient resides. Additionally, to all that is to encourage them morally which can be done by giving them the feeling that they are somewhat self-dependent to perform something without external intervention.

This work can contribute in finding better and efficient solutions to be used by this category of people and also to eliminate the lack of the awareness about the special needs and care that they deserve.

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List of abbreviations

WHO	World Health Organization	**SCI**	Spinal cord Injury
CNS	Central Nervous System	**WIFI**	Wireless Fidelity
ADC	Analog to Digital Converter	**DTW**	Dynamic Time Warping
DSC	Digital Signal Controller	**DSP**	Digital Signal Processor
MAC	Multiply Accumulate	**I/O**	Input / Output
RAM	Read Only Memory	**ROM**	Read Only Memory
CPU	Central Processing Unit	**MIC**	Microphone
IC	Integrated Circuit	**DAC**	Digital to Analog Converter
FPU	Floating Point Unit	**SPI**	Serial Peripheral Interface
PCB	Printed Circuit Board	**CO**	Carbon monoxide
CH4	Methane	**HTML**	HyperText Markup Language
URL	Uniform Resource Locator	**HTTP**	HyperText Transfer Protocol

Introduction

The human body is truly the most amazing and the most complex organic structure in the known universe, this complex organic structure which is decomposed of many organs connected together which allows the human being to perform very complex and critical tasks to stay alive, even with the current advancing of robotic technology, it would be impossible to create a machine that defeats the human body in what is characterized with, but even with will all the protection mechanisms that embedded with the human body, injuries can occur and the reaction to them by the human body can vary depends on the level of injury, unfortunately some of these injuries cannot be dealt especially if it is related to nervous system of the human body, the spinal cord is considered one of the most important organ in the human body which allow him to do the vital functions like walking, running and others but unfortunately even this organ can be damaged due to some kind of accidents, which make human body stop doing its normal function and because the spinal cord is decomposed of nerves, the body cannot heal itself and the injured body will stay in state forever even with the latest and the advanced medical technology that we have today, but the technology can be used to assist and reduce the effects of these kind of injures.

The main purpose of this work is to provide some kind of technical solution that can be used by the people who are affected by the spinal cord injury and the work also focuses on giving some information related to this kind of injuries and all of that are going be discussed further in this report which is divided into three chapters mentioned below:

Chapter I gives a brief introduction to the spinal cord injury (SCI) and the anatomy of the spinal cord. Types of this injury is also included and each one is described briefly with details. The causes are also addressed here to give a general idea about them and also explain the importance of the rehabilitations and health care that should be provide

And then the next chapter is an introduction to our system design by explaining some different terms that were used in the project like speech recognition and how it is done from hardware point of view. Sampling theory and the conversion a signal from the analog domain to digital domain also discussed without forgetting DSP engine which considered the heart of any system based on digital signal processing algorithms. Wireless communication is given summary just to give general idea about it.

The final chapter is the most important chapter in this report, starting by a global idea about the project then explaining each section of the project in detail. Speech recognition with the wireless transmitter is introduced with some details related to the hardware design and principle of operation behind this circuit. The receiver also described briefly either as hardware design and software. The last one which is the WIFI environment monitor which is considered as a secondary project which was briefly explained whether the hardware design or software.

Chapter 1
Physical Disability

1.1 Introduction

According to the World Health Organization, a world population of over one billion experience some form of disability. This corresponds to about 15% of the planet's population of whom 2-4% experience significant difficulties in body functioning. Disability is becoming a significant matter, its prevalence is increasing, and this is a cause for concern [1].

Throughout the world, the number of disable people is increasing due to various causes which can be genetically, environmental or unknown. In this chapter we will give an overview about spinal cord injury which considered as one of the main causes of paralysis, and discuss some important issues that encounter this category of people. And also introduce a technical solution to assist people who are affected by this condition [2].

1.2 Spinal Cord Injury - a global picture

Spinal cord injury (SCI) is medically complex and life disrupting condition. Historically, it has been associated with very high mortality rates. Yet today, in high-income countries, SCI can be viewed less as the end of a worthwhile or productive life and more as a personal and social challenge that can be successfully overcome. This change reflects better medical provision, which means that people are able to survive, live and flourish after injury. For instance, people who develop SCI can now usually benefit from improved emergency response, effective health and rehabilitation interventions, and technologies such as respirators and appropriate wheelchairs, together with more extensive social services and more accessible environments. As result, lives can be saved and functioning can be maximized. Many people with SCI can now anticipated not just a longer life, but also a fuller and more productive life, than they would have had in previous generation.

1.3 Understanding Spinal Cord Injury

The spinal cord is long, thin, tubular structure made up of nervous tissue, that extends down from the brain to vertebral level, ending in the Conus medullaris. The spinal cord itself has neurological segmental levels that corresponds to the nerve roots that exit the spinal column between each of the vertebrae. There are 31 pairs of spinal nerve roots: 8 cervical, 12 thoracic, 5 lumbar, 5 sacral and 1 coccygeal. Nerves from each segment connect to specific regions of the body, and thus control motor and autonomic functions.

Damage to the spinal cord may be traumatic or non-traumatic. Traumatic Spinal Cord Injury can result from many different causes including falls, road traffic injuries, occupational and sports injuries and violence. Non-traumatic SCI, on the other hand, usually involves an underlying pathology such as infectious disease, tumor, musculoskeletal disease such as osteoarthritis, and congenital problems such spina bifida, which is a neural tube defect that arises during development of the embryo.

The symptoms of spinal cord injury depend on the extent of the injury or non-traumatic cause, but they can include loss of sensory or motor control of the lower limbs, trunk and the upper limbs, as well as loss of autonomic regulation of the body. This can affect breathing, heart rate, blood pressure, temperature control, bowel and bladder control, and sexual function. In general, the higher in the spinal column an injury occurs, the more function a person will lose [3].

1.4 Spinal Cord Anatomy

Medical providers divide the spinal cord into four distinct regions as illustrated in the Figure 1.1. Knowing the region in which the injury is located is often the key to understanding diagnosis and treatment.

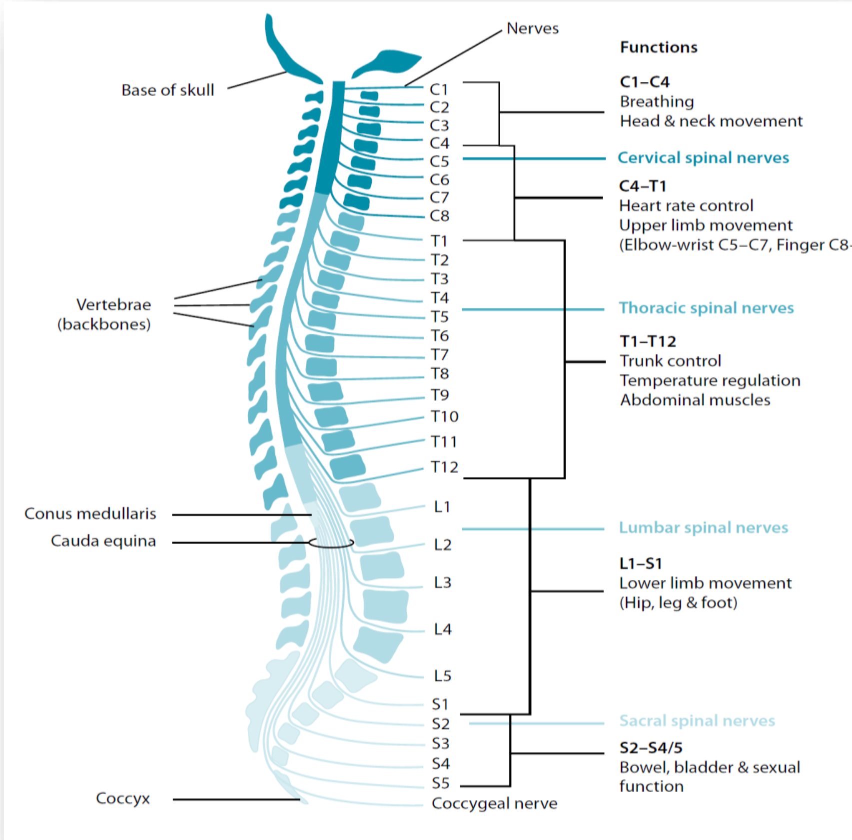


Figure 1.1: Longitudinal organization of the spinal cord (with cervical, thoracic, lumbar and sacral segments shaded), spinal vertebrae, and spinal nerves.

1.4.1 Cervical region

Cervical region is the topmost portion of the spinal cord, where the brain connects to the spinal cord, and the neck connects to the back. This region consists of eight vertebrae commonly referred to as C1-C8 as illustrated in Figure 1.1. All spinal cord numbers are descending, so C1 is the highest vertebra, while C8 is the lowest in this region.

1.4.2 Thoracic region

Thoracic forms the middle of the spinal cord, containing twelve vertebrae numbered T1-T12 as illustrated in Figure 1.1. The thoracic spine is the longest region of the spine, and by some measures it is also the most complex. Connecting with the cervical spine above and the lumbar spine below, the thoracic spine runs from the base of the neck down to the abdomen. It is the only spinal region attached to the rib cage.

1.4.3 Lumbar region

The lumbar region refers to the lower back, where the spinal cord curves inward toward the abdomen. it starts about five or six inches below the shoulder blades, and connects with the thoracic spinal cord at the top and extends downward to the sacral spine. There are five lumbar vertebrae, numbered L1-L5 as illustrated in the Figure 1.1.

1.4.4 Sacral region

The sacral region is at the bottom of the spinal cord and lies between the fifth segment of the lumbar spine (L5) and the coccyx (tailbone) as illustrated in the Figure 1.1. The sacrum is a triangular-shaped bone and consists of five segments (S1-S5) that are fused together.

1.5 Types of Spinal Cord Injuries

The Spinal Cord Injury (SCI) occurs when the bony protection surrounding the cord is damaged by way of fractures, dislocation, burst, compression, hyperextension or hyperflexion. The most common cause of spinal cord dysfunction is trauma, including motor vehicle accidents, falls, shallow diving, acts of violence, and sports injuries. Damage can also occur from various diseases acquired at birth or later in life, from tumors, electric shock, and loss of oxygen related to surgical or underwater mishaps. In reality, there are many types of Spinal Cord Injury because there are innumerable ways that the body can be injured. There are four main categories of Spinal Cord Injury, however, which have to do with the portion of the body that is affected.

1.5.1 Monoplegia

Monoplegia is paralysis of a single area of the body as illustrated in the Figure 1.2, most typically one limb. People with monoplegia typically retain control over the rest of their body, but cannot move or feel sensations in the affected limb. Monoplegia comes aftermath of a stroke or brain injury. When the nerves affecting the paralyzed area are not fully severed, it is often possible to regain significant function through physical therapy.

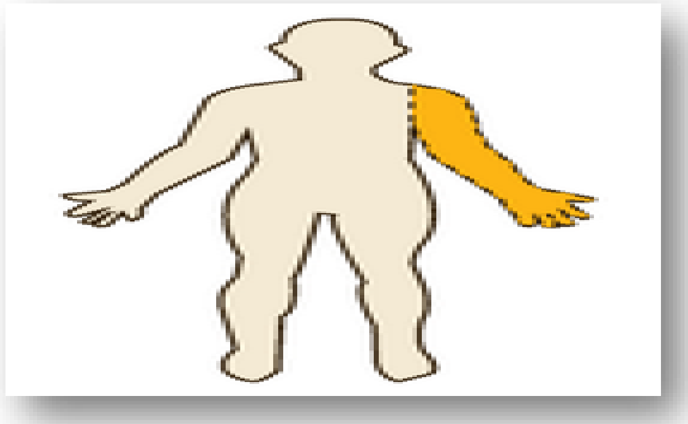


Figure 1.2: Monoplegia which affects a single limb of the body

1.5.2 Hemiplegia

Hemiplegia affects an arm and a leg on the same side of the body as illustrated in the Figure 1.3, and as with monoplegia, the most common cause is cerebral palsy. With hemiplegia, the degree of paralysis varies from person to person, and may change over time. Hemiplegia often begins with a sensation of pins and needles, progresses to muscle weakness, and escalates to complete paralysis. However, many people with hemiplegia find that their degree of functioning varies from day to day, and depending on their overall health, activity level, and other factors. Hemiplegia is sometimes temporary, and the overall prognosis depends on treatment, including early interventions such as physical and occupational therapy.

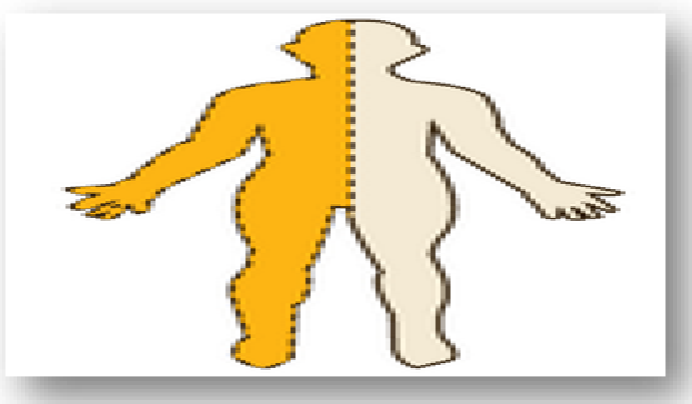


Figure 1.3: Hemiplegia which affects one side of the body including arm, leg and trunk

1.5.3 Paraplegia

Paraplegia refers to paralysis below the waist, and usually affects both legs, the hips, and other functions, such as sexuality and elimination as illustrated in the Figure 1.4.Though stereotypes of paraplegia hold that people with this condition cannot walk, move their legs, or feel anything below the waist, the reality of paraplegia varies from person to person and sometimes, from day to day. Thus, paraplegia refers to substantial impairment in functioning and movement, not necessarily a permanent and total paralysis. Rarely, people with paraplegia spontaneously recover. This may be due to brain or spinal cord functions that are not yet understood, such as regeneration of neurons. More typically, paraplegics are able to regain some functioning with physical therapy, which works to retrain the brain and spinal cord to work around limitations while strengthening muscles and nerve connections.

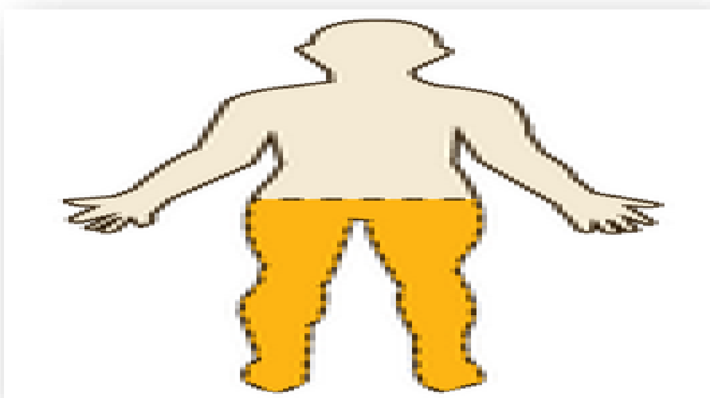


Figure 1.4: Paraplegia which affects the bottom side of the body

1.5.4 Quadriplegia

Quadriplegia, which is often referred to as tetraplegia, is paralysis below the neck. All four limbs, as well as the torso, are typically affected as illustrated in the Figure 1.5. As with paraplegia, though, the degree of disability and loss of function may vary from person to person, and even from moment to moment. Likewise, some quadriplegics spontaneously regain some or all functioning, while others slowly retrain their brains and bodies through dedicated physical therapy and exercise. Occasionally, quadriplegia is a temporary condition due to brain injuries, stroke, or temporary compression of spinal cord nerves. Some spinal cord injury survivors temporarily suffer from quadriplegia immediately after the injury, then experience a less systematic form of paralysis as swelling goes down, the nerves become less compressed, or surgery reverses some damage.

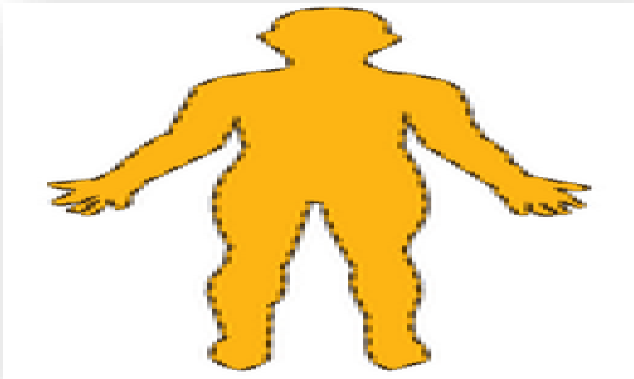


Figure 1.5: Quadriplegia which affects all limbs of the body

1.6 Causes of the Spinal cord injury

Spinal cord injury (SCI) involves damage to t protection he nerves within the bony of the spinal canal. The most common cause of SCI is trauma, although damage can occur from various diseases acquired at birth or later in life, from tumors, electric shock, poisoning or loss of oxygen related to surgical or underwater mishaps.

A common misconception is that a spinal cord injury means the spinal cord has to be severed in order for a loss of function to occur. In fact, most people who have sustained a SCI, the spinal cord is bruised and intact.

The spinal cord and the brain together make up the central nervous system (CNS) as illustrated in the Figure 1.6. The spinal cord coordinates the body's movement and sensation. Therefore, an injured cord loses the ability to send and receive messages from the brain to the body's systems that control sensory, motor, and autonomic function below the level of injury. Often, this results in some level of paralysis.

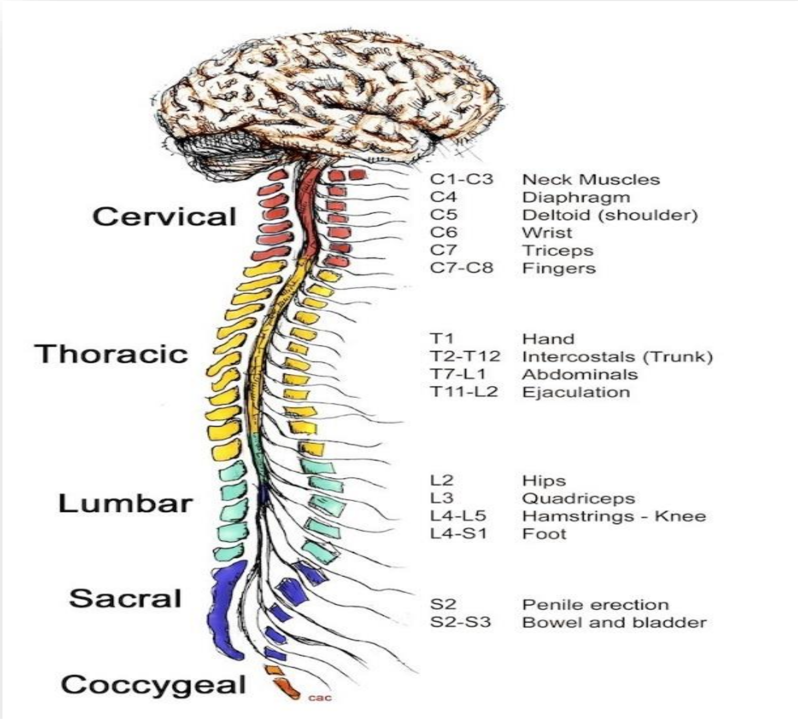


Figure 1.6: The central nervous system (CNS) consist of the brain and the spinal cord.

Spinal cord injury is an age-old problem, but it wasn't until the 1940s that the prognosis for long-term survival was very optimistic. Prior to World War II, people routinely died of infections to the urinary tract, lungs, or skin. SCI went from a death sentence to a manageable condition. Nowadays, people with spinal cord injury approach the full life span of nondisabled individuals.

Spinal cord trauma is more than a single event. The initial blunt force damages or kills spinal nerve cells. However, in the hours and days after injury a cascade of secondary events, including loss of oxygen and the release of toxic chemicals at the site of injury, further damage the cord.

Acute care following an injury may involve surgery if the spinal cord appears to be compressed by bone, a herniated disk, or a blood clot. Traditionally, surgeons waited for several days to decompress the spinal cord, believing that operating immediately could worsen the outcome. More recently, many surgeons advocate immediate early surgery.

Generally speaking, after the swelling of the spinal cord begins to go down, most people show some functional improvement after an injury. With many injuries, especially incomplete injuries (some motor or sensory function preserved below the injury level), a person may recover function eighteen months or more after the injury. In some cases, people with SCI regain some function years after the injury.

There is a lot of information and resources to learn about the effects of a spinal cord injury. However, it is important to understand the functions of the spinal cord and its relationship to the brain.

1.7 Health care and rehabilitation

Spinal cord injury (SCI) is a very significant health condition. While SCI will always be life-changing, it does not have to undermine the possibilities of a good and fulfilling life for individuals.

The social impact of SCI does not necessarily depend on the severity or level of the injury, but on social and environmental factors, particularly the availability of appropriate and accessible health care. With the right treatment, SCI does not have to be a terminal condition, nor does it need to prevent anyone from having an education, finding employment, having a family, and having a successful and productive life. While subsequent chapters explore other social barriers and facilitators, this chapter focuses on health care and rehabilitation including assistive technologies.

Care provided during the first few days following a spinal cord injury is critical and can significantly influence outcomes for an injured person. Pre-hospital management requires a rapid evaluation, including measurement of vital signs and level of consciousness, initiation of injury management, including stabilization of vital functions, immobilization of the spine to preserve neurological function until long-term spinal stability can be established, and control of bleeding, body temperature and pain and prompt and safe access to the health-care.

People with SCI should ideally arrive at an acute care setting within two hours of injury. Interventions in the acute phase, in addition to the techniques applicable in all major injuries (e.g. infusion, bladder drainage, monitoring of vital signs) focus on prioritizing and treating life-threatening injuries to maximize survival and treating potentially disabling injuries so as to minimize impairment and minimizing pain and psychological suffering [4].

Accurate diagnosis of the SCI and any co-occurring conditions (e.g. traumatic brain injury, limb fractures, chest or abdominal injuries, wounds and penetrating injuries) is essential so that appropriate medical care and rehabilitation can be provided. Assessment should commence immediately on arrival at hospital and include a medical history, signs and symptoms, e.g. weakness, sensory and motor deficits, bowel and bladder dysfunction, anatomical deformity, localized tenderness; a neurological (motor and sensory) examination; radiological imaging, i.e. X-ray, computerized tomography, and/or magnetic resonance imaging; and laboratory testing, e.g. blood, microbiology. Conservative and/or surgical interventions are required if the spine is unstable or there is ongoing compression of the spinal cord. For both traumatic and non-traumatic SCI, there are benefits and complications to both conservative treatment and surgery. Many factors should be taken into consideration to determine the most appropriate management approach, including level of injury, type of fracture, degree of instability, presence of neural compression, impact of other injuries, surgical timing, availability of resources such as expertise, and benefits and risks. In all cases people with SCI should be given an informed choice between conservative and surgical management. Conservative management involves measures to immobilize the spine and to “reduce” a dislocation with, for instance, bed rest, traction of the spine or the wearing of orthoses to immobilize the spine, which usually takes place over a period of six weeks or more. Surgical management can be used to decompress the spine by the “reduction” of a dislocation and/or by removal of fracture fragments that are causing compression of neural structures, and stabilize the spinal column by implantation of hardware and the use of bone grafts [5].

1.8 Assistive technology

The need for assistive technology usually begins at the onset of an SCI and continues throughout the person’s life. The type of assistive technology required is influenced by the level of the SCI and associated impairments, environmental factors (e.g. the physical environment, support, relationships) and personal factors (e.g. age, fitness, lifestyle) and any co-morbid health conditions. Wheelchairs, environmental control systems and computer technology appear to be the most widely used assistive technologies. Wheelchairs are one of the most important types of mobility device used by people with SCI [6].

A study in the USA showed that devices for mobility and independent living were the most common devices owned by participants with SCI, with a smaller proportion using computer technology, prosthetics, orthotics, and augmentative and alternative communication devices, people with a high level of SCI such as Quadriplegia, own significantly more assistive devices than people with paraplegia.

1.9 Summary

In this chapter that the spinal cord injury (SCI) is a medically complex and life-disrupting condition. SCI has costly consequences, both for individuals and society. People are left dependent, are excluded from school, and are less likely to be employed. Worst of all, they risk premature death. SCI is both a public health and human rights challenge. However, with the right policy responses, it is possible to live, thrive and contribute with SCI anywhere in the world. People with SCI are people with disabilities and are entitled to the same human rights and respect as all other people with disabilities. Once their immediate health needs have been met, social and environmental barriers are the main obstacles to successful functioning and inclusion for people with SCI. Ensuring that health services, education, transport and employment are available and accessible to people with SCI, alongside other people with disabilities, can make the difference between failure and success. SCI will always be life changing, but it need not be a tragedy and not to be burden.

Chapter 2
System Conception

2.1 Introduction

Spinal cord injury is particularly devastating, it often strikes out of the blue. The consequences of SCI are commonly either premature mortality or at best social exclusion. Trauma care systems are frequently inadequate. For many, access to high quality rehabilitation and assistive devices is unavailable. Ongoing health care is lacking, which means that a person with spinal cord injury is likely to die within a few years from urinary tract infections or pressure sores. Even when individuals are lucky enough to receive the health and rehabilitation care they require, they are likely to be denied access to the education and employment which could enable them to regain their independence and make a contribution to their families and their society. In this chapter we will introduce some concepts concerning the device and explain the functionality and the theory behind it.

2.2 Aim of the project

The objective of this project is design and implement an assistive device for people with physical disabilities based on speech recognition system to recognize user speech instruction whether a single word or two words, in addition to another system which can be used as environment monitor in the place where the patient resides. This is achieved using a hardware consist of three parts, the first one is the transmitter which responsible of performing the recognition of the speech and transmit the data wirelessly in the air, the second one is the receiver which will receive the data from transmitter and perform the required task, and the third one which will be used to monitor the environment data and send them into web using a special hardware which contains a dedicated WIFI to perform this task in real time.

2.3 Speech recognition

Speech is the most natural way to communicate for humans, and this is true since the dawn of civilization, the invention and widespread use of the Telephone, audio-phonic storage media, radio, and television had given even further importance to speech communication and speech processing. The advances in digital signal processing technology has led to the use of speech processing in many different application areas like speech compression, enhancement, synthesis, and recognition. Nowadays, human beings use speech to communicate with machines to perform specific actions by voice command to control. That leads to man-made machines to understand the spoken words and respond to them by recognizing the speech. The basic principle of voice recognition involves the fact that speech or words spoken by any human being cause vibrations in air, known as sound waves. These continuous or analog waves are digitized and processed and then decoded to appropriate words and then appropriate sentences, these steps are illustrated in the Figure 2.1 [7].

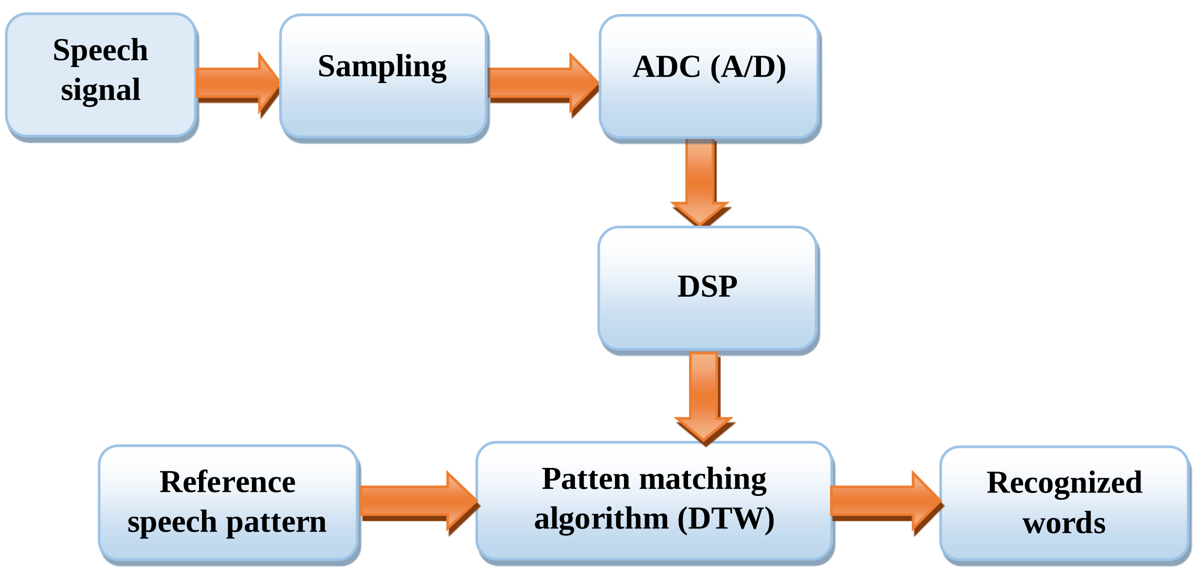


Figure 2.1: Block diagram for speech recognition system

2.3.1 Sampling

Most discrete-time signals come from sampling a continuous-time signal such as speech and audio signals, radar and sonar data in which these data are represented in analog domain, these data must be discrete so the computer can process it because simply this data is processed by a machine which can understand only two states either ‘0’ or ‘1’. The sampling technique is applied under some conditions, the most important one is Nyquist -Shannon theorem which state that to sample an input let`s say F(t) the sampling frequency f_s must be at least twice the input frequency of F(t), practically speaking if we have if the frequency of the input F(t) is 4 KHz the sampling frequency fs must be at least 8 KHz.

The consequence of sampling a signal F(t) at rate below its twice frequency will result a phenomenon called aliasing which means we can`t recover the original signal F(t) if an application requires that. The Figure 2.2 shows the different steps of sampling the signal F(t). Practically sampling is done in computer by using a special circuit which are connected to ADC (analog to digital converter) so they are converted into digital data to be processed later by the computer. The Figure 2.3 is an example of sampling circuit of DSC (digital signal controller) which is 16 bits’ microcontroller made by Microchip company.

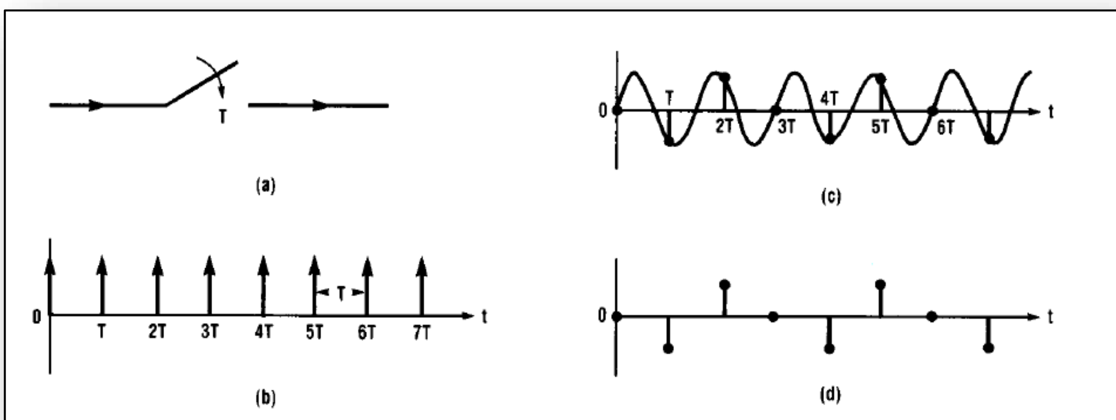


Figure 2.2: Sampling stages. ideal sampler (a) with a sample period T shown in (b) sampling the waveform F(t) as depicted in (c) then the result is samples of the waveform F(t) as shown in (d). (Texas Instruments)

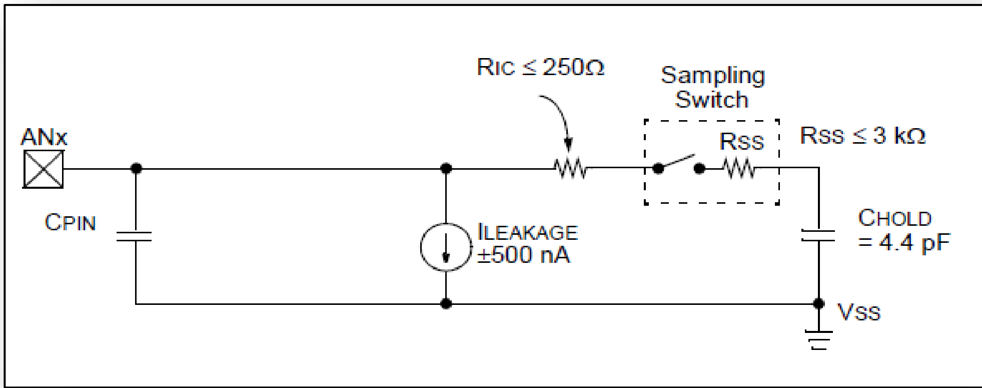


Figure 2.3: Sampling circuit of an ADC input of digital signal processor consist of resistor and capacitor and sampling switch. (Microchip Technology)

2.3.2 ADC (analog to digital convertor)

The first step in a digital processing system is getting the information from the real world into the system. This requires transforming an analog signal to a digital representation suitable for processing by the digital system. This signal passes through a device called an analog-to-digital converter (A/D or ADC). The ADC converts the analog signal to a digital representation by sampling or measuring the signal at a periodic rate. Each sample is assigned a digital code as illustrated in The Figure 2.4. These digital codes can then be processed by a digital system such as processor. The number of different codes or states is almost always a power of two (2, 4, 8, 16, etc.) The simplest digital signals have only two states. These are referred to as binary signals.

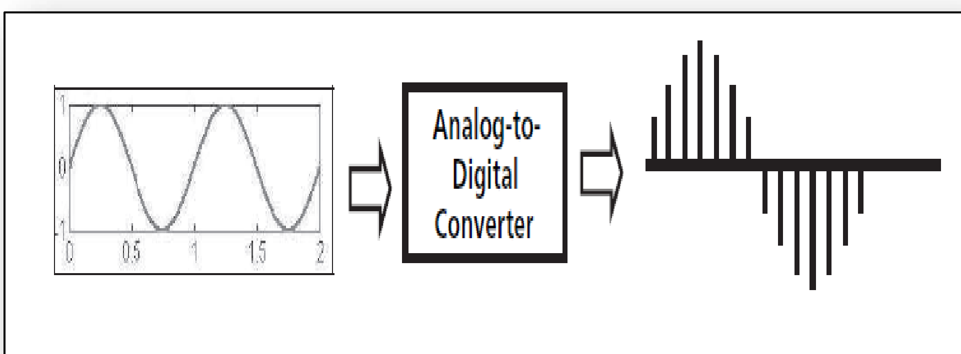


Figure 2.4: Example of converting an analog signal into digital values by the ADC

Practically the analog to digital converters are somehow complicated, advanced and very versatile, we will present an example of this powerful hardware which is illustrated in the Figure 2.5 which is the ADC of digital signal controller dsPIC30F4013 made my microchip technology, usually ADCs have common characteristics such the precision which can be (8, 10, 12, 16, 24, 32 bits), sampling frequency which can be very high (in gigahertz), the reference voltage which make the ADC work properly and without forgetting analogs inputs usually called channels and other characteristics. When the ADC finishes the current conversion, the result will be stored in temporary registers and will be fetched by the CPU to be processed and the cycle repeats forever.

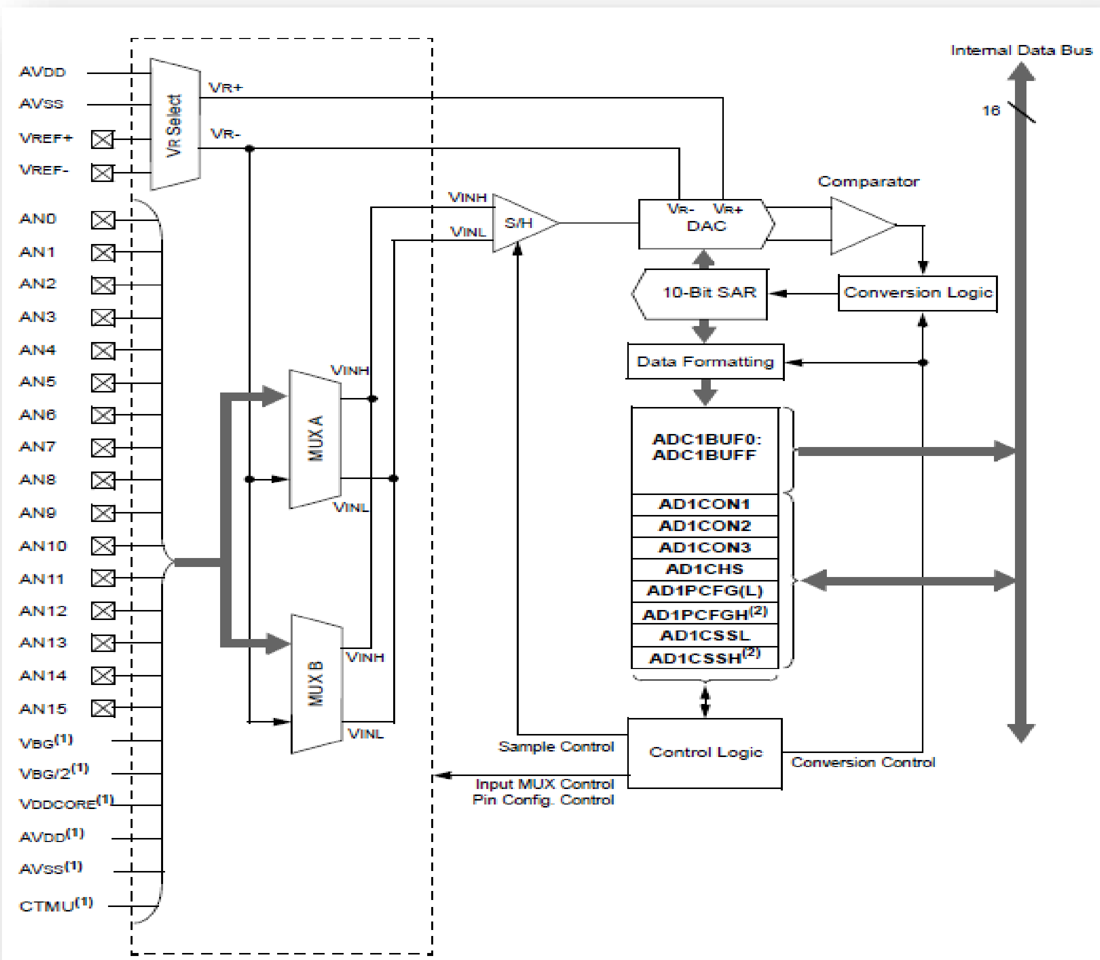


Figure 2.5: Overview of digital signal controller's ADC (Microchip Technology)

2.3.3 DSP (digital signal processor)

A DSP is specialized microprocessor used to perform calculations efficiently on digitized signals that are converted from the analog domain. One of the big advantages of DSP is the programmability of the processor which allows important system parameters to be changed easily to accommodate the application. DSPs are optimized for digital signal manipulation. DSPs are often used in applications that manipulate some sort of continuous phenomena like voice, radio frequency signals or motor current, DSPs like other processors are digital devices, running algorithms that manipulate discreet data.

A dedicated hardware like a DSP has two major speed advantages over a general-purpose processor. A DSP has multiple arithmetic units, which can be all working in parallel on individual terms which can perform filtering algorithms efficiently. These DSPs tends to have special data movement operations. These operations can shift data among special register in the DSP. DSPs almost always have special compound instructions like MAC (multiply accumulate) instruction that allow data to flow directly from a multiplier into an accumulator without processor intervention this hardware is depicted in the Figure 2.6. In DSP context, the MAC is the operation of multiplying a coefficient “a” by corresponding delayed data sample “x” and accumulating the result. FIR filters usually require one MAC per operation [8].

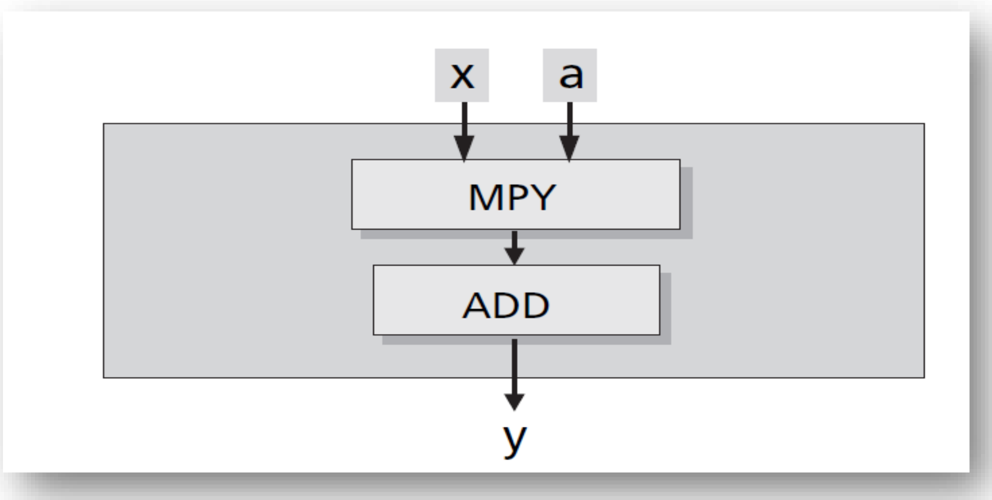


Figure 2.6: MAC instruction performed by DSP MAC unit

Practically performing DSP algorithms such as (FIR, IIR, FFT, …etc) digitally is better than analog due to flexibility of the DSP engines. The figure 2.7 illustrate a DSP processor of certain Microchip Technology controller. This kind of hardware is designed to maximize performance for inner loops containing product of sum such as the FIR and IIR filters thus DSP engine usually include hardware support for fast arithmetic including hardware multipliers, accumulators, shift registers and others [9].

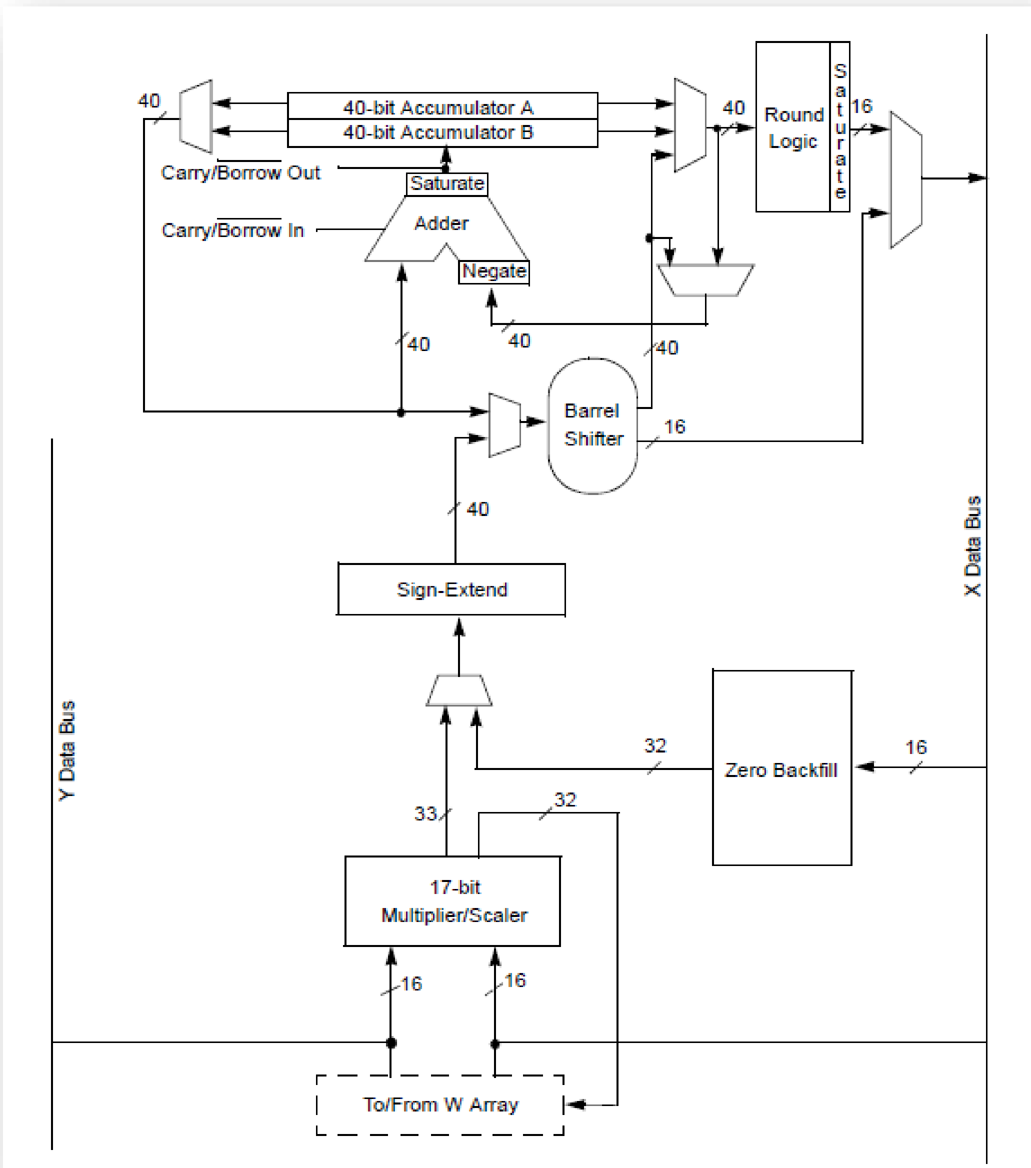


Figure 2.7: DSP processor block diagram (Microchip Technology)

2.3.4 DTW algorithm

Dynamic time warping (DTW) is an algorithm for measuring similarity between two sequences which may vary in time or speed. For DTW has been applied to video, audio, and graphics indeed, any data which can be turned into a linear representation can be analyzed with DTW. well known application has been automatic speech recognition, to cope with different speaking speed. In general, DTW is a method that allows a computer to find an optimal match between two given sequences (time series) with certain restrictions. The sequences are "warped" nonlinearly in the time dimension to determine a measure of their similarity independent of certain non-linear variations in the time dimension. The DTW allows a nonlinear warping alignment of one signal to another by minimizing the distance between the two as illustrated in the Figure 2.8. This warping between two signals can be used to determine the similarity between them and thus it is very useful for feature recognition.

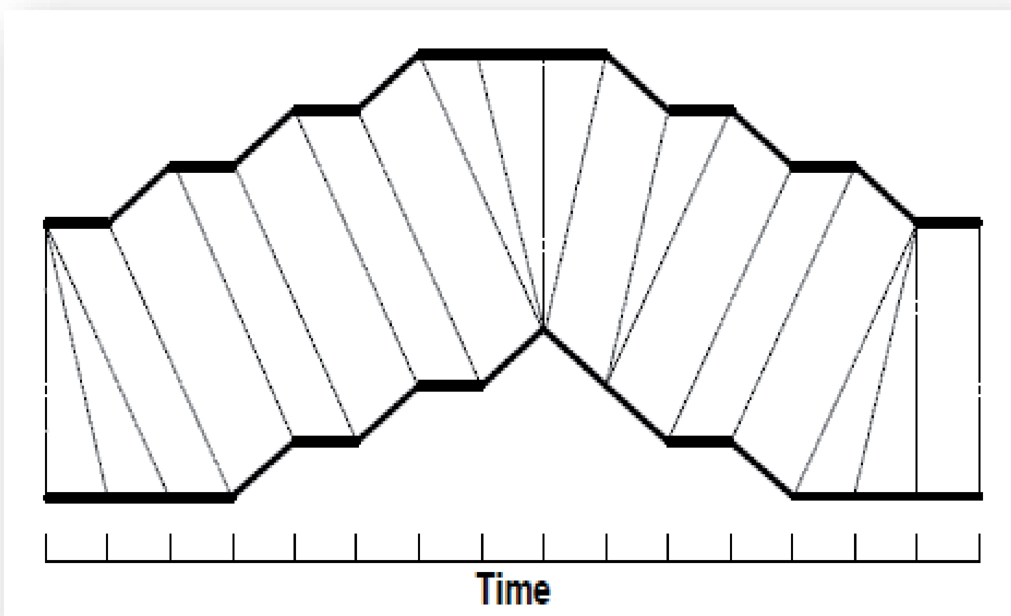


Figure 2.8: A warping between two time series sequences

2.4 Microcontroller

A Microcontroller has a CPU (Microprocessor) in addition to a fixed amount of RAM, ROM, I/O ports, and a timer all on a single chip. In other words, the processor, RAM, ROM, I/O ports, and timer are all embedded together on one chip; therefore, the designer cannot add any external memory, I/O, or timer to it. The fixed amount of on-chip ROM, RAM, and number of I/O ports in microcontrollers makes them ideal for many applications in which cost and space are critical.

Microcontrollers are useful to the extent that they communicate with other devices, such as sensors, motors, switches, keypads, displays, memory and even other microcontrollers. Many interface methods have been developed over the years to solve the complex problem of balancing circuit design criteria such as features, cost, size, weight, power consumption, reliability, availability, and manufacturability.

Due to its powerful capabilities, the STM32 based on ARM cortex M3 is one of the most popular 32 bits microcontrollers that are in use today. Many derivative microcontrollers have been developed that are based on ARM architecture. Thus, the ability to program a STM32 is an important skill for anyone who plans to develop products that will take advantage of microcontrollers.

The ARM cortex M3 core is HARVARD architecture -based design with powerful instructions. Each basic instruction cycle takes 1 clock cycle to be executed. The CPU has sixteen 16-bit accumulator for data holding within the CPU itself. One of these Microcontrollers family is called the STM32F101xx, the architecture is illustrated in the Figure 2.9 manufactured by STMicroelectronics which is widely used, its cheapness and it uses flash memory for storing programs. The last feature mentioned makes it ideal for experimentation due to the fact that program can be loaded and erased from it for many times. Besides, the program can be loaded to the microcontroller even after embedding the chip in the target device [10].

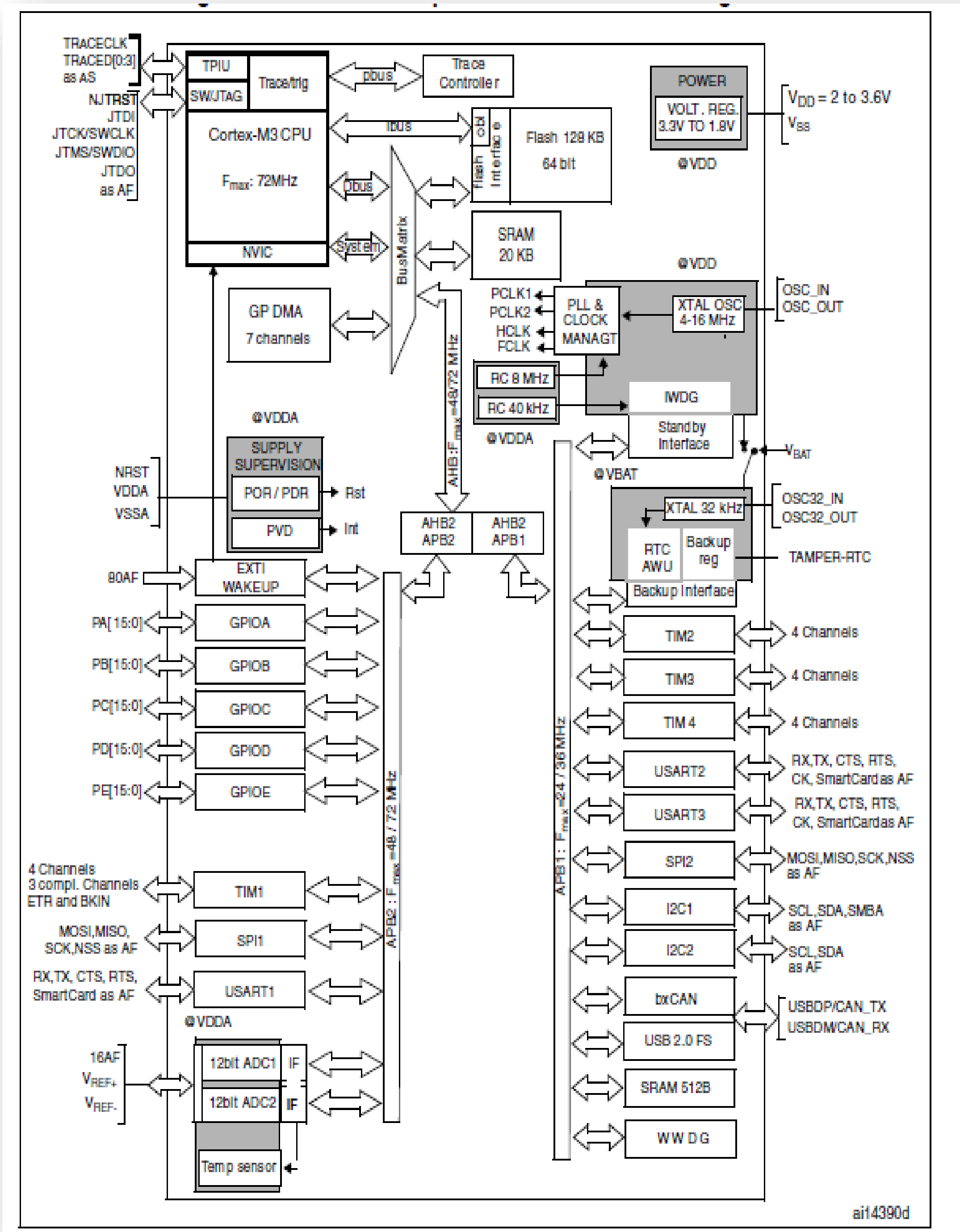


Figure 2.9: STM32F101xx microcontroller block diagram (STMicroelectronics)

2.5 Wireless communication

Wireless communication involves the transmission of information over a distance without the help of wires, cables or any other forms of electrical conductors which mean that incorporates all procedures and forms of connecting and communicating between two or more device using a wireless signal through wireless communication technologies and devices and also involves transfer of information without any physical connection between two or more points. because of this absence of any physical infrastructure, wireless communication has certain advantages, this include collapsing distance or space.

Due to the complexity of wireless communication systems, it is necessary to just give a general idea about it, because the technology in this field is always advancing, all devices which communicate wirelessly between each other has the same fundamental, we have a transmitter which transmit data and other hand we have a receiver which receive the data and process it, all this is done without a single wire, the techniques which applied for any system depends on the requirements of the system (output power, type of modulation, carrier wave frequency,……etc), the Figure 2.10 illustrate the principle of the wireless communication which is being used with all devices such as cell phones, WIFI, radio, remote control and others.

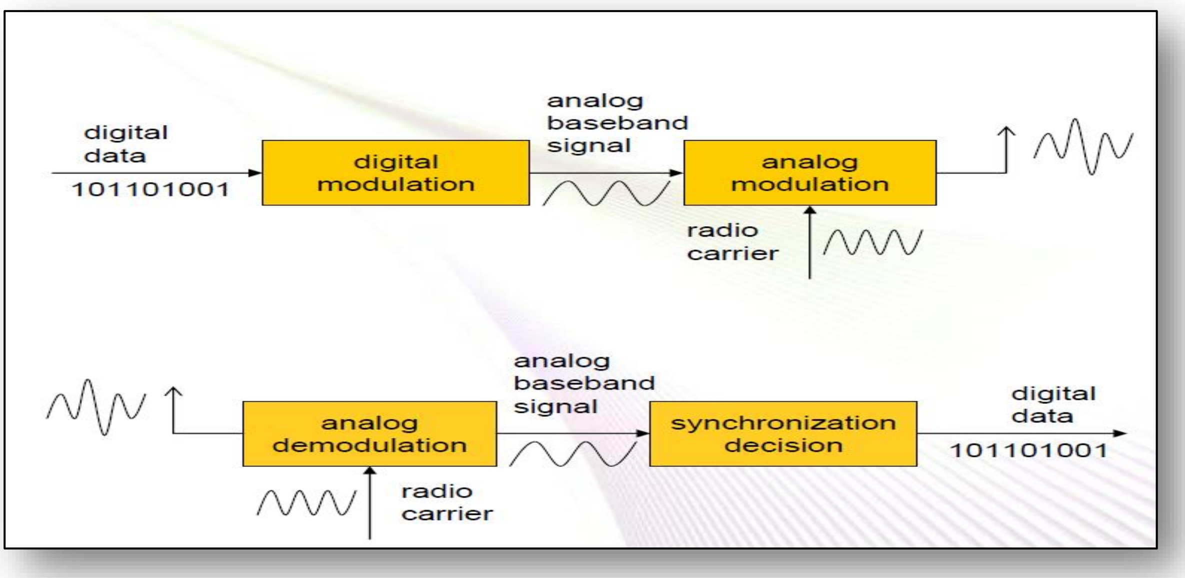


Figure 2.10: Wireless data transmission and reception block diagram (Texas Instrument)

2.6 Summary

In this chapter we saw that the people with any kind of physical disability need an assistance in their life, the current technology can be very helpful in this field which can provide a lot of solutions for this category of people to help them to live a normal life, one of these solutions is the system that we developed which can provide a great assistance especially for people with dangerous injuries like paraplegia, it based on speech recognition system where the patient can control some internal device only by voice which mean that no body movements are needed and can be also used by other people who has other types of disability in addition to that environment monitor which helps keep the track of room condition, all of these was introduced superficially in this chapter, in the next chapter will introduce the system in more great detail, how it functions and the implementation of it.

Chapter 3
Implementation of the system

3.1 Introduction

The number of people with physical disabilities is increasing around the world due to many factors (car accidents, diseases…etc), unfortunately most of these injuries can`t be cured using the ordinary medical treatments even with the rehabilitation, the patient is still can`t recover and live a normal life. In this case the technology can provide a great chance for this category of people which is by developing some tools and devices which can be used to assist the damaged parts of the human body, because the consequence of this category on the economy is big, now days big companies around the world are trying hard to come up with solutions which can assist the paralyzed people and help them to be involved in the community like having a job and others, in this chapter we are going to introduce and provide a unique solution for this problem, and also we will explain the different parts of the system and the implementation steps of it in great details.

3.2 System design – global overview

In the part we will take a global overview of the system that we have developed and how it works superficially, it consists of three main parts: the first part is the transmitter which is responsible of performing the speech recognition and then send the data using wireless transmitter after that we come to the second part which is the receiver, this part the receiver will receive the transmitted data using a wireless receiver, process them and then execute the required function, we come to the third part: the environment monitor which perform the measurement of some parameter (temperature, humidity, illumination, gas detection) and send them to the internet via WIFI technology which allow the user to see these data in real time, all these parts are illustrated in the Figures

3.1, 3.2, 3.3 respectively, the functionality of each part is going to explained in more details in the next sections.

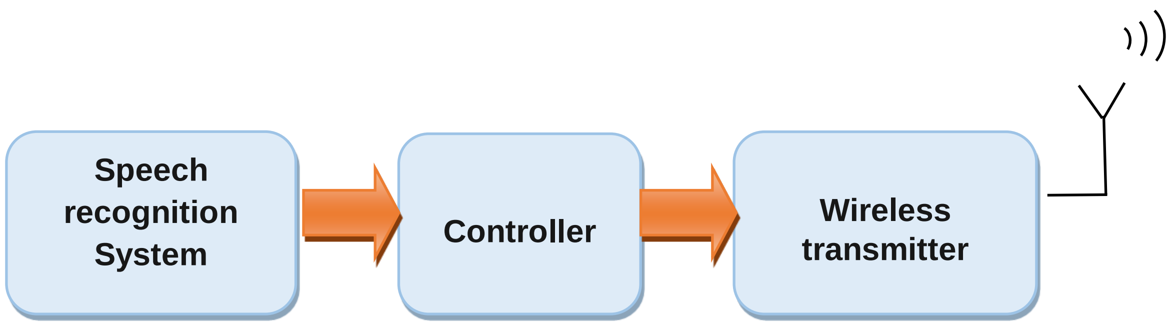


Figure 3.1: Global overview of the transmitter

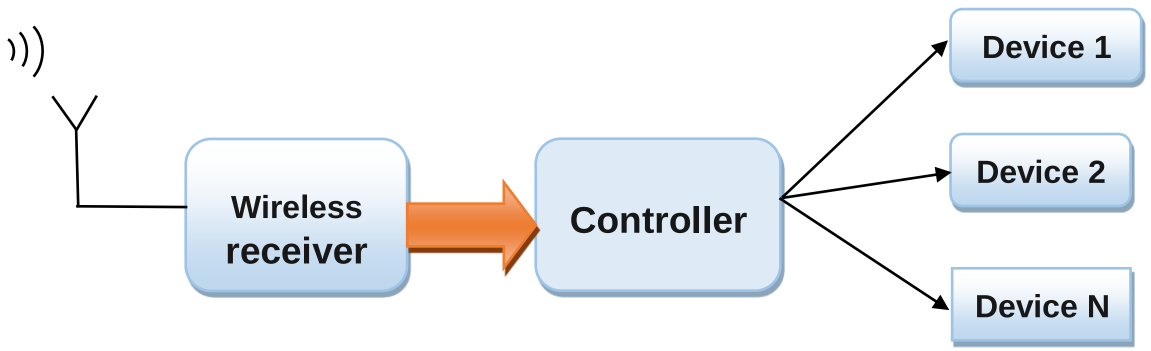


Figure 3.2: Global overview of the receiver

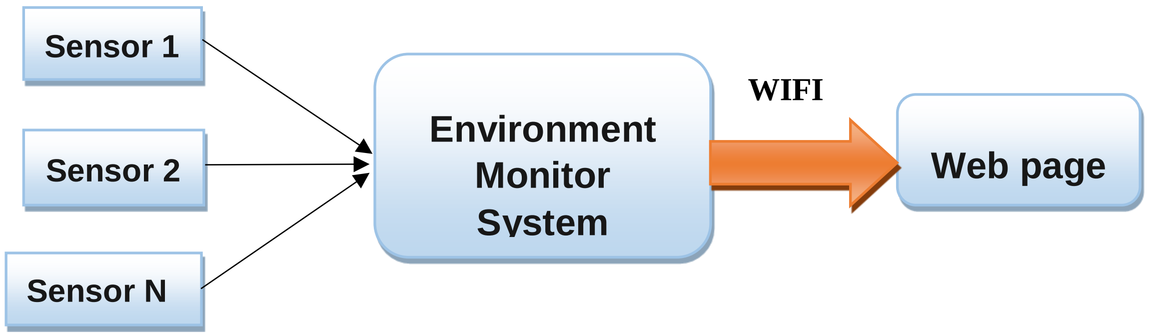


Figure 3.3: Global overview of the WIFI environment monitor

3.3 Speech recognition with wireless transmitter (C1+C2)

The functionality of the whole system depends on this part of the system, it is responsible of performing the most critical task which is identify the commands and send them wirelessly. The construction of this part of the system is explained in details started from hardware design to the software, the Figure 3.4 illustrates the different component used to accomplish this full task, it consists mainly of two different circuits called C1, C2 respectively.

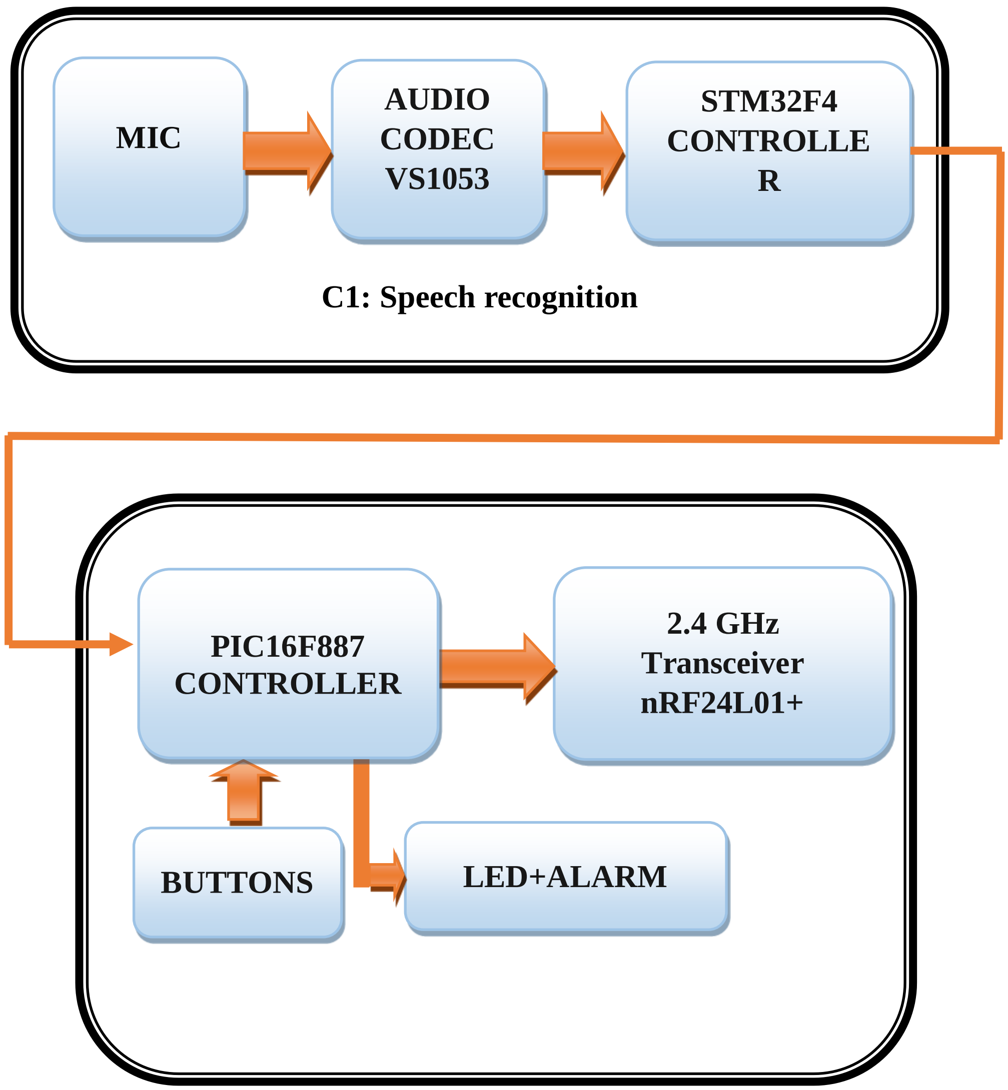


Figure 3.4: Speech recognition with wireless transmitter block diagram

3.3.1 Speech recognition (C1) hardware design

This part is considered the heart of whole the system, we will take a look at the different components and explain the function of each component in details and also, we will include the whole schematic of this hardware design to understand the operation of it, so we can know how to make speech recognition using this hardware possible.

3.3.1.1 Audio Codec (VS1053)

The Audio Codec is just system on chip (SoC) where many components are integrated in a single chip called integrated circuit (ICs), the Audio Codec is powerful chip which allows the analog signals such as Audio to be processed digitally, VS1053 is one of many Audio Codecs available in the market, this chip is provided with all necessary components such as (DSP,RAM,ROM, stereo ADC, stereo DAC, Amplifiers, serial communication), which allows the chip to encode analog Audio to digital and to decode Audio digital back to analog, the application is versatile, it can found in MP3 player to the most complicated devices such as TVs and phones, the chip components are illustrated in the Figure 3.5 [11].

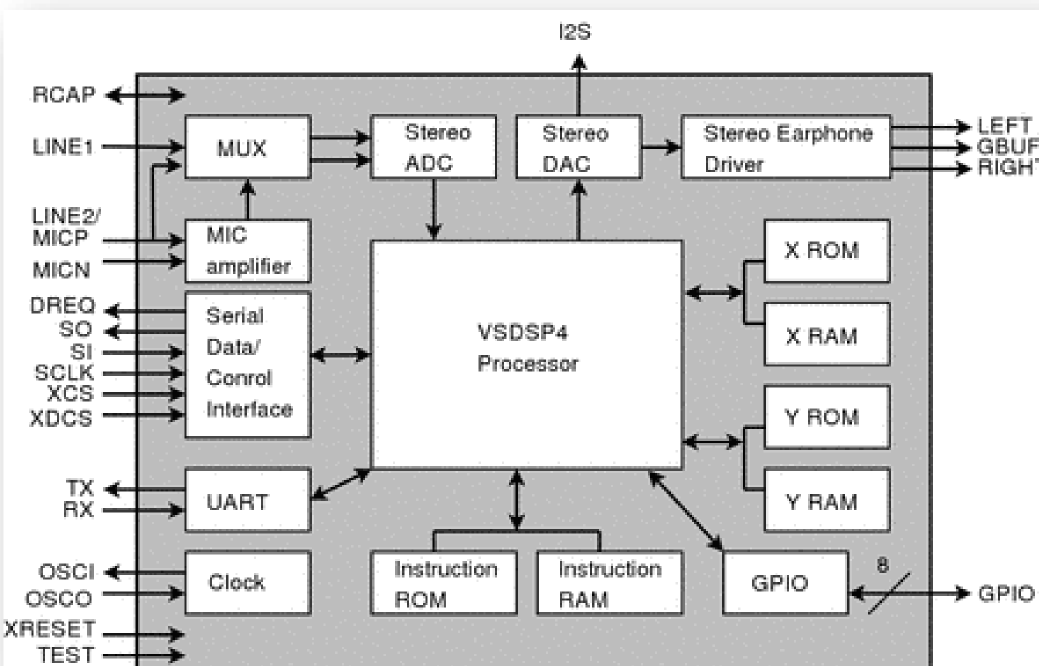


Figure 3.5: Block diagram of VS1053 Audio Codec (VLSI solutions)

3.3.1.2 STM32F4 Controller

The world of Microcontrollers is so big that most electronic devices around the globe contain at least one Microcontroller inside it, due to the rise of demanding of these chips, many companies around the world are trying to come up with new advanced families of Microcontrollers to the markets, one of these families is STM32F4 family which is developed by STMicroelectronics, this family was designed to handle a complex tasks and critical situations in minimum time with low power consumption, one member of this family is STM32F415RG Microcontroller which is used in this project, this chip is integrated with a powerful 32 bits ARM Cortex M4 processor which can execute more than 180 million instructions per second, up to 1 Mbyte of flash memory to store code and up to 192 Kbytes of data memory furthermore it is provided with floating point unit (FPU) which used to speed up floating numbers operations, also a powerful DSP engine used to perform DSP algorithms efficiently, without forgetting all the necessary peripheral such as serial communications, GPIOs, Timers, ADC, and others. All these features are needed to handle a sophisticated application such as speech recognition.

3.3.1.3 Schematic

Designing a system which perform speech recognition has never been easy task due to hardware and software factors, the Figure 3.6 illustrate the whole schematic of the hardware which performs this task, it consists mainly of two important components, the first component is the Audio Coded which handle the input Audio signal by doing some processing such filtering, converting the signal from analog to digital then processed by the DSP processor, the second component is the STM32F415GR controller which is responsible of doing further processing on data received from the Audio Codec using serial communication such serial peripheral interface (SPI) and performing the DTW algorithm to recognize the command, other components are also included such as the microphone which used to convert sound to electrical signals, voltage regulators to provide the appropriate voltages for different chips, USB connector used to connect the system to a computer and finally, resistors and capacitors to satisfy further requirements of the circuit.

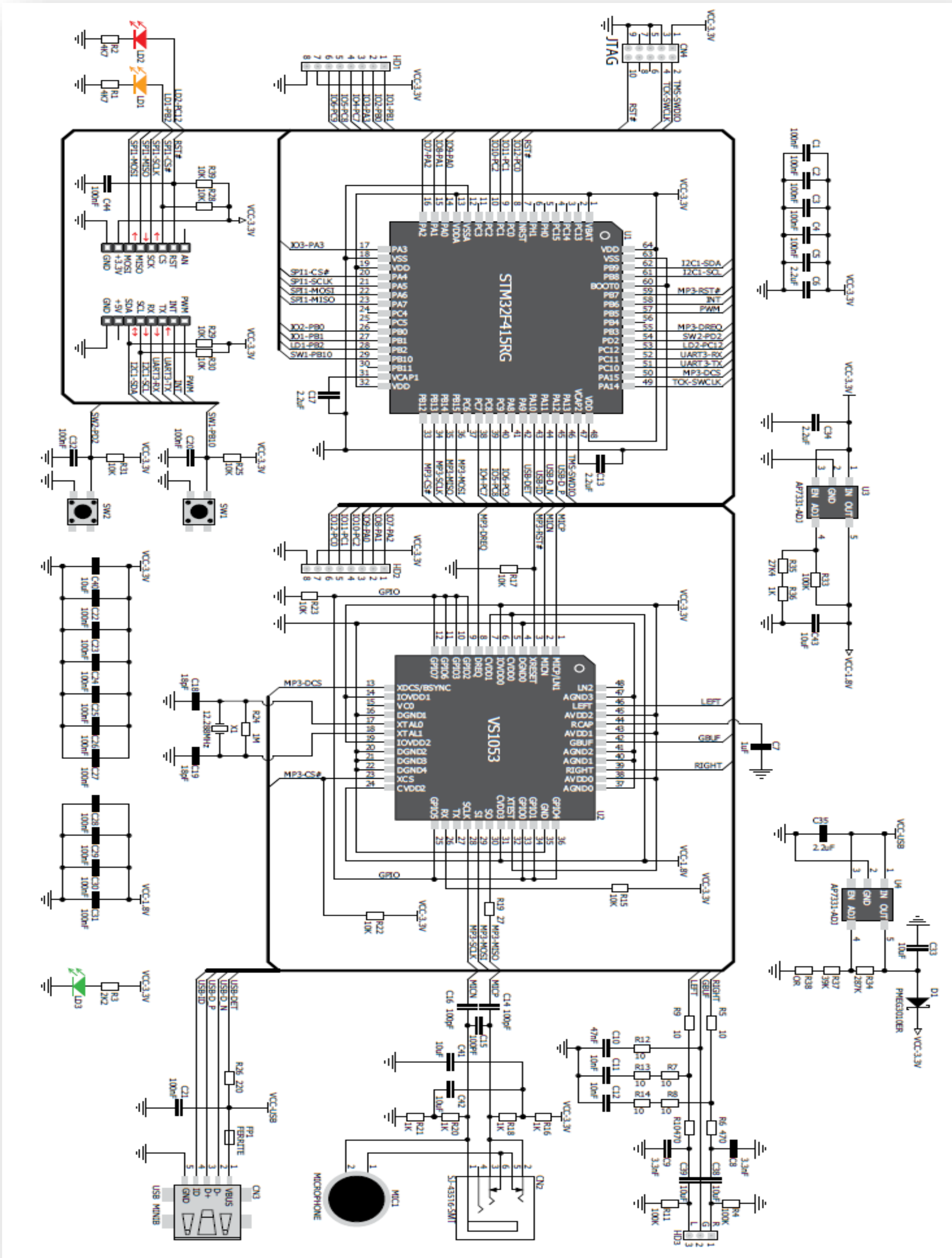


Figure 3.6: speech recognition full schematic

3.3.2 Controller + wireless transmitter (C2) hardware design

This circuit design is crucial to be able to send the data wirelessly, it Receives the commands which were recognized by the speech recognition (C1) and then doing some encoding on this data to be ready before transmitting it, we will take a look at all components which make this function possible and also include the schematic and layout to understand the operation of this circuit in depth.

3.3.2.1 PIC16F887 Controller

The PIC16F887 controller has been used in this project as intermediary chip between the speech recognition (C1) system and the wireless transmitter, this chip is 8 bit microcontroller developed by Microchip Technology as illustrated in the Figure 3.7, it provides all the necessary peripherals such as (GPIOs, Serial communication, …etc) which make this chip ideal to satisfy the requirement of this project [12].

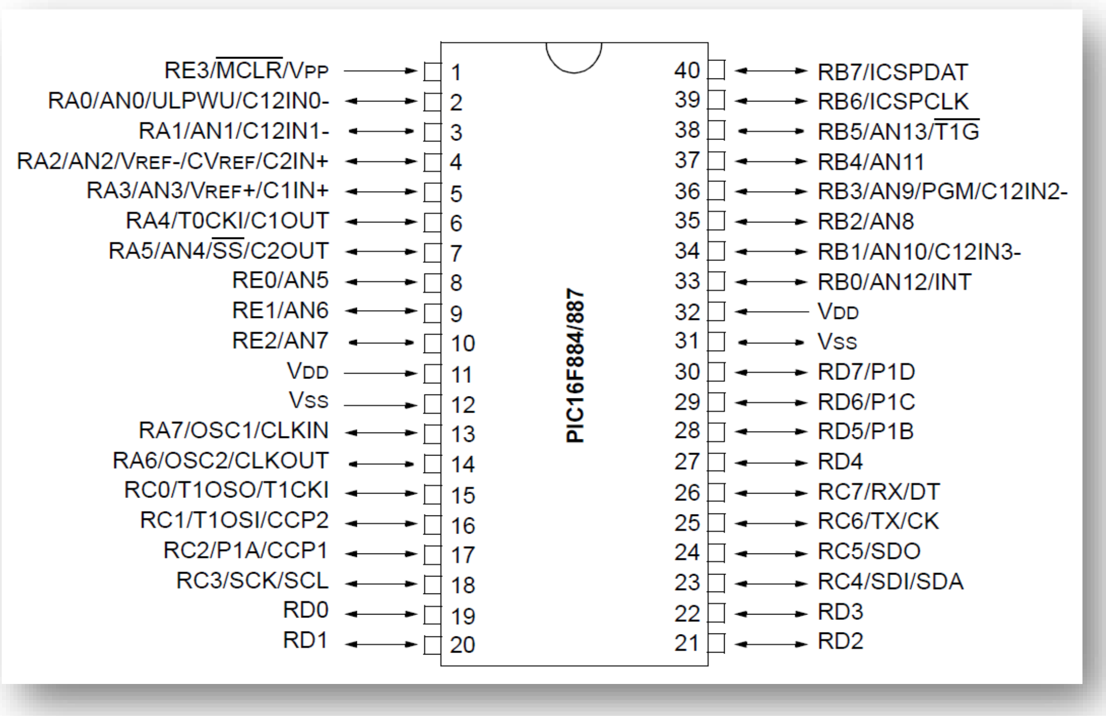


Figure 3.7: PIC16F887 Microcontroller pinout (Microchip Technology)

3.3.2.2 Wireless Transceiver (nRF24L01+)

With the advancing of telecommunication technology that we see today, dealing with Wireless communication became much easier due to the integration of all complex components in single chip, this property allows the user to construct a simple wireless network easily without being specialist in telecommunication engineering, many companies around the world are providing many solutions in this field, NORDIC SEMICONDUCTOR is one of these companies, its chip (nRF24L01+) is illustrated in the Figure 3.8 is very powerful which it can programmed to perform a certain functionality depending on the user preference, this allows the user to build a system with wireless communication easily, this chip provides a lot of properties such as SPI protocol which allows a controller to communicate with the chip, internal registers which control the operation of the chip, buffers for either transmission or reception of data, modulator and demodulator, filters and amplifiers, integrated antenna and other characteristics which make this chip ideal for our application [13].

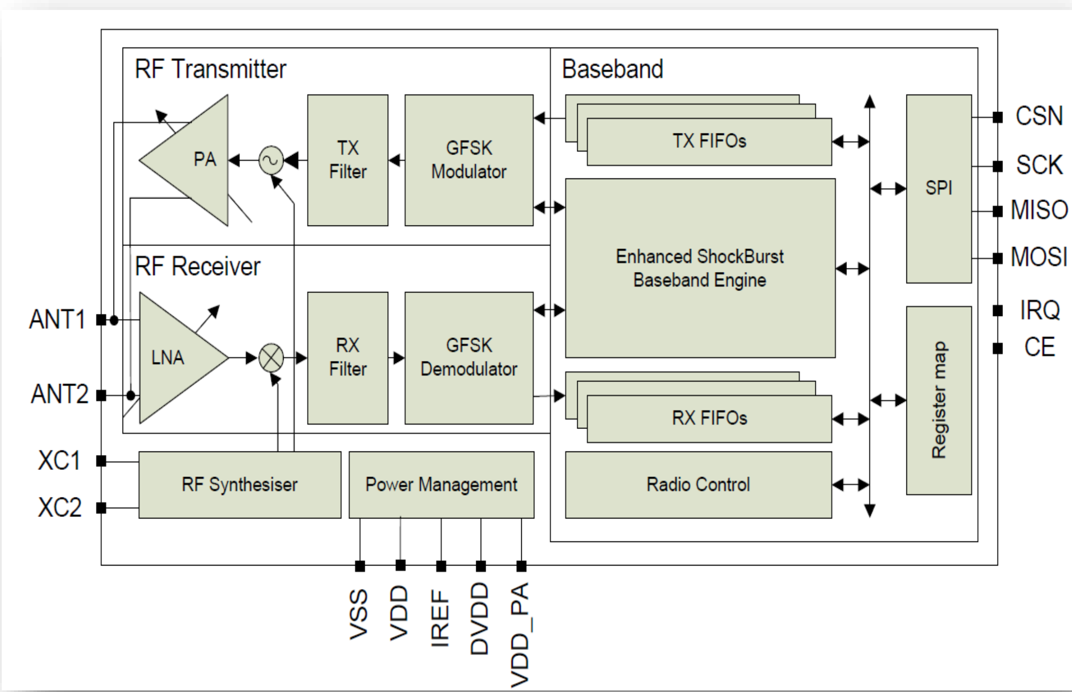


Figure 3.8: Transceiver chip block diagram (NORDIC SEMICONDUCTOR)

3.3.2.3 I/O Interfacing

PIC16F887 is interfaced with other external components such as buttons which can be used for manual control instead of using speech command for control, led also is included as indicator of data reception and transmission and we also used a buzzer which works as alarm in case the receiver is turned off or is out of range.

3.3.2.4 Schematic and Layout

The schematic is illustrated in the Figure 3.9, the heart of this circuit is the PIC16887 microcontroller which does the most work, what the microcontroller does is to continuously monitors any parallel data sent by the speech recognition system (C1), after that the microcontroller will do some proper encoding before sending the data, then the controller will send this data to the transceiver chip via SPI (serial peripheral interface) protocol to be transmitted by the chip wirelessly using a special protocols, in addition to that the controller monitors also the buttons to be pressed in parallel so the used can the used can activate or disactivate a certain device or devices in the receiver side, the controller contains a special algorithm to implement all that which will be discussed later, the schematic was drawn using EAGLE software which is professional circuit designer with well-known reputation among electronic design engineers, it allows the user to draw either the schematic or the layout .

The layout in the other side is illustrated in the Figure 3.10, after the drawing the layout a special process is done to convert the layout to PCB (Printed Circuit Board) which is a board where all electrical and electronic components such as (ICs, resistors, capacitors, diodes, transistors, led, ….etc) are assembled together in one board then soldered using a special equipment. The same process of drawing schematic, layout and the PCB are done for all boards made in this system which are going to be discussed later.

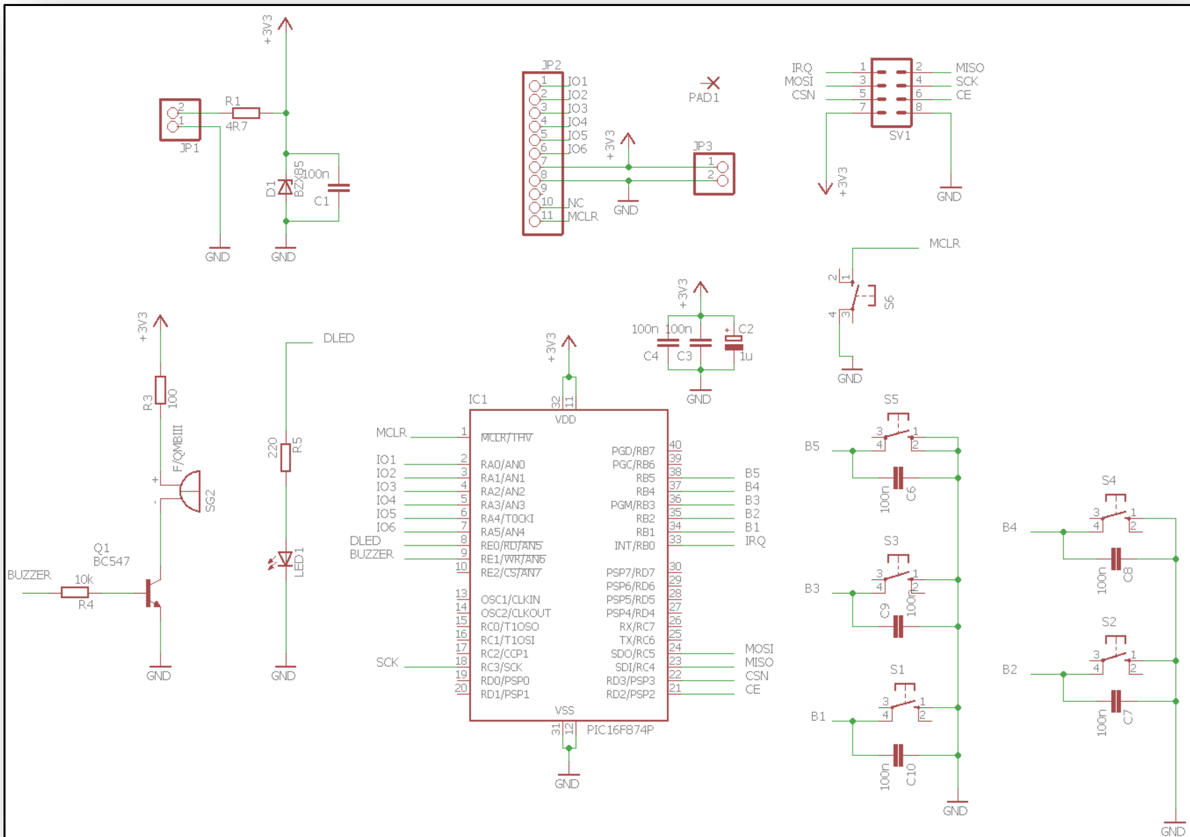


Figure 3.9: Schematic of the controller with the wireless transceiver

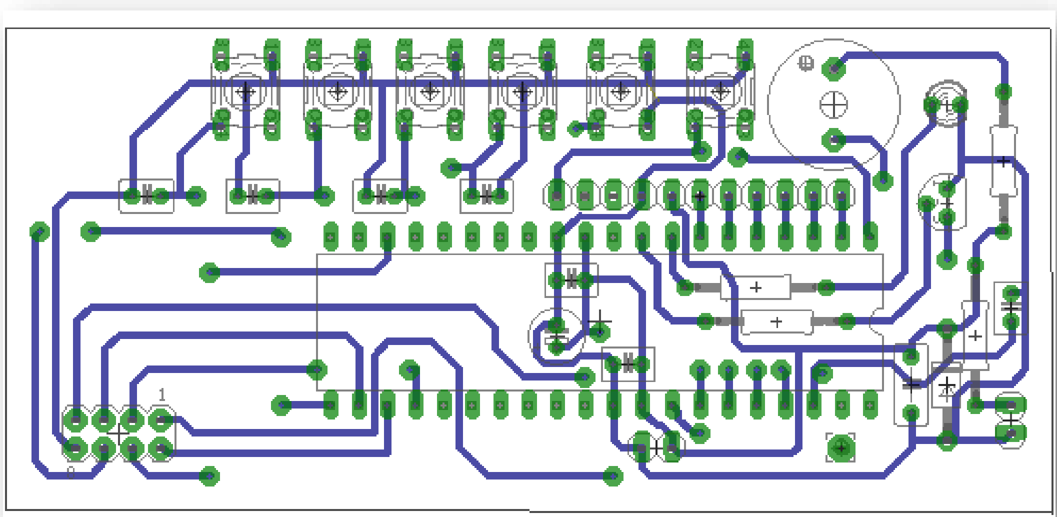


Figure 3.10: layout of the controller with the wireless transceiver

3.3.2.5 Software

Basically, the software which is running inside the PIC16F887 core was written using C language and due to its complexity, we are going to use the flowchart technique to simplify and summarize the software, the hierarchy of the software is illustrated in the Figure 3.11.

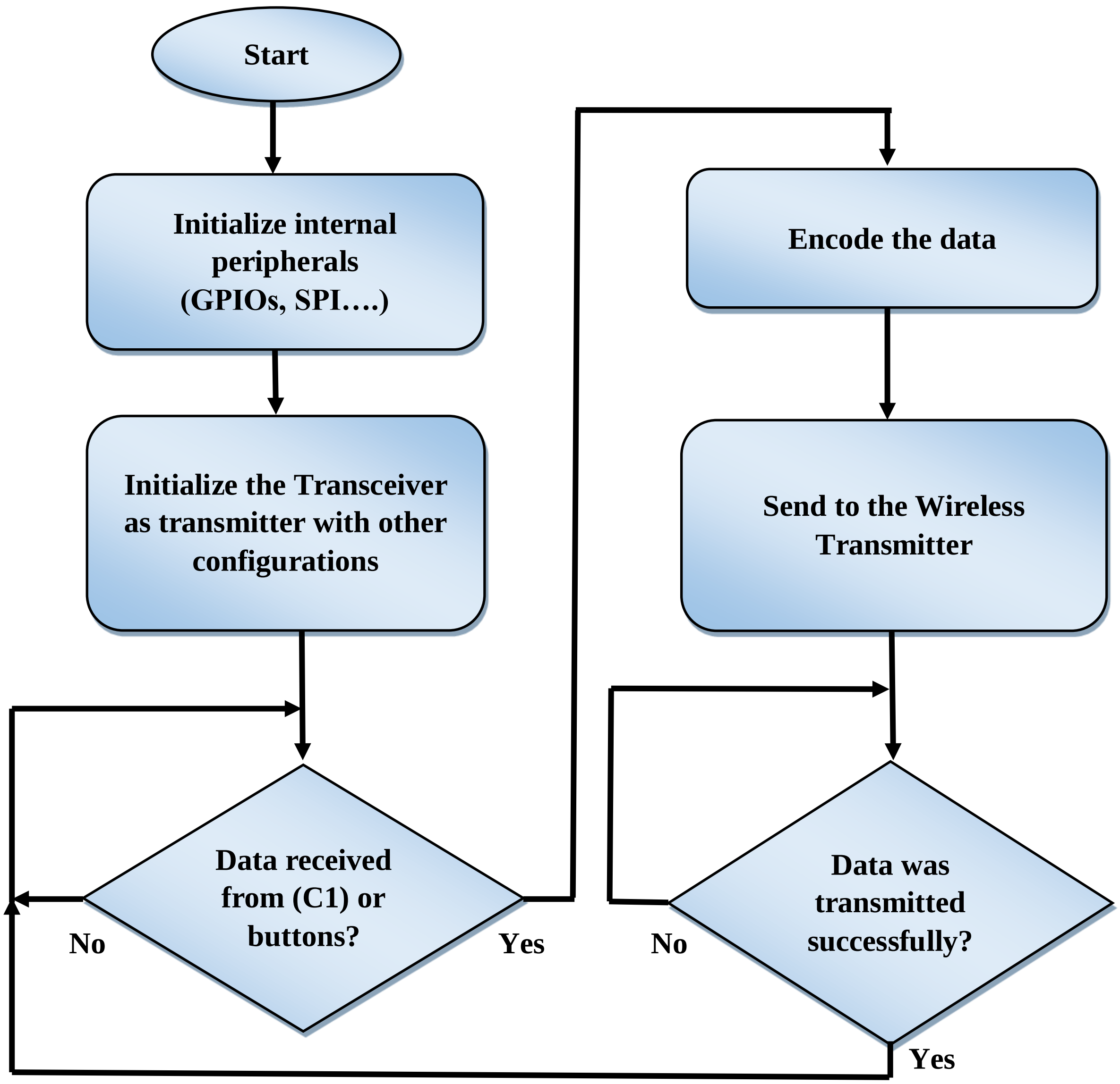


Figure 3.11: Simplified flowchart of the controller with the wireless transmitter

3.4 Receiver hardware design

To make the system useful we need some kind of a circuit that can receive the data from the previous transmitter which were discussed in the section 3.3 and then do a useful function with it, this part concerning the hardware design of the receiver which will perform important role for whole system which is receiving wireless data from the transmitter and then control the operation of some devices connected the receiver such as switching ON and OFF of a lamp or motors, the components which are involved in this design as illustrated in the Figure 3.12, schematic and layout are going to be explained in depth in this section.

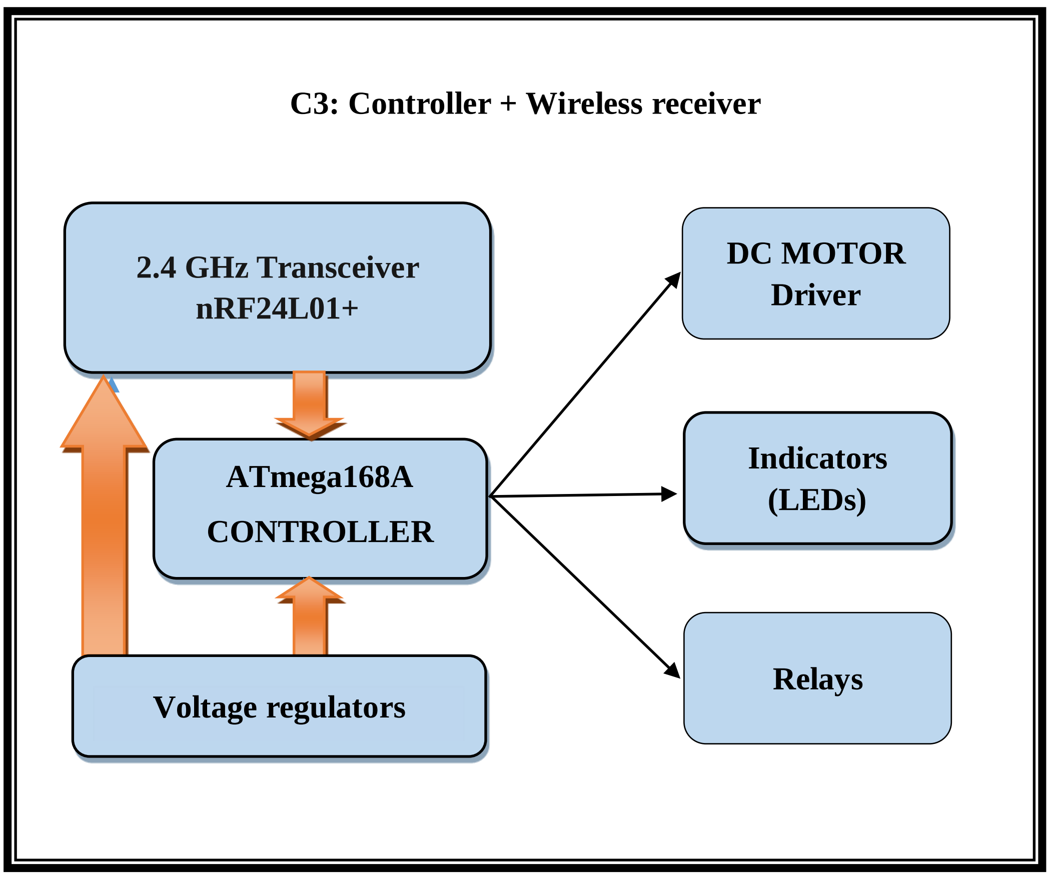


Figure 3.12: Receiver block diagram

3.4.1 Wireless Transceiver (nRF24L01+)

The same chip that we used in the transmitter side is also used in the receiver side, they are identical in the hardware except one thing which is the software, the function of the chip either transmitter or receiver is determined by programming the proper registers using a software installed in the controller.

3.4.2 ATmega168A controller

Designing the hardware of the receiver is challenging task due the different requirements of systems itself, for the sake of the diversity in the project, we used a different family of controllers called AVR (Advanced Virtual RISC) developed by ATMEL company which is now owned by Microchip Technology, due to the different characteristics which this family provide such low power consumption and the speed, it is ideal chip to be used in this circuit [14].

ATmega168A chip is used in this design as illustrated in the Figure 3.13, it is 8 bits controller with core speed up 20 MIPS and it come with different memories such as 16K of program memory, 1K of RAM memory and 512B of EEPROM memory, in addition to all that it is provided with powerful peripherals such as ADC, serial communication (I2C, SPI, UART), Timers and others which make this controller ideal for our hardware design.

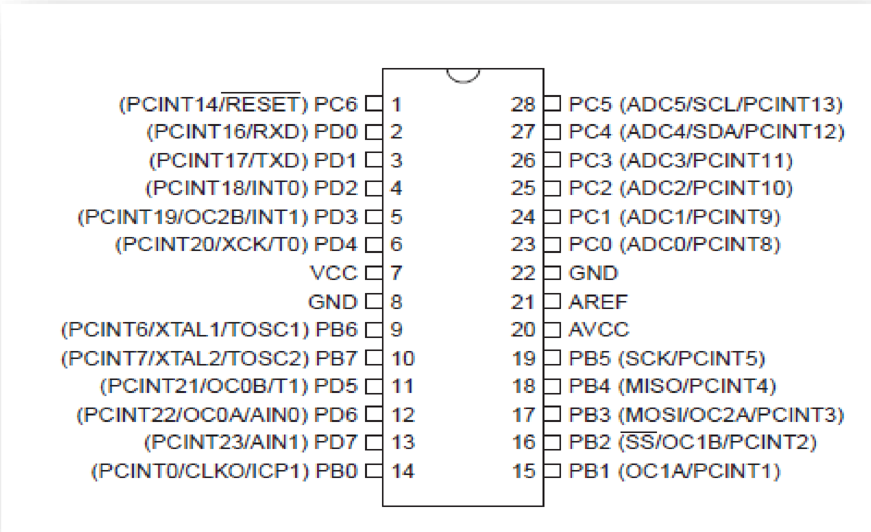
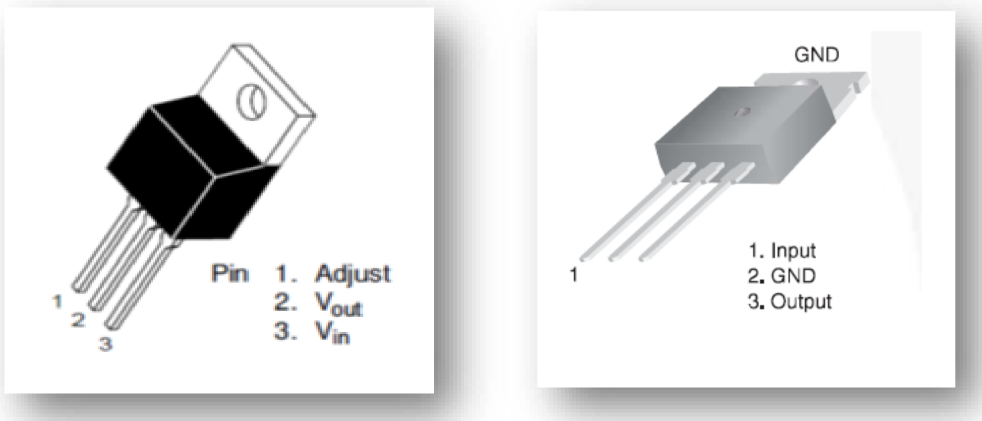


Figure 3.13: ATmega168A controller pinout (ATMEL)

3.4.3 Voltage regulators

Voltage regulator is just an active component in another word, it is an integrated circuit which is used to automatically stabilize the output voltage at certain level, in receiver hardware design we used two voltage regulators, one is for 5V and the second one is programmable at 3.3V, they have been used to provide the necessary voltages required by the different chips in the board, these chip are illustrated in the Figure 3.14.



(a) (b)

Figure 3.14: Voltage regulators. (a) programmable at 3.3V. (b) constant at 5V. (ON SEMICONDUCTOR)

3.4.4 I/O interfacing

The controller is not useful without interfacing circuits, in the receiver side we are going to control in AC lamp, AC motor and maybe also DC motor for some application, and these devices cannot be connected directly to the controller, so we need intermediary component between them which will be further explained in the next sections ,the only exception are the LEDs which are used are indicators and due the low current absorbed from the controller, connecting those LEDs directly to the controller throw a resistors will be acceptable.

3.4.3.1 DC MOTOR Driver

In our interfacing circuit we may want to control a DC motor for some reasons, because the current consumption of the motor is too high for the controller to provide, we need some kind of a driver to separate between them, many solutions are provided to solve this problem, in our design we used the chip L293D for this purpose as illustrated in the Figure 3.15 [15].

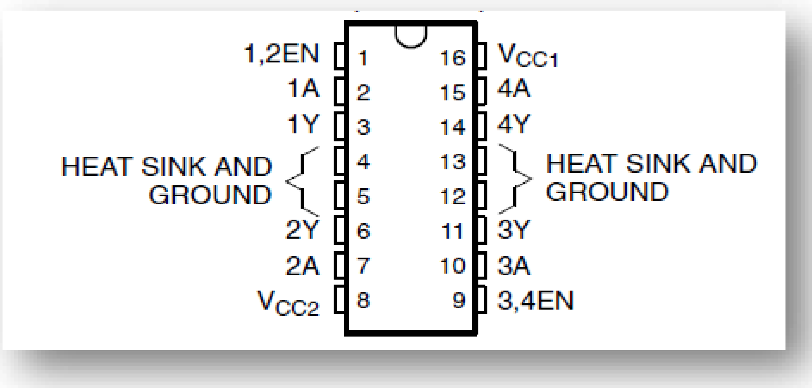


Figure 3.15: DC Motor driver chip (Texas Instruments)

3.4.3.2 Relays

Connecting some loads which operates with AC voltage is not possible directly, we need relays which are mechanical switches controlled by internal inductor, the principle is somewhat easy, when the inductor is energized it acts as magnet and close the switch in the other side of the circuit which provide a good isolation between the control circuit and the load.

3.4.5 Schematic and layout

The schematic and the layout below as illustrated in the Figures 3.16 and 3.17 which depict the receiver hardware design, the process of drawing the schematic and the layout then converting it to PCB is the same with transmitter, the difference of course is the functionality and the components, as seen in the schematic the ATmega168A is the heart of this system surrounded by external peripheral which were discussed in previous sections.

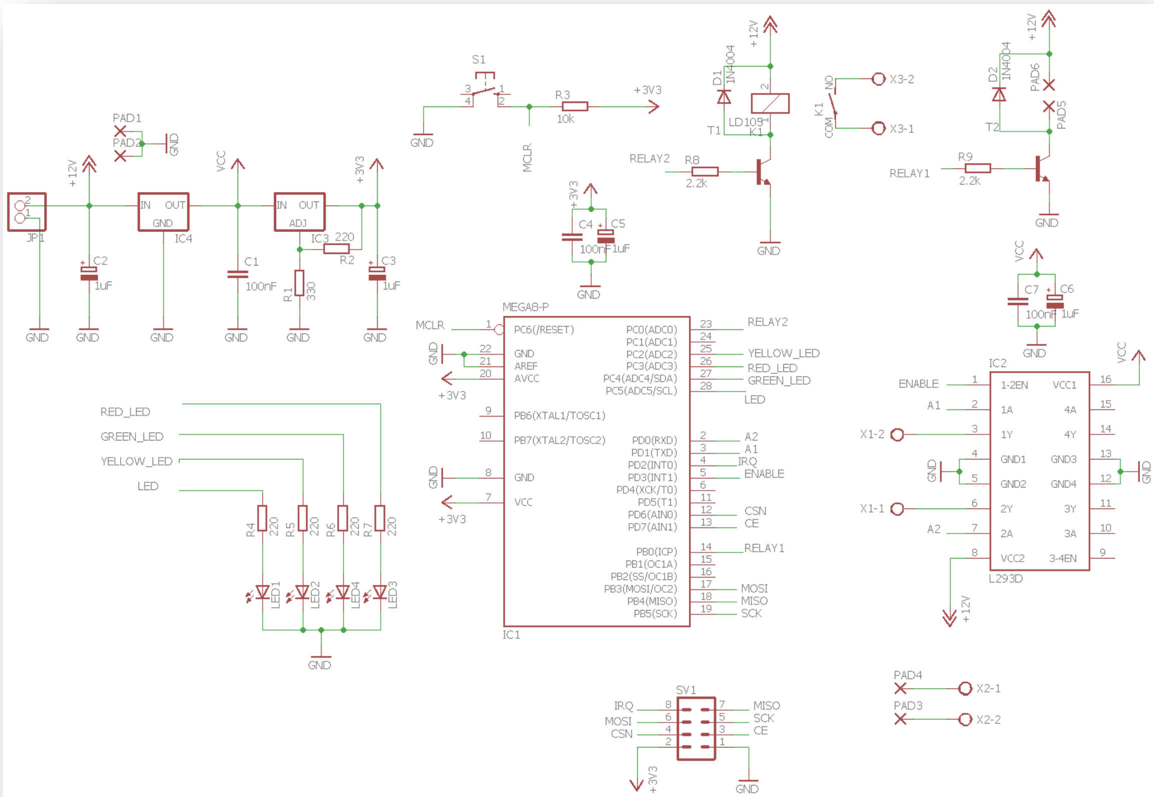


Figure 3.16: Schematic of the receiver with Wireless transceiver

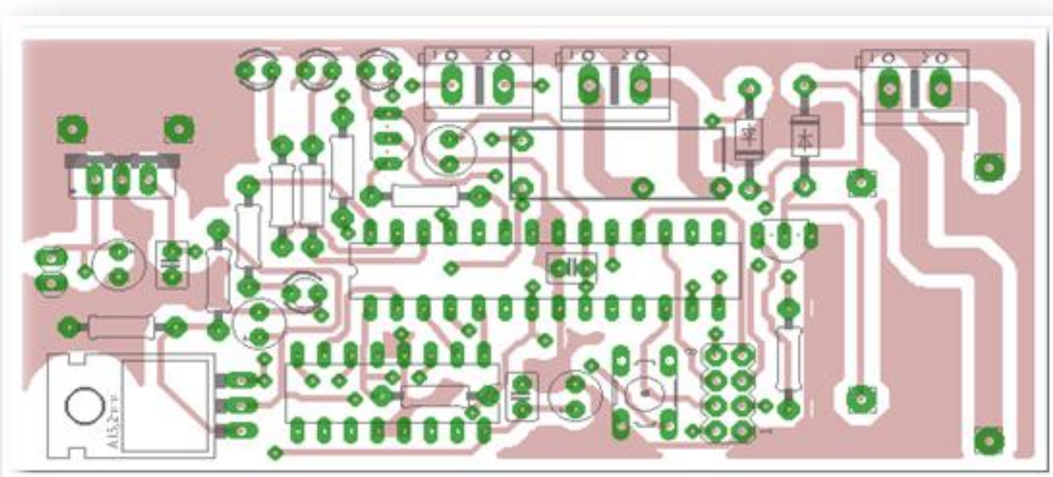


Figure 3.17: Layout of the receiver with Wireless transceiver

3.4.6 Software

The software of receiver is written in C language is similar to the transmitter in the initialization process with minor differences except the body of the software, the flowchart is also used to simplify and summarize the whole code, the flowchart is illustrated in the Figure 3.18.

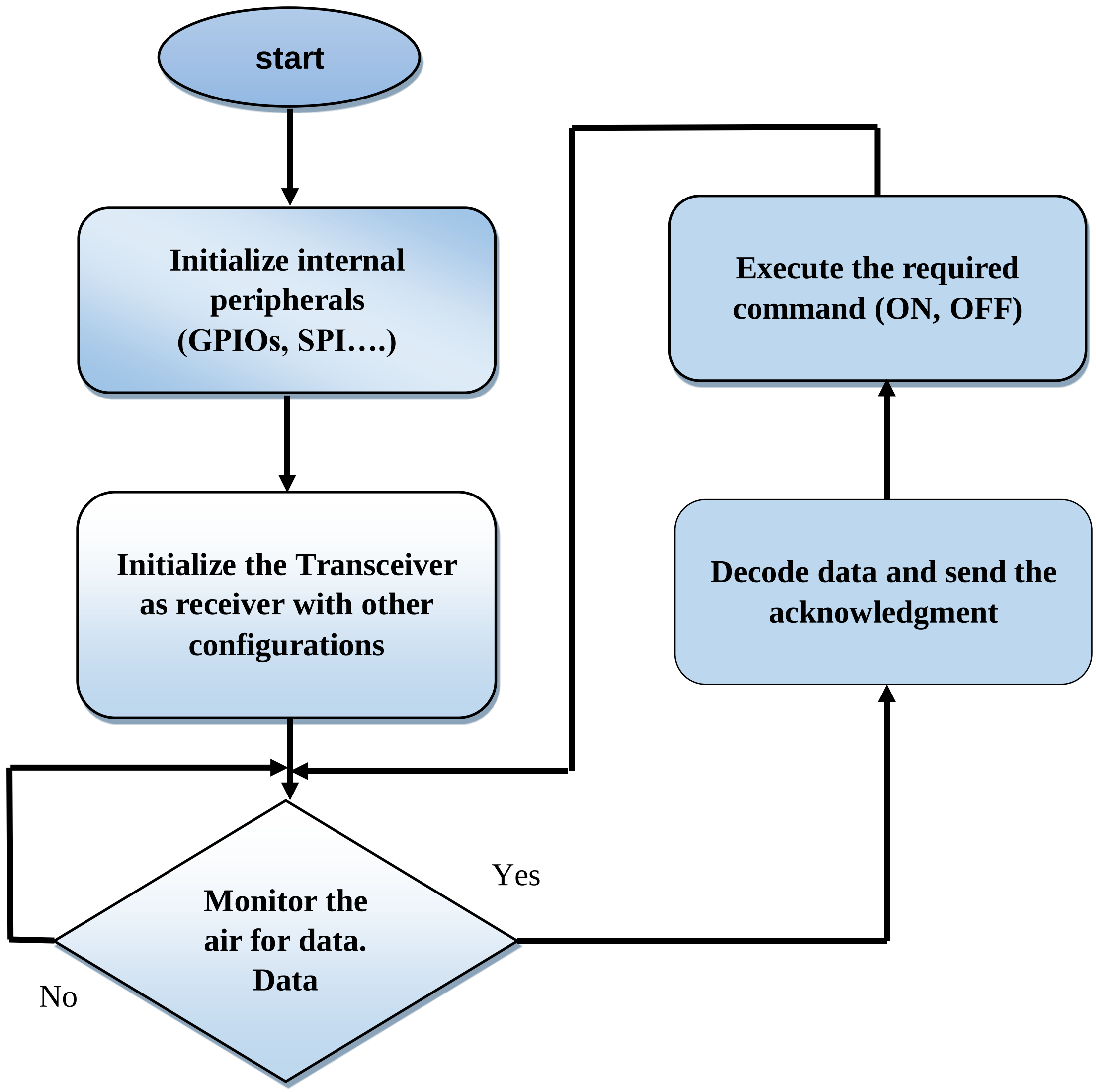


Figure 3.18: Simplified flowchart of the controller with the wireless receiver

3.5 WIFI environment monitor hardware design

The speech recognition transmitter and the receiver were developed mainly to be used by paralyzed people to control some device using their sound instead of their bodies, an extra circuit is introduced to satisfy other requirements as illustrated in the Figure 3.19 which is the WIFI environment monitor, the principle operation of this system is to measure some environment parameters such as (temperature, illumination, humidity) and also measure the gas density such as (CO, CH_4) in the air, and then send all these data to a certain website in the internet by using a special hardware which uses WIFI protocol for sending the data, these data can be observed by the users via some devices which have the access to the internet, the system update these measurements periodically to make work in real time, this system is used to monitor the environment parameters where the paralyzed people resides.

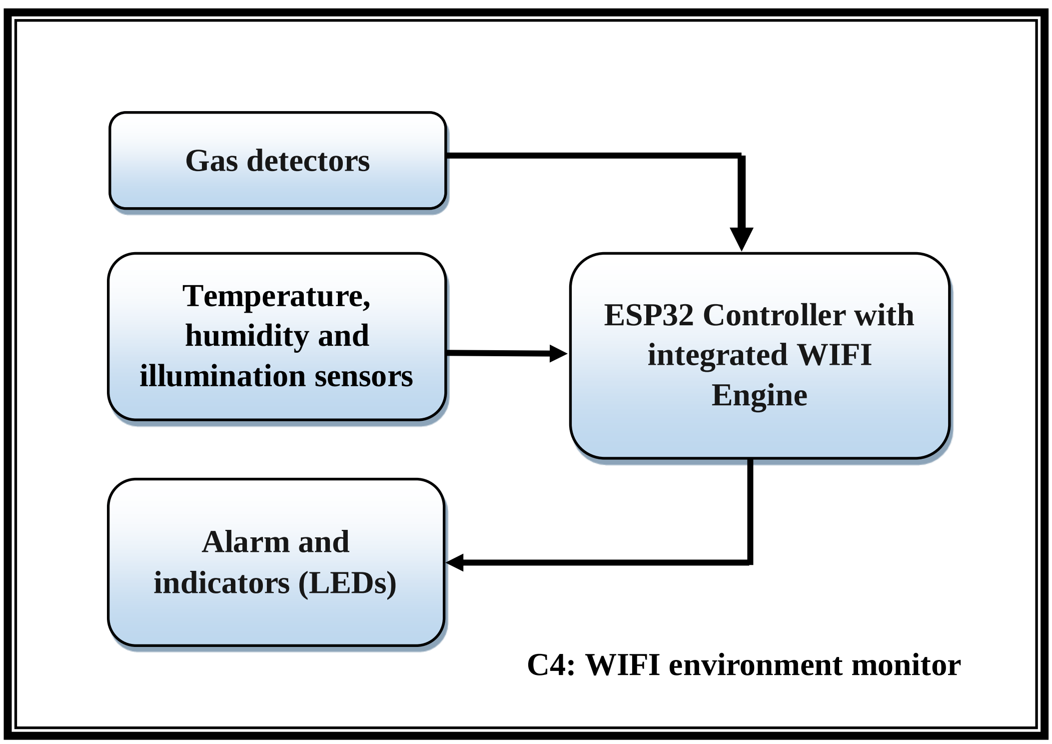


Figure 3.19: WIFI environment monitor block diagram

3.5.1 ESP32 Controller

Designing this monitor is challenging especially using WIFI for data transmission and reception, dealing with WIFI has not been easy task in electronic system design in general and like our system, fortunately many big companies have overcome this problem by providing a especial hardware to deal and facilitate working with WIFI, ESP32 chip is one these solutions which was developed by Chinese manufacturer called ESPRESSIF, this chip is so powerful that all known peripherals used in embedded systems design are integrated in it as illustrated in the Figure 3.20, these characteristics made this chip ideal for our application and it can be used also to develop some powerful projects related to telecommunication just by writing a piece of code installed inside the program memory of chip [16].

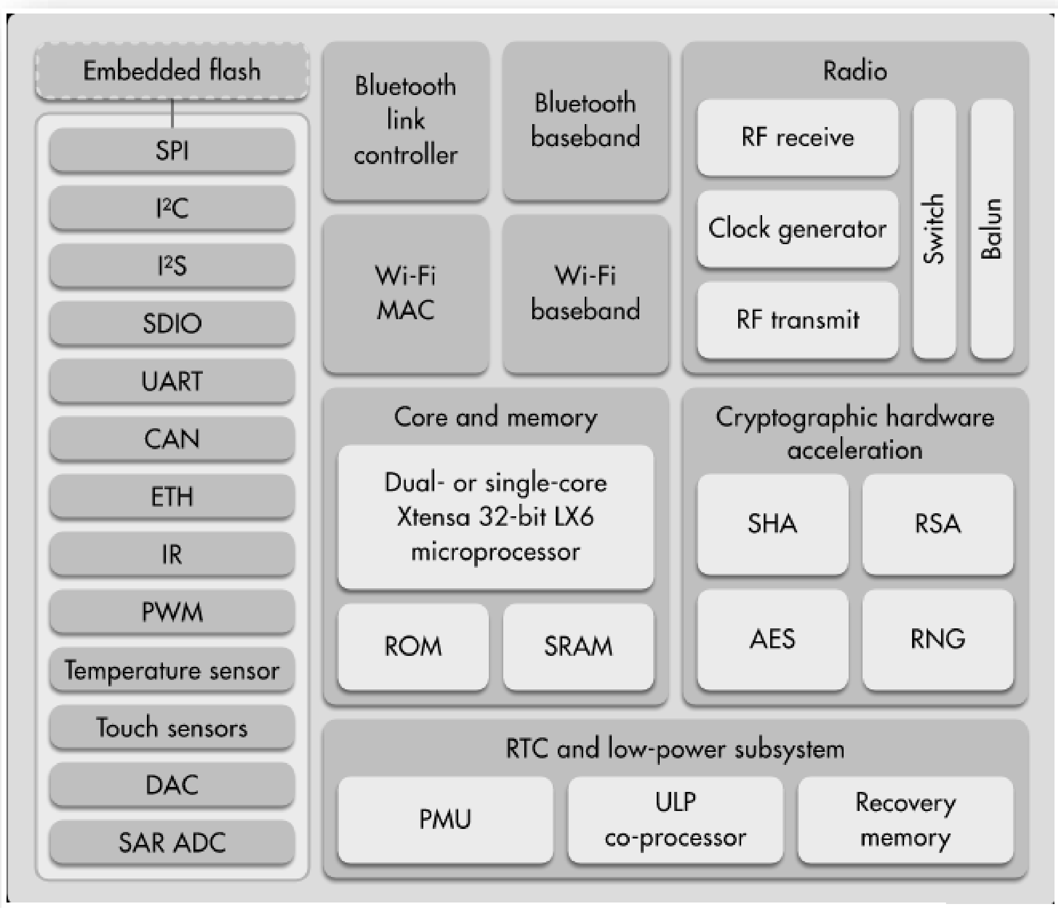
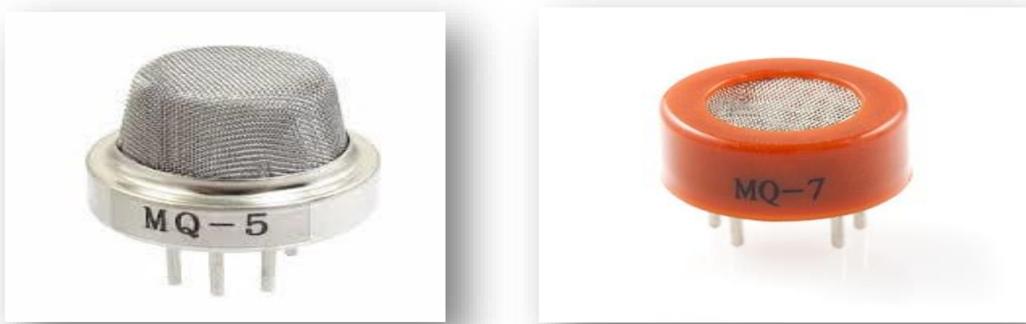


Figure 3.20: ESP32 Controller block diagram (ESPRESSIF SYSTEMS)

3.5.2 Gas detection

Any environment monitor should have the ability of detecting harmful gases in the air, our system in not an exception, it is provided with two gas detectors as illustrated in the figure 3.21, one for the carbon Monoxide and the other one is for Methane, when the level density of certain gas is above the tolerant value, the system will generate an alarm.



(a) (b)

Figure 3.21: Gas detectors: (a) Methane detector. (b) carbon monoxide detector.

3.5.3 Sensors

Beside gas sensor, other sensors should be used to measure the temperature, humidity and illumination, these parameters are important in any environment monitor, our system is also not exception so it is provided with two sensors as illustrated in the Figure 3.22, one for temperature, humidity and the other one is for illumination.

(a) (b)

Figure 3.22: Sensors: (a) illumination Sensor. (b) temperature and humidity sensors

3.5.4 I/O interfacing

Including some I/O components with the main controller is sometimes necessary, LEDs and a buzzer is included in this circuit, LEDs are used as indicators for some operations is being done such as WIFI connectivity and others, buzzer is used as alarm when the system detect harmful gas in the air.

3.5.5 HyperText Transfer Protocol (HTTP)

Because this protocol is used in this project for transmit and receive data from the internet, it is necessary to talk about it, this protocol is the underlying protocol used by the World Wide Web and this protocol defines how messages are formatted and transmitted, and what actions Web servers and browsers should take in response to various commands. As an example, when the user enters a URL in the browser, this actually sends an HTTP command to the Web server directing it to fetch and transmit the requested Web page. The other main standard that controls how the World Wide Web works is HTML, which covers how Web pages are formatted and displayed.

3.5.6 Schematic and layout

The schematic and the layout are illustrated in the Figures 3.23 and 3.24 respectively which depict the WIFI environment monitor hardware design, the heart of this system is the ESP32 controller as shown in the schematic which has the responsibility of doing all necessary functions to make the system work properly, what the controller does is scan all analog inputs like the gas sensors and also the illumination sensor and convert these analog voltages to the digital value, then read the temperature and humidity from the sensor which the data is already represented in digital domain using a special protocol, after reading all these data the controller must process these data before sending them via WIFI, also other component are added like potentiometer which can be used to calibrate the sensors, drawing the schematic, layout and converting to PCB process is the same with previous circuits.

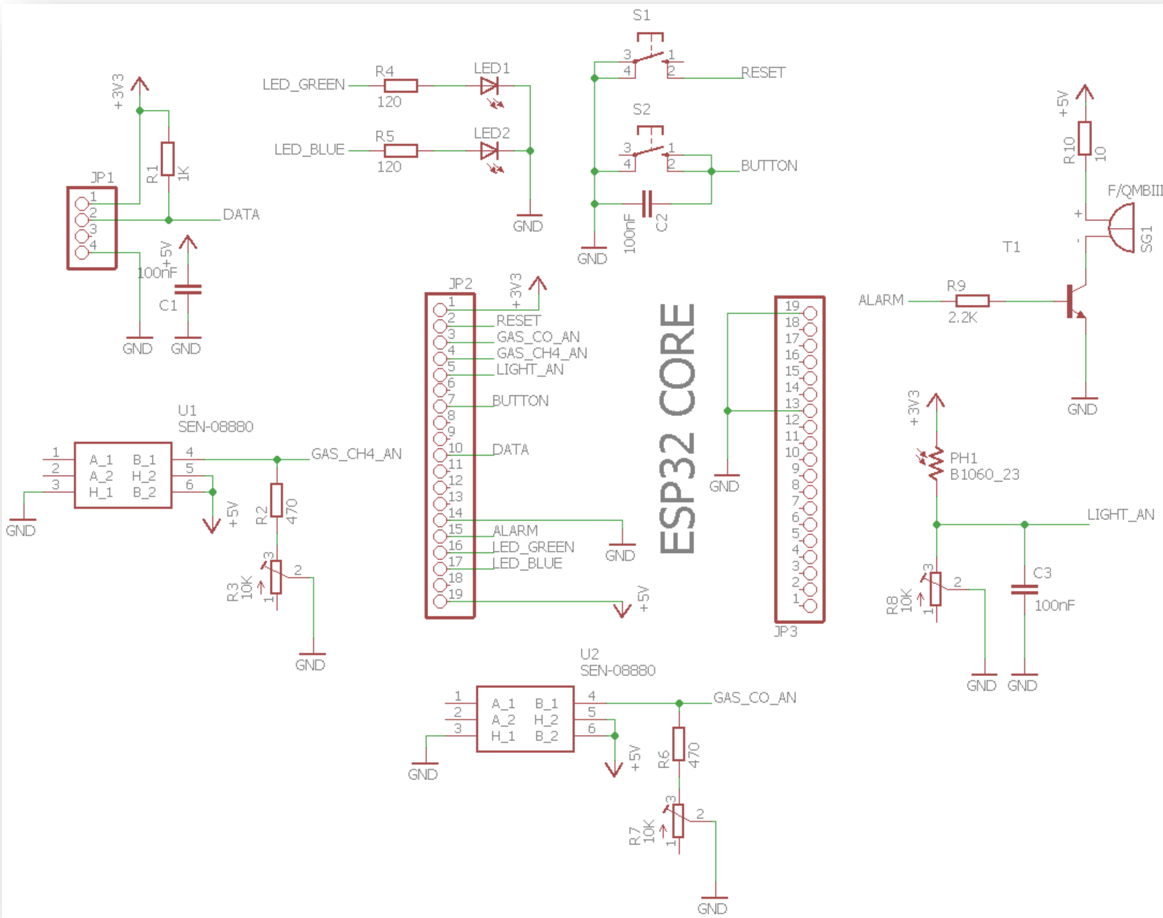


Figure 3.23: Schematic of the WIFI environment monitor hardware design

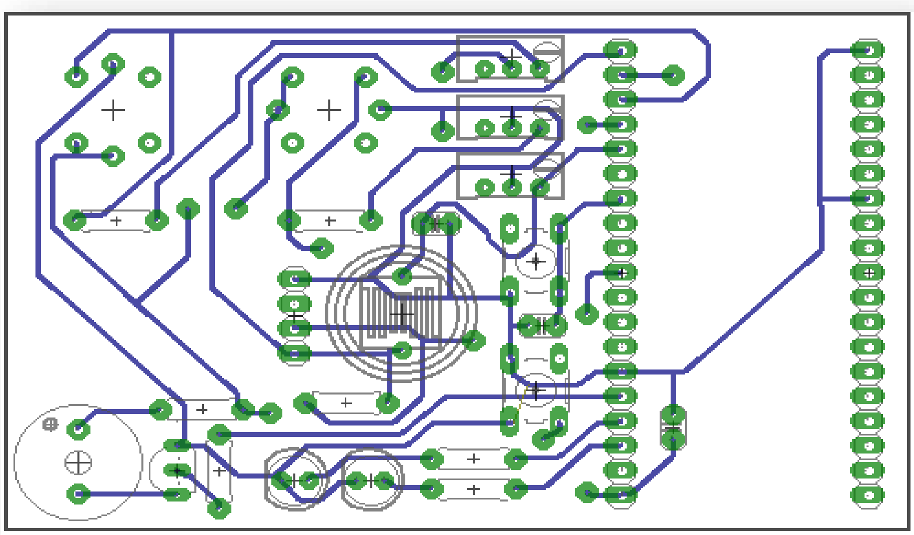


Figure 3.24: Layout of the WIFI environment monitor hardware design

3.5.7 Software

The software which being executed by the ESP32 controller is written by freeRTOS which is a real time operation system, FreeRTOS is ideally suited to deeply embedded real-time applications that use microcontrollers or small microprocessors. This type of application normally includes a mix of both hard and soft real-time requirements, to make the code easy to understand the flowchart is used to simplify it as illustrated in the Figure 2.25.

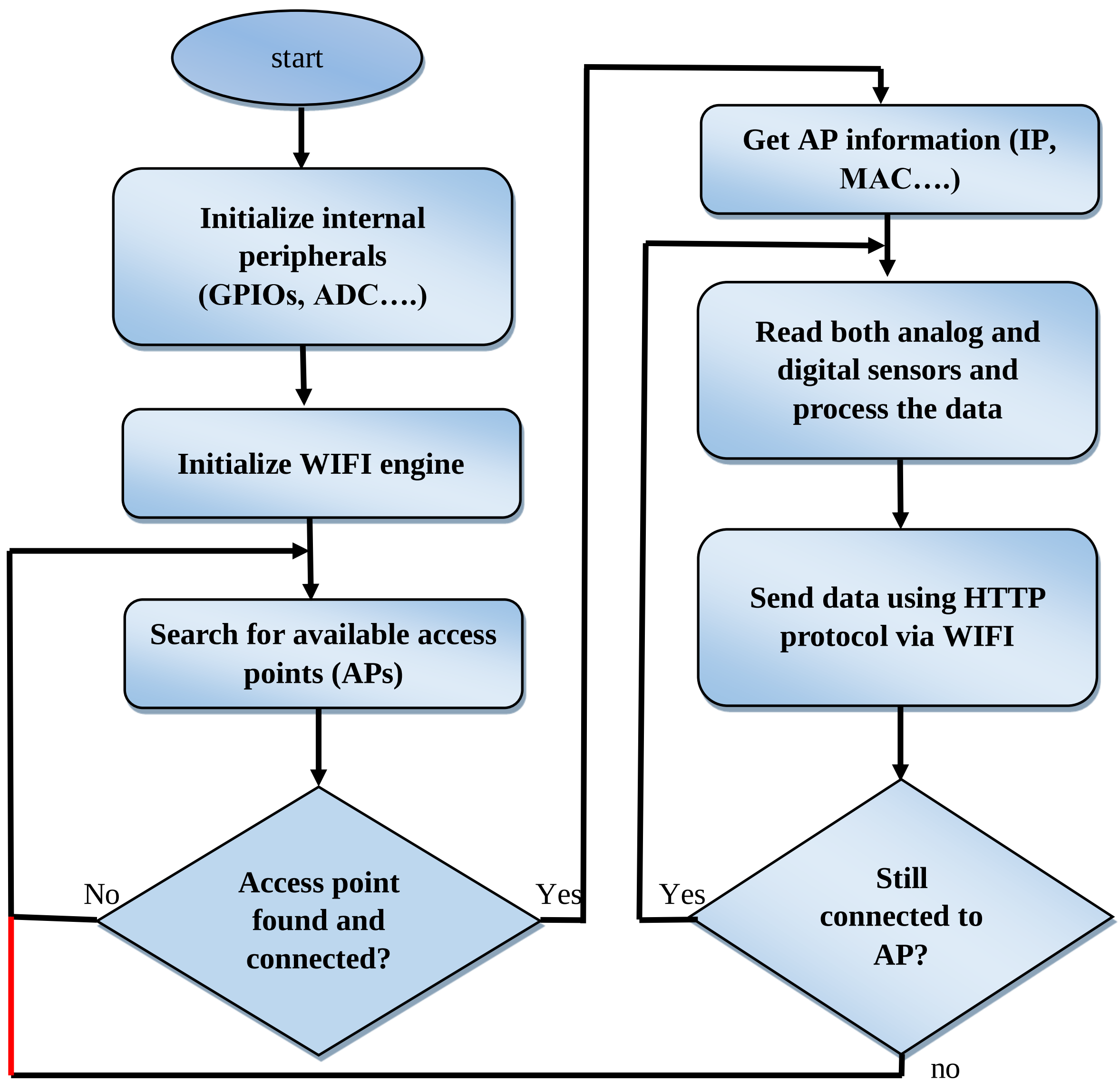
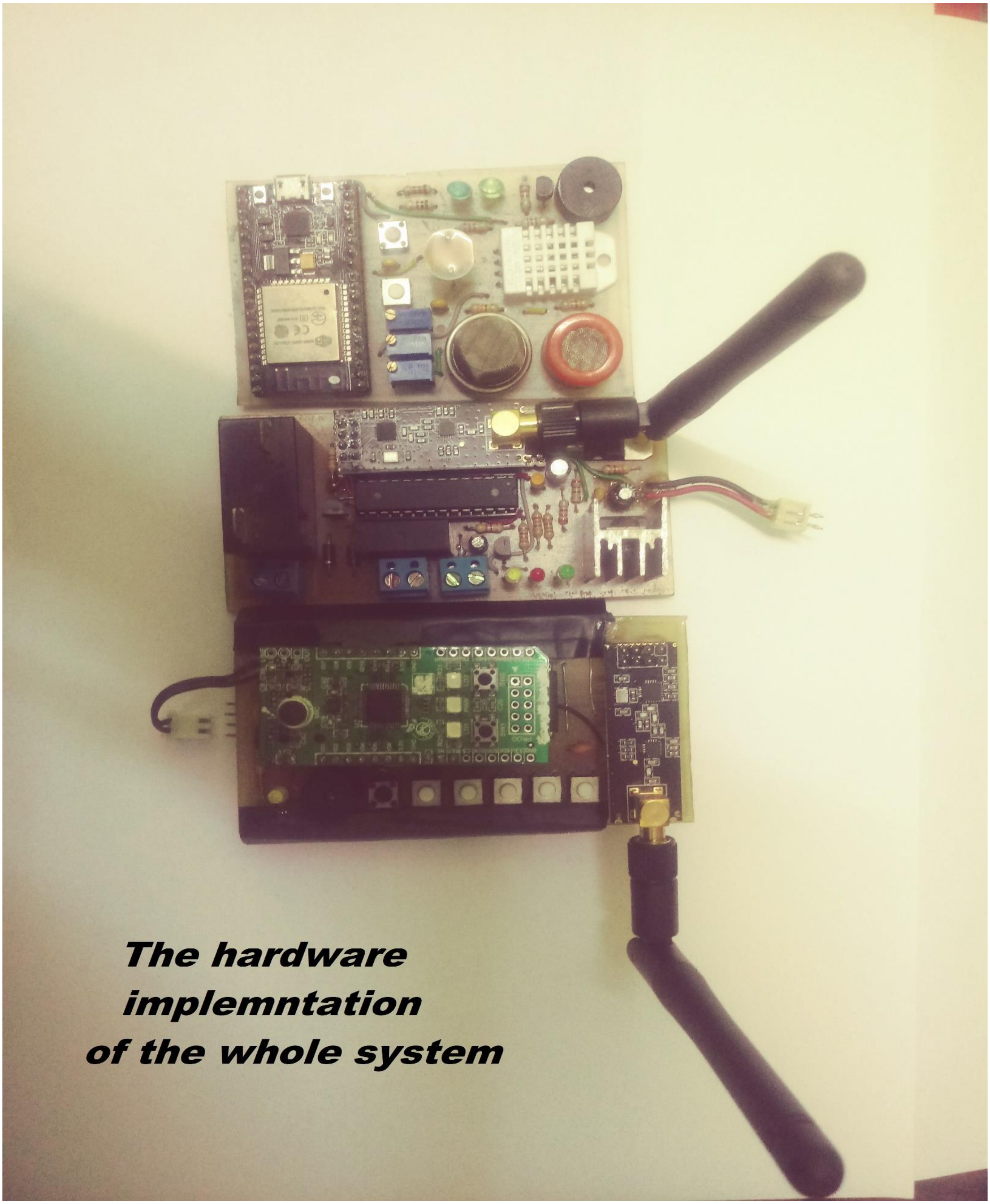


Figure 2.25: Simplified flowchart of the WIFI environment monitor

3.5.8 Summary

In this chapter we have explained the different parts of the whole system hardware design, starting with the speech recognition with the wireless transmitter where we have discussed all different components in details and the construction process of this unit, then started with receiver by doing the same process from explaining the different parts to the construction process, and the last one which is the WIFI environment monitor that was explained in detail like the previous circuits, all different part of this system was uniquely designed and developed by overcoming many obstacles and using limited equipment that we have, although all the difficulties this system has achieved his goal which is providing some kind of assistance for the people who have a certain physical disability.


The hardware
implemntation
of the whole system

Conclusion

In conclusion, we have introduced in the this work the system design which can be used to provide some assistance to the people with physical disabilities and despite of the complexity and the challenges, we managed to come up with a great system design that will be very helpful for the people and community in general, the basic information of the spinal cord injury (SCI) and other information relevant to it were discussed in the first chapter. In the second chapter we talked about some fundamentals and conception that should be known for the system to be comprehended and applied. Then concluding by the chapter three which is related the implementation of the whole system with the explanation of the different sections of each hardware been used in this project.

To achieve the goal which is the construction of this system, we start collecting various data about the physical disability especially the spinal cord injury because it is main cause of disability, and then start looking for various technical solutions that can be efficient and reliable, the developing process started by selecting the right components provided in the market, then start working of the complete design at least as prototype, then the construction process come which is the most difficult part due the efforts which must be done to make the project successful and then comes the last process which is testing and troubleshooting.

Finally, we hope that this work can beneficial for the people physical disabilities and can inspire the next generation of students to come up with technical solution better than this so we can help this category of people to live normal life like a healthy people.

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