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Smart Speed Limit Sign Powered by Solar Energy

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Dedication

I dedicate my dissertation work to my family and many friends. A special feeling of gratitude to my loving parents, Samia and Lounis, whose words of encouragement and push for tenacity ring in my ears. My sisters Yasmine, My brother Amine have never left my side and are very special. I also dedicate this dissertation to my grandmother and aunt who have supported me throughout the process. I will always appreciate all they have done.

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This work is dedicated to my parents:

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Who offered unconditional love and support and have always been there for me.

Thank you so much!

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Abstract

This report opens up a new field of research called "Intelligent Transport Systems" which is an interactive system for the collection, processing and dissemination of information applied to the field of transportation an interactive system for the collection, processing and dissemination of information applied to the field of transportation. As we know, speed is a central issue in road safety. In fact, speed is involved in all accidents: no speed, no accidents. Speed has been found to be a major contributory factor in around 10% of all accidents and in around 30% of the fatal accidents. Both excess speed (exceeding the posted speed limit) and inappropriate speed (faster than the prevailing conditions allow) are important accident causation factors.

This work tries to solve this problem by realizing an intelligent speed limit panel; which can determine the suitable speed for a safe driving according to the weather conditions and road characteristics. To do this we have used special kinds of sensors to collect information from the external environment then transmit it to the main unit where the system can decide the real time speed limit and display it for the drivers. Finally, we moved on to the testing part where we demonstrated the effectiveness of our solution and its future extension.

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List of Abbreviations

ADAS: Advanced Driver Assistance Systems.

ATM: Active Traffic Management.

CMS: Changeable Message Signs.

DMS: Dynamic Message Signs.

HF: High Frequency.

IRS: Intelligent Road Signs.

ITS: Intelligent Transport Systems.

IVHS: Intelligent Vehicle-Highway Systems.

LCD: Liquid Crystal Display.

LDR: Light Dependent Resistor.

LED: Light Emitted Diode.

MUTCD: Manual on Uniform Traffic Control Devices.

NTC: Negative Temperature Coefficient.

PV: Photo Voltaic.

RACS: Road / Automobile Communication System.

RWIS: Road weather information system.

TMC: Traffic Management Centers.

VMS: Variable Message Signs.

VSL: Variable Speed Limit.

VSLS: Variable Speed Limit Sign.

Introduction

Recently, much attention has been paid to the development of intelligent transport systems (ITS) that can improve the safety and efficiency of road transport while improving user comfort and convenience. Many countries have been involved in developing or deploying these technologies to some extent. As this process has moved forward, a great deal of information has been developed concerning the benefits that can be realized over time with the full deployment of ITS. Among other things, safety benefits have been measured or estimated for a wide variety of technologies [1].

Modern transportation systems aim at maximizing the use of available resources in a sustainable manner to deliver efficient and safe movement of traffic. Variable Speed Limit (VSL) system is one of the techniques adopted in order to improve mobility and in which speed of traffic stream is decreased in small values in order to harmonize the traffic flow [2]. On the majority of the roads, fixed speed limits are set to represent the appropriate speed for average conditions. However, in order to take account of real time traffic, road and weather, (VSLS) can be applied. This work deals with the definition of the above system and showing the advantage of using Variable speed limits in the real life. It includes four main chapters.

Chapter I presents an overview of the ITS, its types and applications. As well as its contribution to solving road safety problems. Chapter II introduces the use of Variable Message Signs (VMS) in general, describes their benefits on traffic safety, and reduce accidents. However the chapter III introduces the variable speed limit sign systems(VSLS) as ITS' solutions that enable dynamic changing of posted speed limits in response to prevailing traffic, incidents and/or weather conditions. The last chapter describes the steps used to realize a prototype which is an intelligent speed limit panel powered by solar energy that allows us to determine the suitable speed for the safest possible driving due to the weather information collected from the various sensors installed. Finally, a conclusion has been given at the end of the report.

CHAPTER I

INTELIGENT TRANSPORT SYSTEMS

I.1. INTRODUCTION

A new field of research called "ITS" was born after introducing intelligence into transport systems. ITS is an interactive system for the collection, processing and dissemination of information applied to the field of transportation, based on the integration of information and communication technologies into infrastructures and vehicles in order to improve the management and operation of transportation networks and associated user services [3]. In what follows we will present ITS while focusing on road transport systems and road safety.

I.2. DEFINITION OF ITS

An ITS is an advanced application which aims to provide innovative services relating to different modes of transport and traffic management and enable users to be better informed and make safer, more coordinated, and 'smarter' use of transport networks [4]. ITS is also the application of sensing, analysis, control and communications technologies to ground transportation in order to improve safety, mobility and efficiency. ITS also includes a wide range of applications that process and share information to ease congestion, improve traffic management, minimize environmental impact and increase the benefits of transportation to commercial users and the public in general [5].

I.3. HISTORY OF ITS

At the end of 1960-beginning of the 70's, the first motorway guidance programs, in particular with installation of the first speed and flow sensors motorway and occupation of road surfaces. Will be thus generalized the first electronic signals of traffic (Dynamic Message Signs) and the first algorithms location with their representation on digital maps. All of these innovations will be capitalized by creating the first traffic management centers (TMC Traffic Management Centers) which integrate data related to meteorology, vehicle speed, congestion and accidentology. In the mid-1980s, ITS took an important place in the world when communication technologies became much cheaper and reliable and computing capacities increased considerably. The auto industry has valued their products and government agencies with opportunities to solve congestion and safety issues.

Large projects have been launched with the government-industry partnership. The European Union has set up a dedicated road infrastructure for vehicle safety in Europe (DRIVE).

During the 1990s, the concept of an ITS appeared. ITS reflect the notion of a systemic loop of interaction around the four components: the vehicle, the infrastructure, the management system and the driver. Technological innovations will thus focus on improving and the standardization of management systems transport, on integrated navigation systems for the driver (GPS, traffic management, dashboard) and on electronic toll systems. Since the 2000s, ITS's have become widespread and were driven by the digitalization process observed in different segments of the economy. The main changes have made it possible to improve the driver assistance systems, but the priorities of the players are diversified. The launch of the iPhone in 2007 and the spread of smartphones more generally will accelerate the dynamics of ITS [6].

I.4. APPLICATIONS OF ITS

ITS have brought a lot of improvement in overall safety or congestion. The successful evolution of ITS includes:

- Route guidance systems which have become commercially available and in wide use.
- Highway toll collection and passenger information systems.
- Road pricing and electronic vehicle monitoring systems in cities.
- Management of public transport with vehicle tracking and passenger information systems.

I.5. APPLICATIONS ON INFRASTRUCTURE

Currently, in order to increase, modernize and develop the infrastructure in road, rail, airport, waterways and seaport modes, several methods have been proposed such as: the construction of new highways, speed bumps, public lighting, the development of materials and innovative techniques to mark the ecological footprint of linear infrastructures, VMS, reduction of energy consumption and greenhouse gas emissions, installation of radars, traffic lights etc.

I.5.1. DYNAMIC SIGNAGE

Dynamic signage relating to operation and road safety is intended to deliver messages that need to be changed frequently or that need to be activated very quickly.

It informs users of disruptions affecting or which may affect their route and advises them in difficult situations.

In order to ensure dynamic signage, VMS, were first introduced in England in 1962. They can consist of several parts:

- Apictogram part intended to display signals.
- A text part intended to give literal information.
- A sign part, located below the pictogram part or possibly under a sign, intended to display a distance, an extent, etc.

VMS are extremely beneficial for increasing road safety performance because they can directly signal to a motorist onthe road many types of information quickly and effectively.

There are two main types of VMS, Permanent and Portable VMS. Both types of VMS come in a range of sizes for different applications. Fixed and Mobile VMS have many similarities including dynamic messaging, remote programming, numerous communication options, and bright multi-color displays.

I.5.2. RADAR

Radar is an electromagnetic sensor used for detecting, locating, tracking, and recognizing objects of various kinds at considerable distances. It operates by transmitting electromagnetic energy toward objects, commonly referred to as targets, and observing the echoes returned from them. The targets may be aircraft, ships, spacecraft, automotive vehicles, and astronomical bodies, or even birds, insects, and rain. Besides determining the presence, location, and velocity of such objects, radar can sometimes obtain their size and shape as well. What distinguishes radar from optical and infrared sensing devices is its ability to detect faraway objects under adverse weather conditions and to determine their range, or distance, with precision.

Radar is an “active” sensing device in that it has its own source of illumination (a transmitter) for locating targets. It typically operates in the microwave region of the electromagnetic spectrum—measured in hertz (cycles per second), at frequencies extending from about 400 megahertz (MHz) to 40 gigahertz (GHz). It has, however, been used at lower frequencies for long-range applications (frequencies as low as several megahertz, which is the HF [high-frequency], or shortwave, band) and at optical and infrared frequencies (those of laser radar, or lidar). The circuit components and other hardware of radar systems vary with the frequency used, and systems range in size from those small enough to fit in the palm of the hand to those so enormous that they would fill several football fields [7].

I.5.2.1. FIXED SPEED CONTROL RADARS

In this section we will describe three types of fixed speed control radars as follow:

- **The fixed speed radars:** Installed on the side of roads, it monitors the speed of drivers in the most dangerous areas and is the first type of radar to be installed. It instantly calculates the speed of the vehicle as it passes, forward or backward, in one or both directions.
- **The discriminating radar:** Similar to the fixed speed camera, it makes it possible to differentiate the categories of vehicles, and in particular heavy goods vehicles from light vehicles, in order to control the specific speed limits according to the category of the vehicle. This equipment also makes it possible to identify with certainty the offending vehicle in the event that several appear on a photograph. It is equipped with 3 modules respectively allowing speed measurement, the Light Vehicle / HGV distinction and the track identification.
- **The average speed radar:** also called section radar - calculates the average speed achieved on a section of road in order to encourage users to adopt responsible driving throughout their journey. The place of the offense is the exit checkpoint. At the entry point of the section, a video camera - associated with an automatic license plate reader - takes a snapshot of each vehicle and records its license plate and time of passage. At the exit point, a processing unit calculates the average speed on the section by each vehicle on the basis of this information. Fixed speed control radars are installed on sites proposed by the department prefects on the following criteria:
  - Areas where accidents occur where excessive speeds are the main cause.
  - Routes with heavy vehicle traffic (especially expressways and motorways), on which the speed limit is regularly ignored.
  - At regular intervals on long stretches to lower average speed over the entire journey.
  - Areas where users must be extra vigilant, especially sections of road where improvements would be difficult or extremely expensive (tunnels, bridges).
  - In places and on sections of the road where the presence of law enforcement is impossible to allow traditional speed checks to be carried out [8].

I.5.2.2. NEW GENERATION MOBILE RADAR

The new generation mobile radar is automatic radar onboard an unmarked car.
Its particularity is to be able to flash vehicles in excess of speed when it rolls in the middle of the traffic flow. The first new generation mobile radars appeared in 2013 to replace the MESTA 210, an old model of mobile radar deployed between 2004 and 2005 [9]. This kind of radar driven by gendarmes or police officers in uniform, in order to detect without visible flash and while driving, all speeding vehicles.

Figure I.2: New generation mobile radar [9].

1.5.3. TRAFFIC LIGHTS

A road traffic light, also called a traffic light, is a device allowing the regulation of road traffic between road users, vehicles and pedestrians. Today essential to manage the flow of traffic in cities, the traffic light has not always been the one we know. It was in 1868 in a district of London that the first traffic light appeared to regulate the flow of horses and pedestrians in the streets. Very different from ours, it took the form of a gas lantern emitting a red or green light, and was manually controlled by a police officer. But it was in 1914 in Cleveland in the United States that the first electric road traffic light (two-tone) was born. Six years later in 1920, the first traffic lights as we know it were installed in Detroit and New York. In France, the first traffic light regulating motorist traffic was installed in Paris in 1923. It was single-colored (red) and emitted an audible signal when the motorist had to stop. It took ten years to see traffic lights in France. At present, new intelligent traffic lights manage traffic in Toronto (Canada). These assess road traffic and adapt the lighting time of the lights to allow smoother traffic and avoid traffic jams [10].

Today and with the arrival of the concept of ambient intelligence, the idea of making traffic lights themselves intelligent has appeared on the horizon, These traffic lights, which are nicknamed "intelligent", have the principle of switching to red or green light depending on the speed of the approaching vehicles. This is a behavioral fire system intended for motorists to change their behavior on the road.

I.6. VARIABLE MESSAGE SIGNS

Road traffic safety has become a significant global public health issue. The number of traffic crashes is increasing in alarming proportions, leading to a large number of deaths and injuries. Most road accidents occur due to human errors including exceeding speed limit and failure to abide by driving rules [11].

Therefore, in order to solve this issue, advanced driver-assistance systems and ITS are more and more in use thanks to their capabilities in minimizing the human error. The most famous traffic control devices are VMS, (VMS) are electronic and intelligent display panels for road traffic management that allow text and graphic variable messages to be combined, resulting in a more effective means of controlling traffic. Some VMS's are built with long life LED technology that improves the visibility in all types of weather. Through the use of a solar sensor, the brightness can be adjusted for both clear day and night viewing. Other benefits include increases in safety, lower stress levels, better decisions and mobility. The versatility of VMS makes them suitable for providing traffic information for a variety of situations including emergencies and road closures [12].

I.6.1. AIMS OF VMS

The aim of using VMS is to provide drivers with mandatory and/or advisory information, at the roadside, relating to situations ahead or in the immediate vicinity. In relation to congestion VMS can assist drivers in selecting appropriate routes avoiding a traffic queue and to reduce drivers' stress by improved information. Signs have different benefits depending on the type of message they are designed for. In particular cases VMS can reduce the likelihood of dangerous driver behavior. A type of VMS that can be feasible along a minor road is one activated by the speed of a driver that approaches them. This type of sign can for example show a single standard message such as 'SLOW DOWN' to inform the driver that she is approaching a bend at an excessive speed. The expected impact of such signs is a reduction in the number of violations of speed limits. These sign are normally free-standing from a control center. VMS can sometimes reduce the number of signs and amount of information, since their content can vary. This is however rarely a dominant aim of VMS as costs of signs are high.

I.6.2. Types of VMS

There are two types of VMS, which are:

- **Permanent/ Fixed VMS**

Permanent or Fixed VMS as shown in the figure I.1 can be found in many different sizes, depending on the application, primarily in a large rectangle shape. They are designed to effectively deliver traffic information to motorists. Such as information reporting traffic congestion, temperature, lane controls, speed limits, and changes in usual traffic conditions. Occasionally known as VMS Tunnel, as they are often equipped to tunnel entrances to display travel time and tunnel lane closures. Permanent VMS are often used on highways, roadways and tunnel entrances.

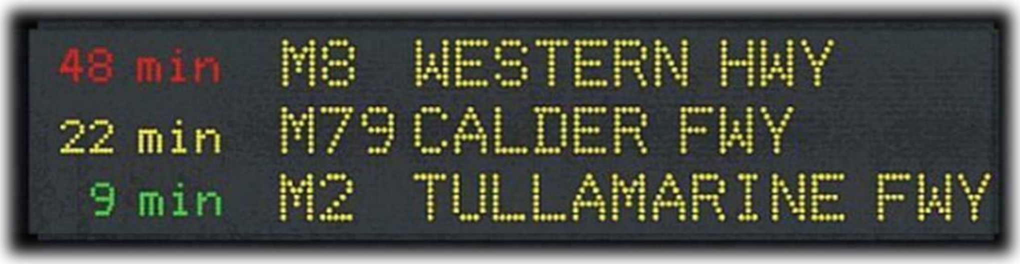


Figure I.1: Fixed VMS [13].

- **Mobile/Portable VMS**

Mobile VMS have become a staple part in traffic management and community awareness projects, as they have been shown to effectively disperse traffic away from work sites, potential bottlenecks or known problem areas. Mobile VMS can be used for several different reasons including traffic management, road works, advertising, and events.

For traffic management application portable VMS can be used to advise road/lane closures, communicate with a motorist and local traffic of any changes usual traffic conditions, providing directional information, displaying safety information, accident management and speed related messages [13].

I.6.3. POTENTIAL USES OF VMS

Some examples of the potential uses of VMS are:

- **Lane closures and recommended speed by lane:** VMS can be used to provide information about approaching lane closures and to show variable speed limits, either to enable drivers to slow down before reaching a downstream hazard such as slow/stationary traffic) or to improve the general traffic flow by the use of variable speed limits.
- **Weather information:** VMS can be used to inform drivers of weather conditions such as fog, ice or snow. The information is normally only useful it relates to downstream conditions on the road ahead. However, they can also combine these with corresponding speed advice.

- **Parking guidance information:** A parking guidance system needs four elements: a monitoring system; an organizing system; a communication system and a display system. The VMS is the display. Monitoring of the car park needs to be done, the information monitored needs to be communicated and relayed/organized before it is ready to display.
- **Variable tolling:** VMS can be used to display the price of variable tolls on roads or bridges or in areas of congestion charging. Connecting the VMS to relevant traffic flow devices can reduce the need for human intervention.
- **Generic Dangers and Safety Messages:** VMS is often used as a mechanism to provide general road safety advice, for example related to 'drink driving' or 'take a break [14].

I.6.4. SOLAR ENERGY AND VMS

Solar energy technologies, which harness the sun's energy to generate electrical power, are one of the fastest growing sources of renewable energy on the market today. Engineers and scientists are collaborating to lower the material costs of solar cells, increase their energy conversion efficiency, and create innovative and efficient new products and applications based on photovoltaic (PV) technology around the world. On the other hand, vehicular travel is increasing throughout the world, particularly in large urban area. Traffic control systems have also increased in installation as a result. However, it is still economically difficult to provide traffic control in country and rural areas, primary due to cost of building power infrastructure over long distances. Solar traffic signs have many uses. They can be used in manufacturing facilities, for pedestrian safety, stop and yield signs, vehicle directions, emergency instructions, parking and school zone safety [15].

Figure I.3: The use of solar energy in mobile VMS [15].

Solar powered VMS are now used extensively to reduce energy consumption and thereby reducing the overall total cost of ownership in many applications like traffic system control, transportation, municipal system. Recently, solar powered VMS are being used to provide dynamic and real time information to the driver. Solar powered VMS solutions can be installed where traditional electricity lines are not available or a distant place from electric connection. Considering these factors, the adoption of solar powered VMS has been growing in the market [16].

Figure I.4: Solar powered VMS [16].

Solar powered VMS have many benefits including:

- **Installation time and cost reduction:** For installation of solar powered VMS there are no needs of large electrical cables which can save a large share of money from investment. The energy autonomy in solar powered VMS eliminates the need for electrical cables. This largely reduces the installation cost and time of VMS.
- **Reduction in operating cost:** Solar powered VMS have an efficiency of over 75% and a large reduction in heat dissipation. With this energy reduction, the VMS can be powered at maximum brightness with a deep cycle battery and recharged with a photovoltaic panel. The recharging of the battery through solar panels reduces operating costs by 70% through the reduction of energy consumption based on average cost.
- **Reduction in Maintenance Cost:** The finless cooling system enables the solar powered VMS to operate without the regular cleaning of filters. The high-quality electrical and electronics components ensure a high a level of reliability, thus reducing the maintenance cost significantly [16].

I.7. CONCLUSION

In this chapter, we learned about ITS and their types, as well as their contribution to reducing road hazards and solving road safety problems. We also indicated the extent of development that these systems have witnessed thanks to information and communication technology. VMS can be used for many different purposes with the potential benefits of reducing car drivers' stress, travel time and increasing traffic safety. VMS may ask drivers to change travel speed, change lanes, divert to a different route, the available parking space, or simply to be aware of a change in current or future traffic conditions by providing information. The information is intended to assist drivers in selecting appropriate routes avoiding congestion and to reduce drivers' anxiety. In the next chapter, we will learn about a special type of VMS; which is the variable speed limit sign (VSLS).

CHAPTER II

VARIABLE SPEED LIMIT SIGNS

II.1. INTRODUCTION

One of the most important types of VMS which has a big role in traffic safety is the ‘’ (VSL) sign’’, this kind of signs is used across the country to lower posted speed limits in certain areas. VSL signs allow operators to adjust the posted speed limit without changing the physical sign. They are used in conjunction with ITS to lower speed limits for several reasons including congestion, construction, accidents, fog, snow, and ice. As technology advances, the ease of use of VSL signs is also increasing, as the speeds can now be changed remotely via email or telephone, at pre-set times of day, or manually. In the near future, VSL signs may be used to alter speed limits based on real time traffic or weather conditions [17]. In this chapter, we go through the different stages of modeling an intelligent road sign.

II.2. VARIABLE SPEED LIMIT SIGNS

VSL systems are ITS solutions that enable dynamic changing of posted speed limits in response to prevailing traffic, incidents and/or weather conditions. VSL systems utilize traffic speed, volume detection, and road weather information systems to determine the appropriate speeds at which drivers should be traveling, given the current conditions. Changes in posted speed limits are indicated by displays on overhead or roadside VMS’s as shown in the figure below [18].

Figure II.1: Solar powered VSLS [18].

II.2.1. TYPES OF SPEED LIMITS

Figure II.2 shows the different types of speed limits.

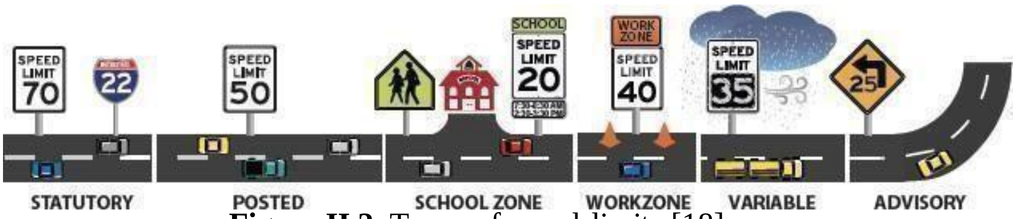


Figure II.2: Types of speed limits [18].

Types of speed limits are:

- **Statutory speed limits:** Statutory speed limits are established by State legislatures for specific types of roads (e.g., Interstates, rural highways, urban streets) and can vary from State to State. They are enforceable by law and are applicable even if the speed limit sign is not posted. Examples of statutory speed limits include:
  - 25 mph in residential or school districts.
  - 55 mph on rural highways.
  - 70 mph on rural Interstate highways.

- **Posted speed limits:** Posted speed limits (sometimes called regulatory speed limits) are those that are sign- posted along the road and are enforceable by law. A posted speed limit could be the same as the statutory speed set by the State legislature, or it could be established by a city, county, or State transportation agency as an adjustment to the statutory speed limit. Some cities and counties will establish a blanket speed limit for roads in their jurisdictions. Those limits are generally posted at the city limits or county lines. The posted speed limit can differ from the statutory speed limit; in these cases, the posted speed limit is determined using an engineering speed study and takes priority over the established statutory speed limit.

- **"Special conditions" speed limits:** there are three types of special conditions speed limits which are:
  - **School zone speed limits** are used in specific locations during the hours when children are going to and from school. Most States use a school zone speed limit of 15 to 25 mph in urban and suburban areas.

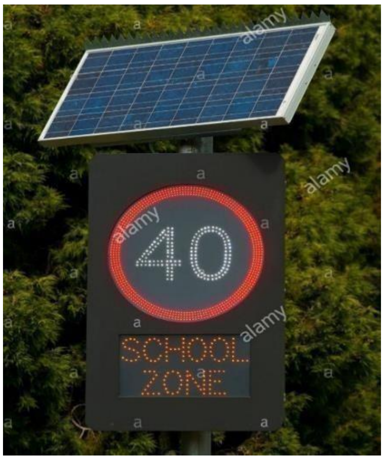


Figure II.3: Solar powered school zone speed limit sign [18].

- **Work zone speed limits** are set as part of the work zone's traffic control plan, which is used to help facilitate safe and efficient movement of traffic through a work zone. Factors that influence work zone speed limits can include:
  - The posted speed limit when the work zone is not present.
  - The location of the work zone and workers in relation to traffic.
  - The type of traffic control (e.g., cones, barrels, concrete barriers).
  - The complexity of the work zone (e.g., lane shifts, narrowed lanes).

Figure II.4: solar powered work zone speed limit sign [18].

- **VSL** are displayed on changeable message signs (CMS) at locations where roadway conditions regularly require speeds to reduce more than 10 mph below the posted speed limit. These instances typically occur due to weather conditions, congestion, traffic incidents, and/or work zones. Advisory speeds are a non-regulatory speed posted for a small portion or isolated section of a roadway (e.g., a sharp curve, an exit ramp) to inform a driver of a safe driving speed. They are set using an engineering speed study and in accordance with guidance in the *Manual on Uniform Traffic Control Devices* (MUTCD) [18].

II.2.2. BENEFITS OF VSLS

In most cases, VSL deployments are capable of generating desired traffic efficiency and safety system benefits. Because VSL systems have varying deployment goals and corresponding system design, varying system benefits resulted. Speed homogenization projects usually use simple algorithms in response to real-time traffic, road, and other conditions (e.g., weather, work zone, incidents, visibility, etc.), and report safety improvements. Multi-objective projects, mostly as a part of active traffic management (ATM) systems, report positive effects on mobility, safety, and even the environment. System benefits vary from site to site and it is difficult to generalize the reasons for these discrepancies due to many uncontrolled factors among different sites, such as compliance rate, driver behavior, or road geometry.

However, VSL systems generally result in the following benefits:

- **Smoother traffic flow and less delay**. As a component of ATM, VSL proactively manages speed to improve traffic flow and safety. Generally, some of the benefits of VSL include shortened queues, reduced congestion, and quicker clearance during incidents, and fewer crashes.
- **Safer speeds in work zones**. While agencies have found that performing nighttime construction reduces congestion and shortens traffic queues (compared to daytime construction), the lower volume also allows for faster speeds creating dangerous conditions in work zones. A VSL system allows the speed limit to be reduced so that vehicles approach construction areas and pass through work zones at safer speeds.
- **Ability to tie to road weather information system (RWIS) data to reduce speeds during inclement weather**. When installing a VSL system for weather, many agencies can tie into existing RWIS stations to provide the data needed to determine when the speed limit should be reduced. Implementing VSL during adverse weather conditions can significantly improve safety and, in some cases, traffic efficiency [18].

II.3. SYSTEM DESCRIPTION

To minimize the damage of road accidents, and avoid the inconsistency of current signs with road and weather conditions, we offer an intelligent traffic sign that takes care of all the useful information in order to determine the suitable speed for the safest possible driving. Thanks to this system, the panel becomes intelligent. The concept of intelligence manifests itself in the ability of the panel to communicate with the external environment, equipped with a processing unit, which gives it this intelligence.

This communication is carried out using sensors, which provide it with the various information necessary for the operation of the system. Thus, they require a source of energy provided by solar energy. In this section, we will present the overall architecture of the proposed system, as well as the on-board system that will be installed at the panel level.

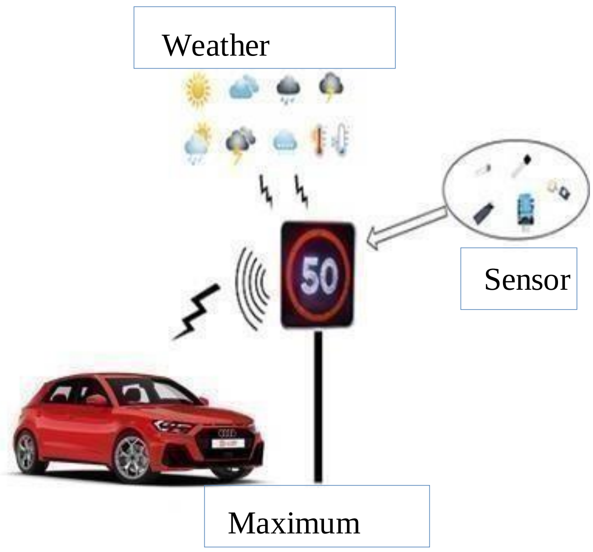


Figure II.5: Overall System diagram.

II.4. SYNOPTIC DIAGRAM OF THE SYSTEM

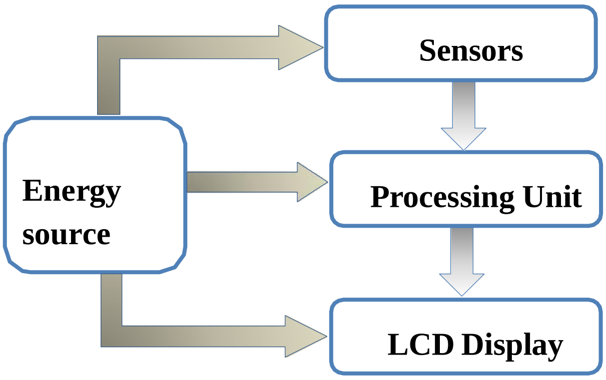


Figure II.6: Synoptic diagram of the on-board system

Sensors: In the broadest definition, a sensor is a device, module, machine, or subsystem whose purpose is to detect events or changes in its environment and send the information to other electronics, frequently a computer processor [19]. In our project, sensors are used to collect information from the outside such as (humidity & temperature sensors, water sensors, and light sensors).

Energy source: A solar panel is used as an energy source; nowadays-solar technologies allow the deployment, at a reduced installation cost, of light signals in isolated sites where this was not possible before.

Processing unit: This unit is the main one. It is used to process the information collected and then perform calculations in order to obtain the maximum speed.

II.5. GENERAL SYSTEM OPERATION

Once we put the sign on the road, it receives information about the weather conditions from various sensors installed on the sign. Via a processing unit the system uses all the data collected so that it can determine the suitable speed, then it will display it in real time on the screen.

II.6. OPERATING MODES

II.6.1. CASE OF RAIN

When it rains, driving can be dangerous so the speed must be reduced, and for safety the smart signs will display a speed appropriate to the variation of the weather. The table II.1 represents speed limitation in case of rain:

Traffic way	*In normal case*	*In case of rain*
On motorways	120 Km/h	100 Km/h
On separate carriageway	100 Km/h	80 Km/h
On ordinary road	80 Km/h	50 Km/h
In built-up areas	50Km/h	30 Km/h

Table II.1: Speed limit in case of rain

II.6.2. CASE OF SNOW

Driving on a snowy road is a perilous exercise. You have to be well prepared, especially by equipping the car correctly. In addition, of that you have to drive slowly. The table II.2 represents the speed limitation in case of snow:

Traffic way	*In normal case*	*In case of snow*
On motorways	120 Km/h	60 Km/h
On separate carriageway	100 Km/h	50 Km/h
On ordinary road	80 Km/h	30 Km/h
In built-up areas	50Km/h	20 Km/h

Table II.2: Speed limitation in case of snow.

II.6.3. CASE OF ICE

It comes from a rain or a mist of super cooled water (that is to say, remaining liquid despite a negative temperature) which freezes on coming into contact with a surface whose temperature is below 0 ° C. Very slippery, the ice transforms the roads into gigantic ice rinks and makes traffic difficult, if not impossible, even at very low speed.

In this case the speed limit is greatly reduced regardless of the type of road displayed on the smart panel is 10 to 20 km/ h at the maximum.

II.6.4. CASE OF A REDUCED VISION

In case of fog, or lack of lighting or whatever that has an effect on the driver vision. The driver should reduce speed to have better braking luck in the event of an obstacle. This is why the smart panel will react automatically and display speed limits. The table II.3 represents the speed limitation in case of lack of vision:

Traffic way	*In normal case*	*In case of snow*
On motorways	120 Km/h	80 Km/h
On separate carriageway	100 Km/h	80 Km/h
On ordinary road	80 Km/h	50 Km/h
In built-up areas	50Km/h	30 Km/h

Table II.3: Speed limitation in case of lack of vision.

II.7. CONCLUSION

Signs that can be changed to alert drivers when traffic congestion is imminent enact VSLS. Sensors along the roadway detect when congestion or weather conditions exceed specified thresholds and automatically reduce the speed limit to slow traffic and postpone the onset of congestion. The system’s goal is to slow traffic uniformly in a way that allows smooth traffic flow and avoids stop-and-go conditions. Depending upon the objectives set for the system, speed limits can be regulatory or advisory. Dynamic message signs (DMS) can also be deployed in conjunction with this system to give drivers travel-time information or explanations. In this chapter, a global architecture of the system has been proposed, with a description of its operation. In the next chapter, we will present the different stages of producing a prototype of the system studied.

CHAPTER III

DESCRIPTION OF THE REALIZED SYSTEM

III.1. INTRODUCTION

In this chapter and after the completion of the system architecture, we will follow a succession of steps in order to realize a prototype that enriches the abstract vision of the system; For that, and in what follows, we will present the hardware and software tools used for the realization of the prototype.

III.2. SHEMATIC DIAGRAM

As it is shown in figure III.1, our system has three sensors that can communicate with the external environment and thanks to the microcontroller, which executes the instructions the system decides the results that will be shown on the LCD display. For the energy source, we have used a solar cell.

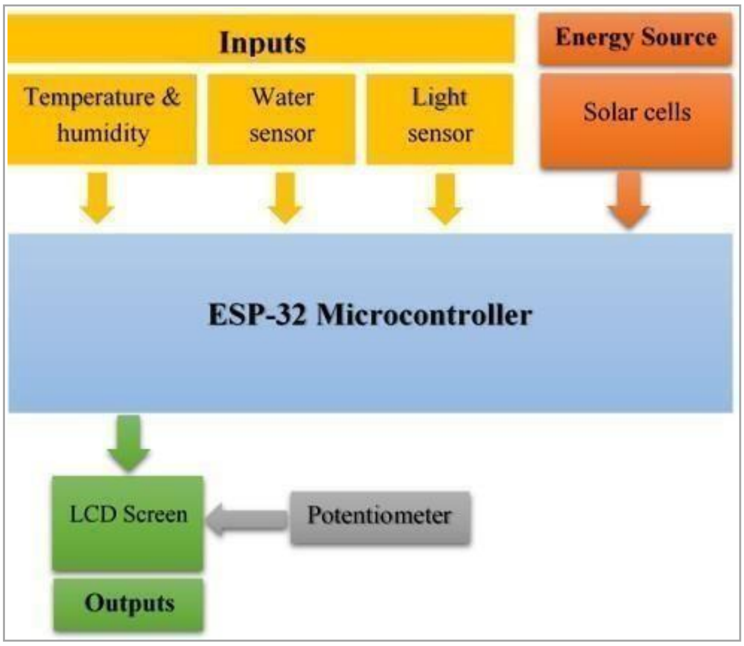


Figure III.1: Project's Diagram.

III.3. MATERIEL WORKING TOOLS

III.3.1. CENTRAL PROCESSING UNIT

The central processing unit contains ESP32 with 39 input/output pins in a series of low-cost low-power system on a chip microcontroller with integrated WI-FI and dual-mode Bluetooth; it is used to communicate with the sensors. The ESP32 series employs a microprocessor in both dual-core and single-core variation and include in-built antenna switches, power amplifier, low noise receiver amplifier, filters and power management modules [20].

Here are the features of the ESP32:

- CPU: Xtensa dual-core (or single-core) 32-bit LX6 microprocessor, operating at 160 or240 MHz.
- Memory: 320 KiB RAM, 448 KiB ROM.
- Wi-Fi: 2.4 GHz (802.11 b/g/n)
- Bluetooth: v4.2 BR/EDR and BLE (shares the radio with Wi-Fi).
- 34 programmable GPIOs.
- UART / I2C / I2S / SPI.
- LED PWM (up to 16 channels).
- Ultra low power analog pre-amplifier.
- Internal low-dropout regulator.
- Wake up from GPIO interrupt, timer, ADC measurements, capacitive touch sensor interrupt [20].

The block diagram below (Figure III.2) shows the main functional blocks presented inside ESP32.

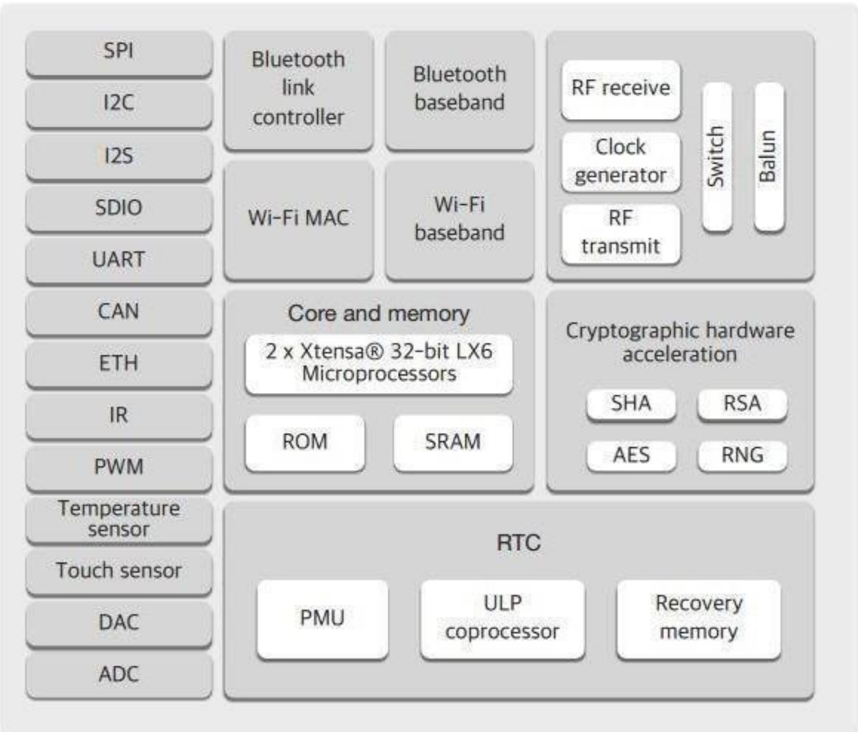


Figure III.2: Functional block diagram ofESP32 [20].

The figure III.3 represents the ESP32's pins. For our project, we have used specific pins of theESP32 that have specific functions, and which are useful for the system.

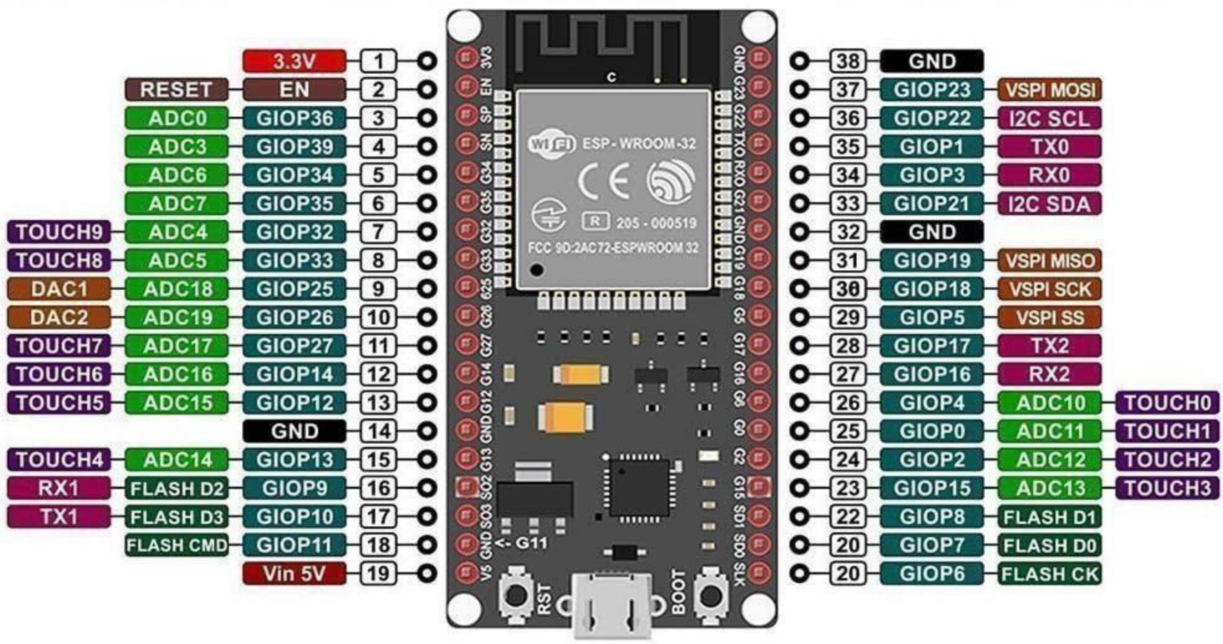
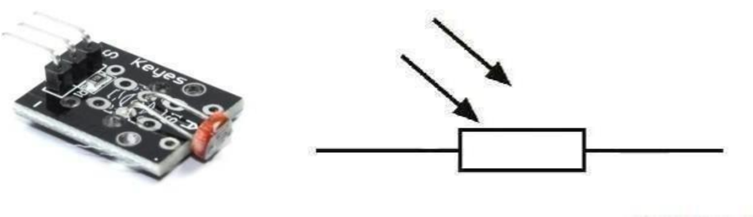


Figure III.3: The ESP32's pins [21].

III.3.2. SENSORS

III.3.2.1. PHOTORESISTOR

The Photoresistor (Figure III.4) is a variable resistor whose resistance varies inversely with the intensity of light. From the relationship between resistivity (ability to resist the flow of electrons) and conductivity (ability to allow the flow of electrons), we know that both are polar opposites of each other. Thus when we say that the resistance decreases when intensity of light increases, it simply implies that the conductance increases with increase in intensity of light falling on the photo-resistor or the LDR, owing to a property called photo-conductivity of the material. Hence these photoresistors are also known as photoconductive cells or just photocell [22].



FigureIII.4: Photoresistor with its symbol [22].

This resistor works on the principle of photoconductivity. When the light falls on its surface, then the material conductivity reduces and the electrons in the valence band of the device are excited to the conduction band. These photons in the incident light must have energy greater than the band gap of the semiconductor material. This makes the electrons to jump from the valence band to conduction [23]. Depending upon the type of semiconductor material used for photoresistor, their resistance range and sensitivity differs. As we can see in the figure III.6 in the absence of light, the photoresistor can have resistance values in mega ohms. And during the presence of light, its resistance can decrease to a few hundred ohms [24].

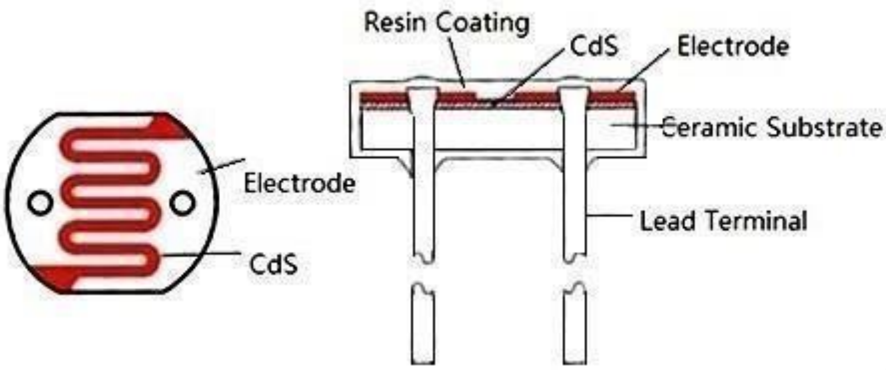


Figure III.5: Photorsistor schematic [25].

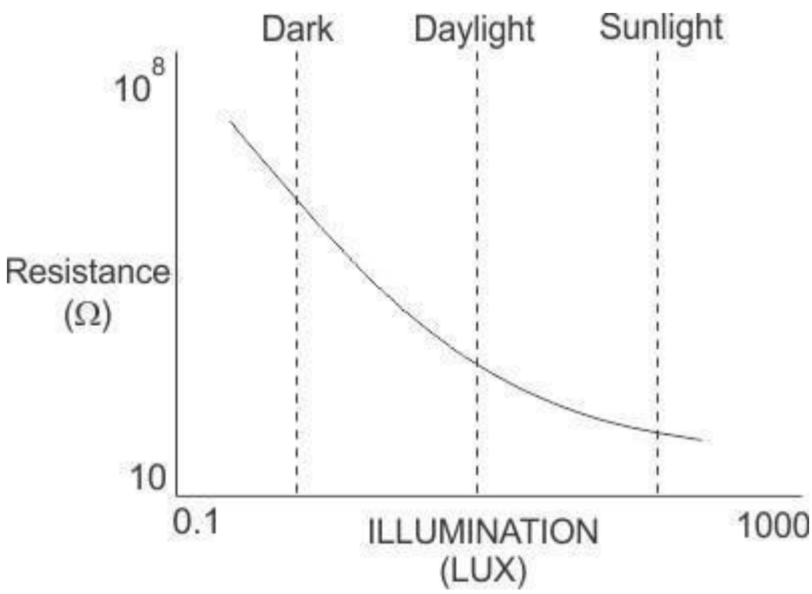


Figure III.6: The resistance vs. illumination curve for a particular **LDR** [26].

The sensitivity of this device varies with the wavelength of light incident on them. Some photocells might not at all response to a certain range of wavelengths. Based on the material used different cells have different spectral response curves. When light is incident on a photocell it usually takes about 8 to 12 ms for the change in resistance to take place, while it takes one or more seconds for the resistance to rise back again to its initial value after removal of light. This phenomenon is called a resistance recovery rate [26].

III.3.2.2. TEMPERATURE &HUMIDITY SENSOR DHT11

The DHT11 sensor (Figure III.5) features a temperature & humidity sensor complex with a calibrated digital signal output. By using the exclusive digital-signal-acquisition technique and temperature & humidity sensing technology, it ensures high reliability and excellent long-term stability. This sensor includes a resistive-type humidity measurement component and an NTC temperature measurement component, and connects to a high performance 8-bit microcontroller, offering excellent quality, fast response, anti-interference ability and cost-effectiveness [27].

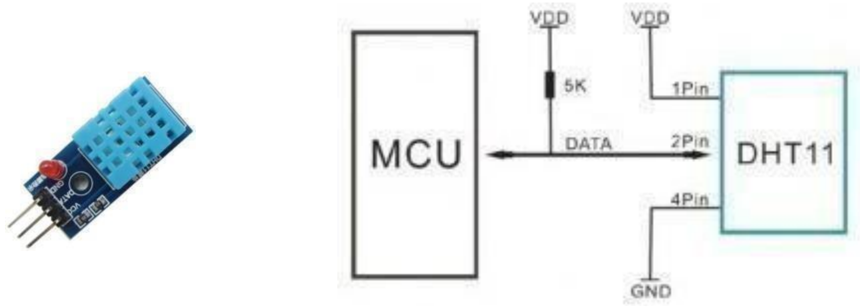


Figure III.7: DHT11 sensor with its pinout diagram [30].

For temperature sensing, DHT11 has an NTC (Negative Temperature Coefficient) temperature sensor(also called a thermistor) mounted on the surface inside the plastic casing, this NTC temperature sensors are variable resistive sensors and their resistance decreases with an increase in the surrounding temperature. Thermistors are designed with sintering of semiconductors materials, such as ceramic or polymers and they provide a large change in resistor with a small change in temperature [28].

- Here's the graph showing the relation between temperature and resistance for the DHT11 sensor:

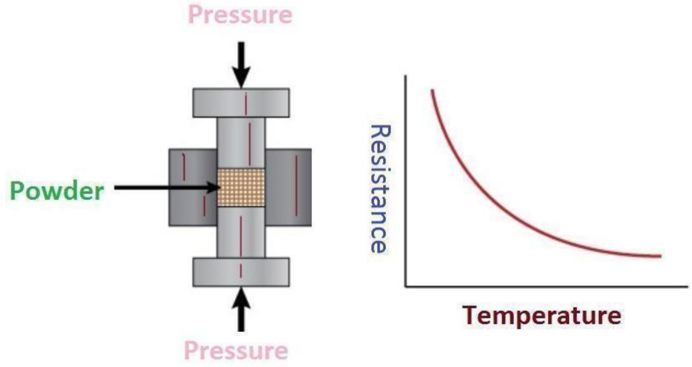


Figure III.8: relation between temperature and resistance for the DHT11 sensor [28].

For Humidity Measurement, it uses a capacitive humidity sensor, which has two electrodes and a substrate material in between. The substrate material is used for holding the moisture on its surface. As moisture content changes in our environment, they are get saturated on the substrate material, which in turn changes the resistance between electrodes. This change in electrode resistivity is then calibrated using the humidity coefficient (saved in OTP memory) and the final relative humidity value is released.

Here's the image showing the internal structure of DHT11 humidity sensor.

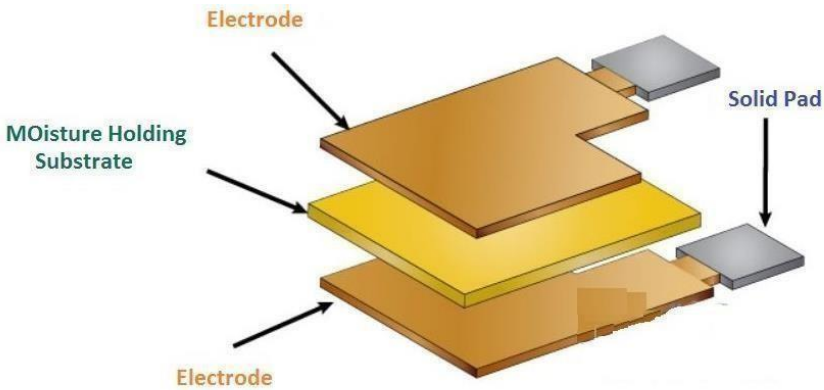


Figure III.9: The internal structure of DHT11 humidity sensor [28].

Here are the technical characteristics of the DHT11 sensor:

- Power supply: 5V.
- Temperature measurement range : 0°Cto 50°C ± 2°C.
- Humidity measurement range: 20-90%RH ±5%RH.
- Measurement period: 2s.
- Dimensions: 12x15.5x5.5mm.

III.3.2.3. WATER SENSOR

Water sensor brick is designed for water detection, which can be widely used in sensing the rainfall, water level, even the liquate leakage. The brick is mainly comprised of three parts: An Electronic brick connector, a 1 MΩ resistor, and several lines of bare conducting wires. The series of exposed parallel conductors, together acts as a variable resistor (just like a potentiometer) whose resistance varies according to the water level. So our system will decide the suitable speed according to the value of the resistance [29].

If It is sunny the resistance will be at the maximum R = 1MΩ, which results a poor conductivity. The state considered is **(sunny),** and the maximum speed will be **80 km/h** on ordinary road; which is the normal case. (Speed will not change).

If It is raining the resistance will decreases R < 1MΩ, which results a good conductivity. The state considered is **(rainfall),** and the maximum speed will be reduced from **80km/h** to **50km/h** on ordinary road.

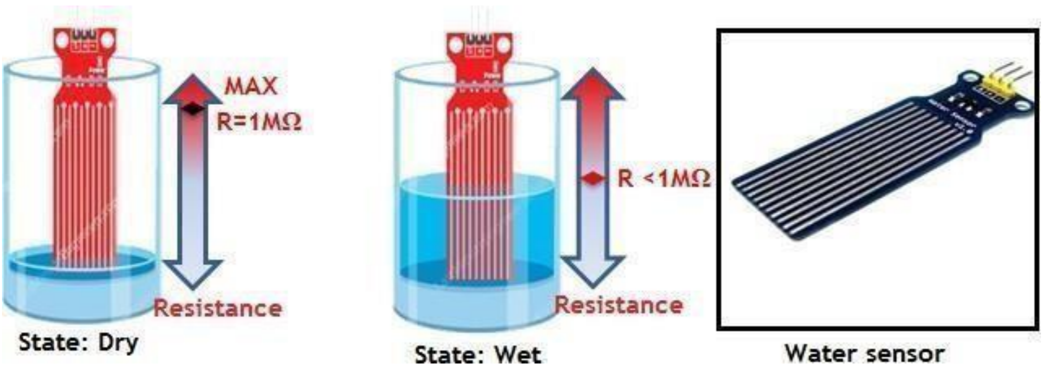


Figure III.10: The variation of the water sensor resistance according to its state [29].

Here are the technical characteristics of the water sensor:

- Working voltage: 5V
- Working Current: <20ma
- Interface: Analog
- Working Temperature: 10°C~30°C

III.3.3. SOLAR PANELS

A solar panel is actually a collection of solar (or photovoltaic) cells , most of them are made up using crystalline silicon solar cells; which can be used to generate electricity through photovoltaic effect. These cells are arranged in a grid-like pattern on the surface of solar panels [30].

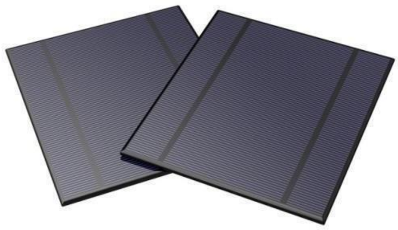


Figure III.11: Solar Panel 5V/2.5W [30].

Solar panels have advantages and disadvantages as listed below:

- **Advantages of using solar panels:** solar power systems derive clean and pure energy from the sun so they have some advantages as:
    - Reduces Electricity Bills.
    - Diverse Applications.
    - Low Maintenance costs.
    - Technology Development.
- **Disadvantages of using solar panels:** although solar panels have many benefits, they also have some disadvantages as:
    - Weather Dependent.
    - Solar Energy Storage is expensive.
    - Uses a lot of space.
    - Associated with pollution [30].

III.3.4. 5V USB OUTPUT BOOST REGULATOR MODULE

Fixed 5V Output Boost Regulator (step-up regulator) module with standard USB Connector accepts input voltage from 0.9V to up to 5V.

Figure III.12: 0.9-5VInput, 5VUSB Output Boost Regulator Module [31].

5V USB Output Boost Regulator Module has special characteristics, which are:

- Input voltage: 0.9V-5V DC.

- PFM Control DC-DC Converter.
- Transfer efficiency: 96%(max).
- With one AA battery power supply output current can be up to 200~300mA.
- Two AA batteries to the output current of 500~600mA.

We can use this regulator for:

- Single Battery Operated Devices.
- Single Cell (AA, AAA Size).
- Small Size Solar Chargers for Cellphones [31].

III.3.5. LCD DISPLAY

A liquid-crystal display (LCD) is a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals combined with polarizers. Liquid crystals do not emit light directly, instead using a backlight or reflector to produce images in color or monochrome. LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images with low information content, which can be displayed or hidden [32].

Figure III.13: LCD Display (16*4) [32].

III.3.6. POTENTIOMETER

The Figure III.14 shows a 1K Potentiometer which is a type of variable resistor with 3 terminals that provides resistance up to 1000 ohm, and it is used to adjust the brightness of the LCD Screen (16*4).

Figure III.14: Potentiometer.

Potentiometers have some basic working principles. A pot has two terminals as input (marked as red and green in the figure III.15). The input voltage is applied across the resistor. Then the output voltage is measured. It comes out as the difference between the fixed and moving contact. The wiper plays a vital role here. While optimizing the output voltage- as per the need, the wiper needs to be moved along the resistive element. Moving the slider helps to balance the galvanometer in case of measuring the emf of a cell. Now it acts as a voltage divider as it continuously produces variable voltage. Based on this concept, a pot measures electrical emf [33].

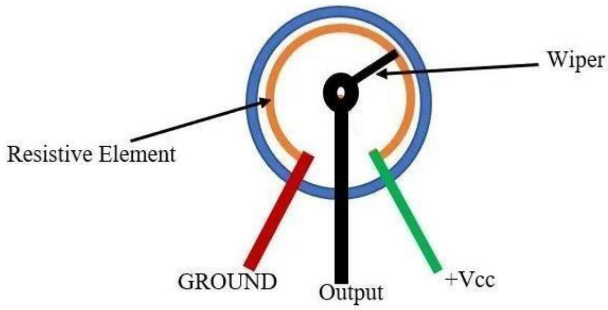


Figure III.15: Basic Structure of a Pot [33].

III.3.7.ZENER DIODE

A Zener diode is a type of rectifying semiconductor diode that is used to regulate voltage in a circuit, working in a reverse-bias mode to avoid failure. That said, Zener diodes also regulate voltage one way (regular) or both ways (bidirectional). It has a wide variety of voltages and, as reverse voltage increases to its breakdown voltage, a current will start to flow through the diode. Because the voltage remains fairly constant across a wide range of power supplies [34].

Since Zener diode can reliably operate in breakdown region, it has two useful nonlinear I-V characteristics curve at both polarities. The current-voltage response of the Zener diode in forward direction is almost identical with the solar panel dark I-V curve. In the reverse-bias configuration, Zener diodes have very high breakdown voltages to allow their usage in solar panel characterization. The Zener diodes used in the system were high power Zener diodes and are commonly used as the voltage regulators in DC current sources [35].

Figure III.15: Zener Diode [35].

III.4 PROGRAMMING THE MICROCONTROLLER

ESP32 can be programmed in several ways that are:

- Using C, with Arduino IDE.
- Using Python, with the firmware MicroPython.
- With the scripts Lua, with the firmware NodeMCU.
- With the firmware Mongoose.

For the programming of our microcontroller, we will use the Arduino development environment because this IDE has several advantages including:

- Free and open-source.
- Multiplatform (Windows, Lunix, or Mac).
- Comprehensive guides and Tutorials are present for users.
- It is easier for users to access their libraries [21].

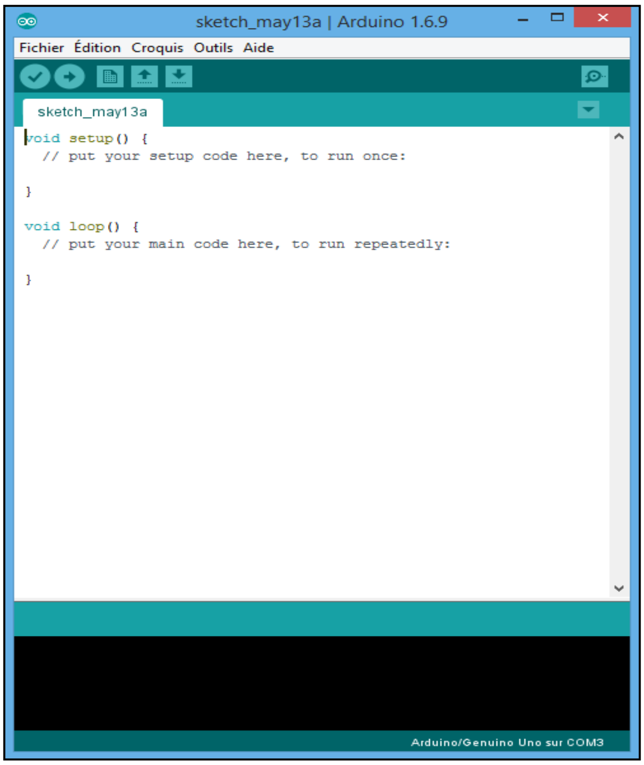


Figure III.17: Arduino IDE.

III.5. CONNECTION OF THE SENSORS AND ESP32

In this section, we describe how sensors are connected with the ESP32 microcontroller and give the wiring diagram circuit of each sensor.

III.5.1 LIGHT SENSOR

The ESP32's analog input pin converts the voltage (between 0 and 3.3V) into integer values (between 0 and 4095), called analog value or ADC value. By connecting an analog input pin of ESP32 to the Photoresistor, we can read the analog value by using analogRead() function.

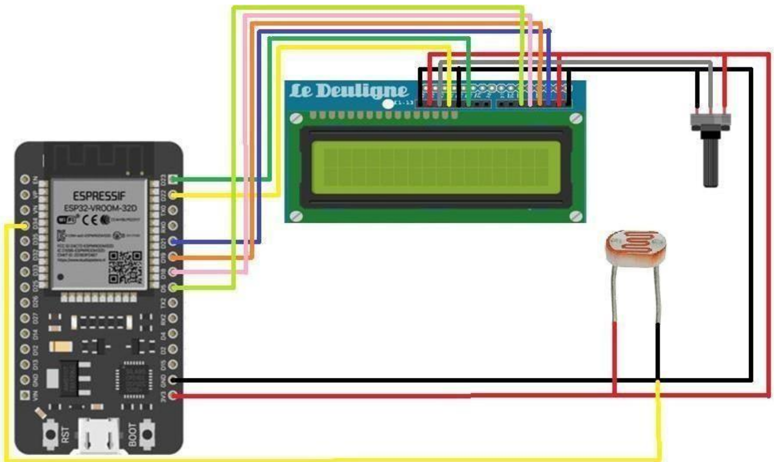


Figure III.18: Wiring Diagram between Light Sensor and ESP32.

III.5.2. TEMPERATURE AND HUMIDITY SENSOR

After connecting an analog input pin of the ESP32 to the Temperature and Humidity Sensor, we need to download a couple of libraries so that ESP32 will properly communicate with DHT11 Sensor. To view the result we used LCD Display to display the temperature values in % for Humidity and degree Celsius for Temperature.

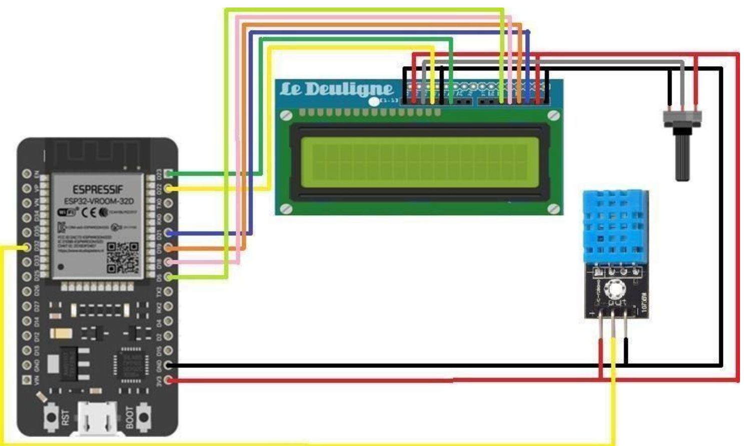


Figure III.19: Wiring Diagram between DHT11 sensor and ESP32.

The following figure shows the screenshot example of the Serial Monitor, which is continuously printing the humidity and temperature reading every 3 seconds.

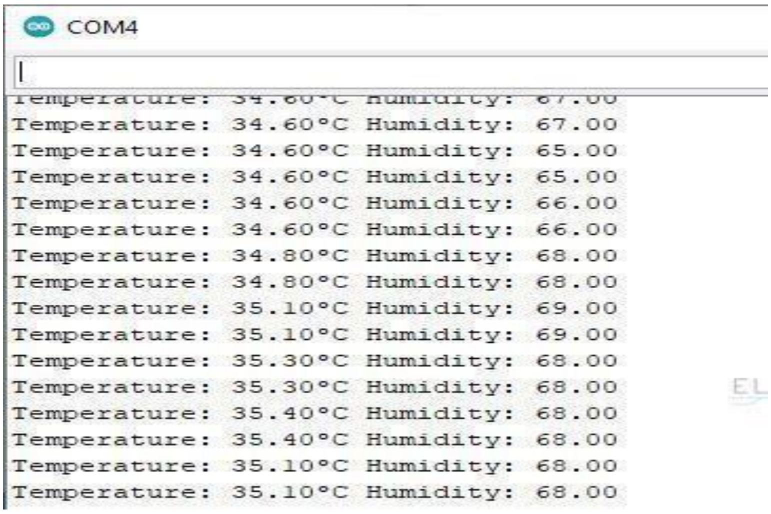


Figure III.20: Continuously printing the humidity and temperature reading every 3 seconds.

III.5.3. WATER SENSOR

To detect the rainfall; we connect the digital input pin of the ESP32 to the S pin of the Water Sensor and we can provide power to the water sensor by connecting the sensor's VCC and GND pins to ESP32's 3.3V and GND pins, respectively.

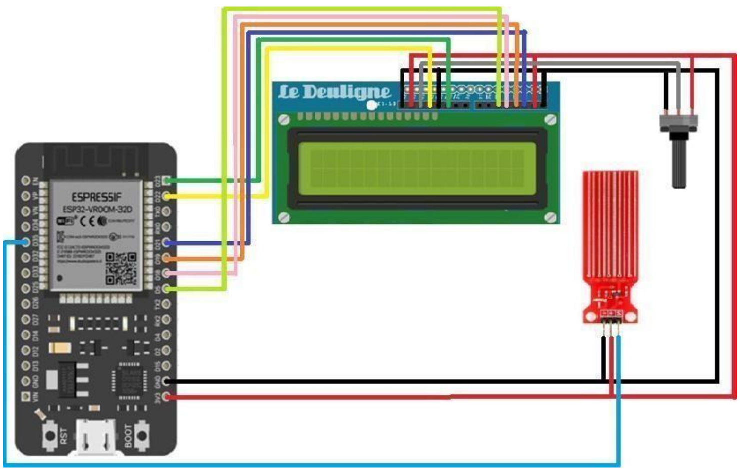


Figure III.21: Wiring Diagram between water sensor and ESP32.

III.6. CONCLUSION

In this chapter, we have presented in details the different tools used in order to construct our prototype, and the wiring diagram between the sensors and the Microcontroller. In the next chapter, we will see the final step of the realization of the complete system.

CHAPTER IV
REALIZATION AND TEST

IV.1. INTRODUCTION

In this chapter, we present firstly, the different steps of the construction of the prototype, from the assembly of the structure to the placement of the sensors and actuators as well as the control board and the power supply .and at the end it will pass through several test to ensure its functionality.

IV.2. WIRING DIAGRAM OF THE CIRCUIT

Figure IV.1 shows the test board view of the project. The colored lines are connecting wires between ESP32 and the other components. Red and black wires are connected to the 3.3V pin and GND pin of the ESP32, respectively.

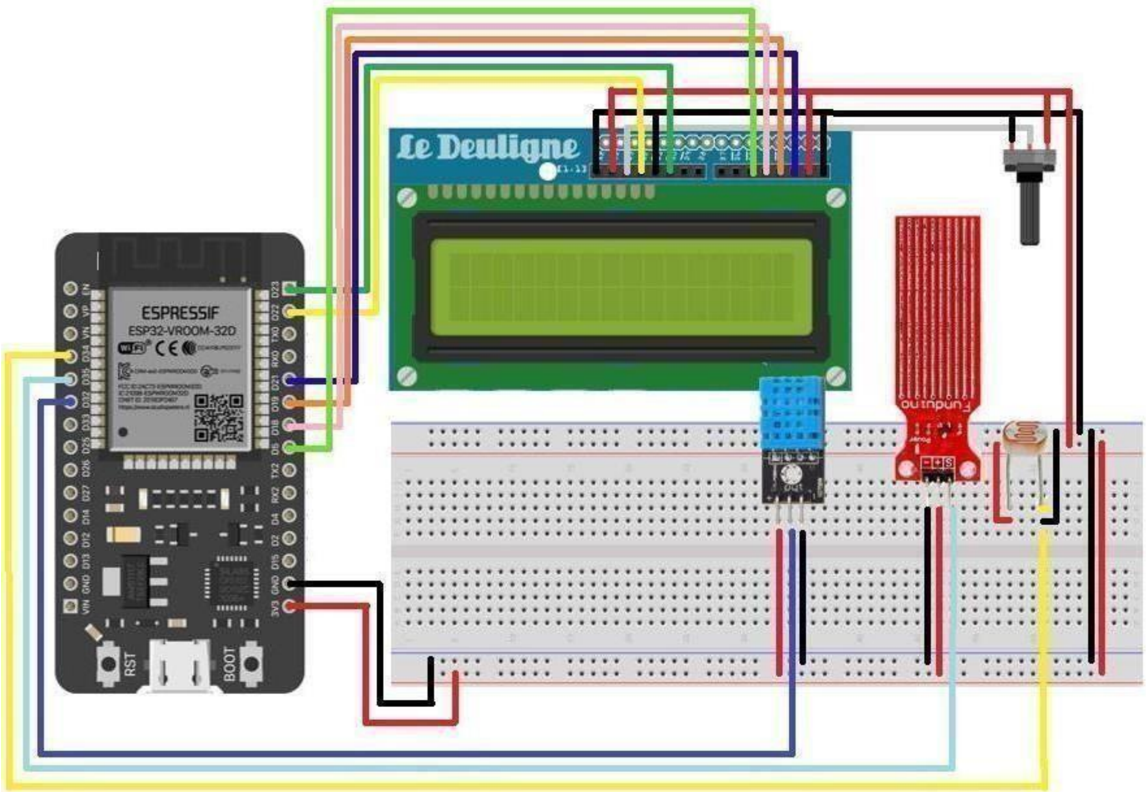


Figure IV.1: Global Diagram of the system.

First, we fixed the components, in order to reveal the various problems that can confront us such as: compatibility problems, programming problems. The result is that the components of our system are in good interaction and our system meets our expectations.

IV.3. REALIZATION OF THE PROJECT

The following part contains the flowchart of the main program and some extracts of the code that we have used to command and operate our project, and captures showing the realized prototype.

IV.3.1. Flowchart

Figure IV.2 shows the flowchart of the main program of the control board.

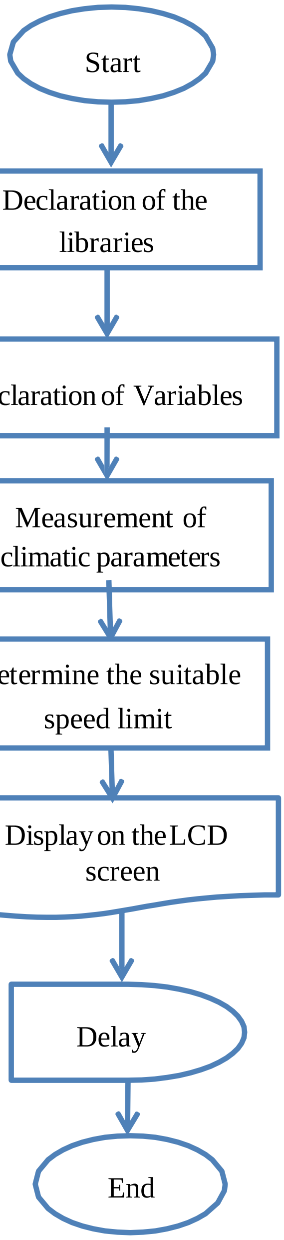


Figure IV.2: Flowchart of the main program.

IV.3.2. Code explanation

To command and operate our project we have written a main program, we have started first by demonstrating the libraries used for the sensors like:

#include <Adafruit_Sensor.h>

#include <DHT.h>

#include <DHT_U.h>

And #include <LiquidCrystal.h> library used for displaying the results in the LCD Screen.

Also we have used several variables and constants during development which are:

int ldrval = 0; // holds the value for LDR.

int ldrpin = 34; // sensor pin used for LDR.

int resval = 0; // holds the value for water.

int respin = 35; // sensor pin used for water.

As well, the various instructions are included in the setup ( ) method, which are initializations of objects already created. The setup method is used to execute the code only once. Our system must always be functional, and interact well with the external environment. In this perspective, we have used the Loop() method. This method is used to execute the code several times.

For the Temperature and Humidity measurement we have written a simple code to transform the measured results result into an integer number in degree Celsius using int t= dht.readTemperature() and int h= dht.readHumidity(), and it will be printed in the LCD Display using simple methods which are: lcd.setCursor(), and lcd.print(). then, for the of a water sensor, ESP32 reads data from analog pin using analogRead() method and store it to "resval" variable declared earlier and check if there is a voltage input to display that there is rain, otherwise it will display it is sunny(sun) using the previous printing methods. Same thing for the photoresistance; The ESP32 will read data from analog pin using analogRead() method and store it to "ldrval" variable; if there is too much light, it sends values higher than 1000 which means that it is day and it will be displayed on the LCD Display.Otherwise, it will be display "night".

IV.3.3. PROTOTYPE

First, we have started by placing the ESP32 onto the breadboard, and then we have connected the VCC pins of the three sensors to the 3.3V pin of the ESP32 and grounds to ground. Our system contains three sensors connected with ESP32 as follow:

- For the DHT11 sensor, we have connected its data pin to the 32 analog pin of the microcontroller.
- For the Light sensor, we have connected its data pin to the 34 analog pin of ESP32.
- For the Water sensor, we have connected its data pin to the 35 analog pin of ESP32.

All the data collected will be displayed on the LCD Display, which is connected to ESP32 using 12 wires from 16 pins on the LCD Display. The VCC pin of the LCD Display is connected to the VIN pin of the microcontroller while we can get 5V.as well we have added a 1K potentiometer, which is used to adjust the contrast of the LCD Display.

We have connected the project's components as it is shown in the figure below:

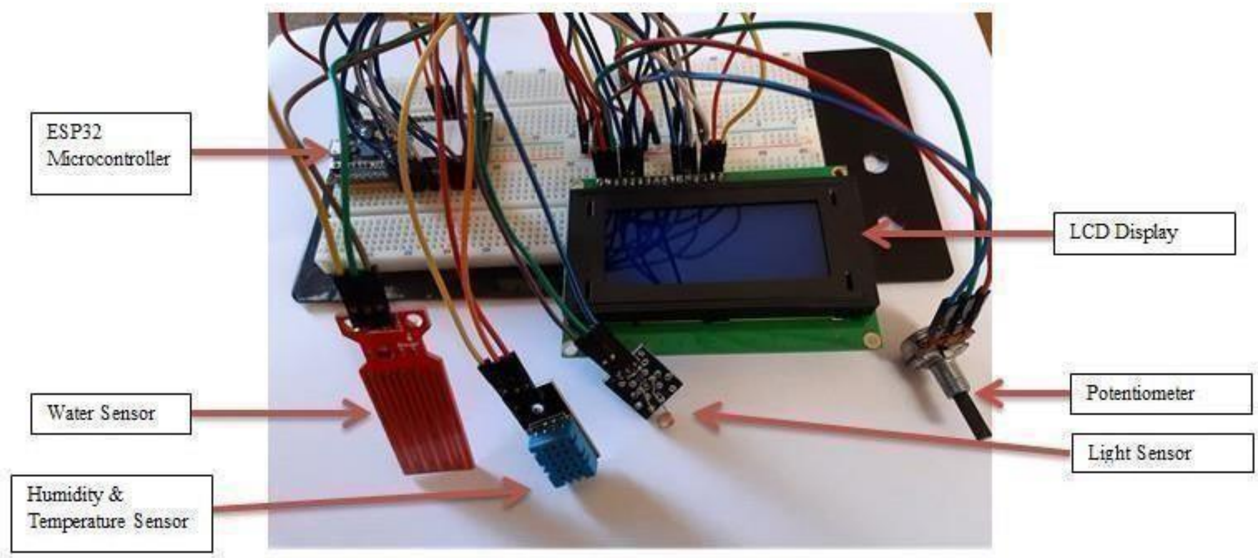


Figure IV.3: Front view of the prototype.

The figure IV.3 above illustrates the physical assembly of our system, with precision of the electronic components and their connections.

For the power system circuit, we held the independence of our project from the high consumption of energy. That is why we had equipped it with a power system that will get the amount of energy needed from the sun using a solar cell to supply our microcontroller. ESP32 has a USB interface for Lipo charging/program that needs a DC power of 5V. This was the reason for choosing a solar cell that produces 5V of energy, but as it is not efficient at 100%, we have preferred to store energy in a constructed lithium battery of 9V to be sure to get the desired voltage at the USB interface of the ESP32 controller. For the total insurance of getting that 5V, we have used a boost regulator module that outputs 5V for our controller. Moreover, as a protection to our system, we have used a Zener diode between the battery and the cell, thus the cell will not be damaged. The figure IV.4 shows the circuit of the power system used to power the controller with its source (Solar cells).

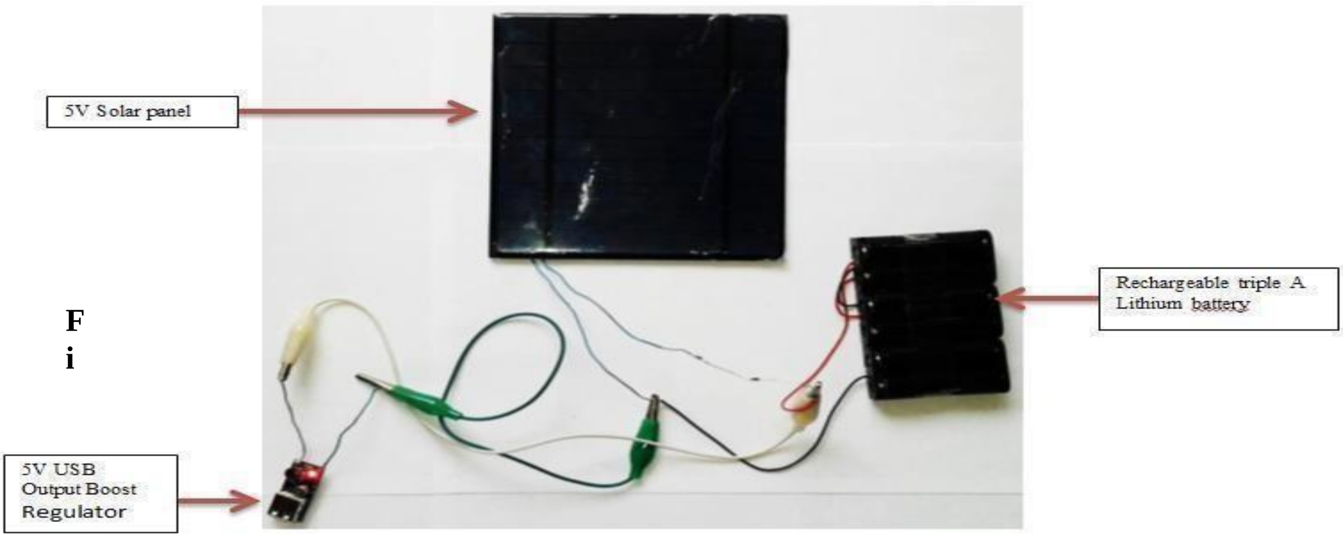


Figure IV.4: Small powering system

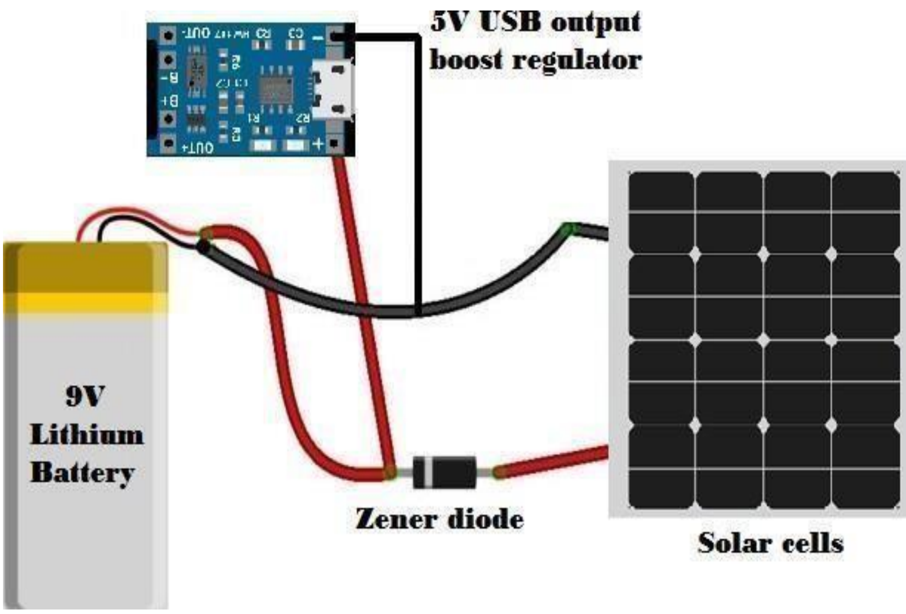


Figure IV.5: Small Powering system Diagram.

IV.4. TESTING

To test its functionality, we have tested our prototype in different cases. The figure IV.6 shows the case panel “Sunny day” with the temperature of 26 °C and a maximum speed of 80Km/h that the driver should not exceed.

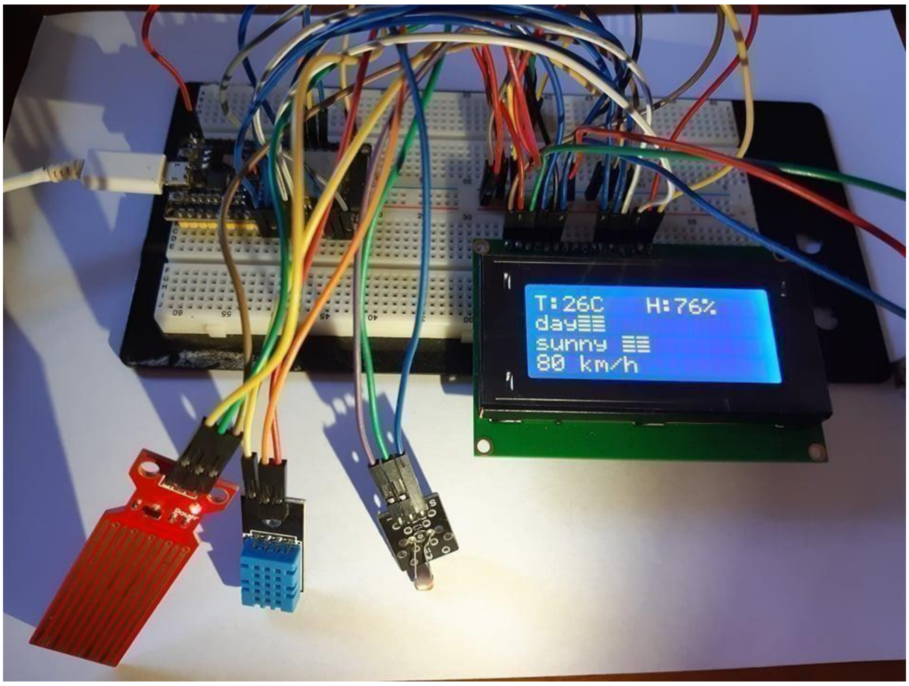


Figure IV.6: Panel “Sunny day case”.

Figure IV.7 shows the panel in the day and rain case, the maximum speed reduced to 50Km/h because of the rain.

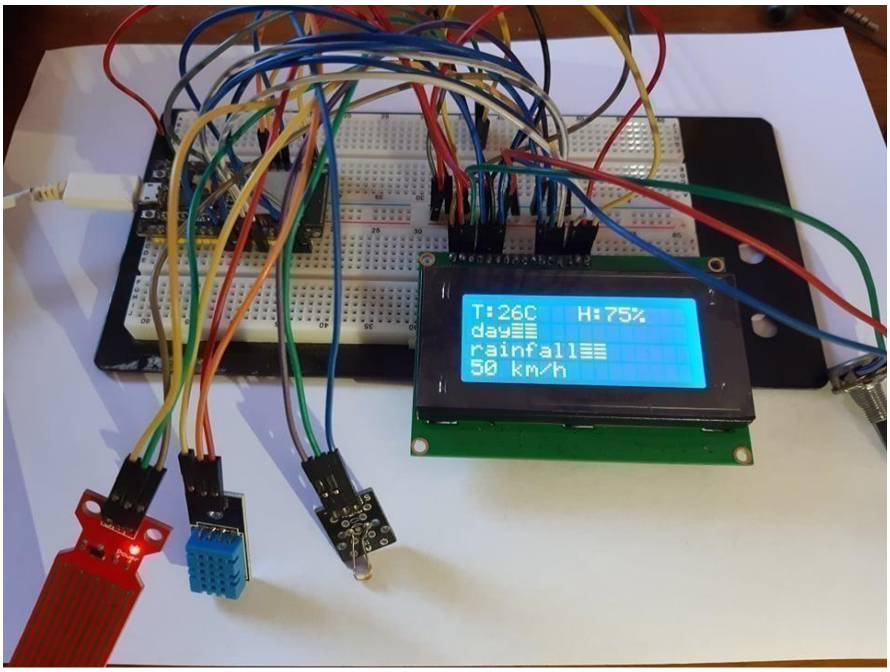


Figure IV.7: Panel in the case of rainy day.

IV.5. CONCLUSION

Throughout this Chapter, we have demonstrated the different stages of the realization of our system starting from wiring all the components demonstrated in the previous Chapter (Microcontroller, Sensors, LCD display…), then writing the program used to command and operate our prototype. After the completion of the realization of our system, it worked perfectly by passing through several tests.

CONCLUSION

In this report, a new field called “ITS” has been introduced. This work involves the followingsteps where road transport system and road safety have been improved:

- Definition of ITS and their different types, as well their contribution of solving most theroad safety problems.
- Presentation of a renewable energy technology, which is the solar one, and its usewith VMS.
- Introduction of our system “VSLS” which has a big role in traffic safety, as well as description of its types and benefits.

All the above data have been used to build up our new system, which is an intelligent traffic sign that takes care of all the useful information necessary for the operation of the system. Furthermore, a realized prototype has been set up to confirm experimentally our theory using different components like Microcontroller, Sensors and LCD Display… etc. All controlled bya specific written program.

In this context, the final prototype is an intelligent speed limit panel powered by solar energy; which can determine the weather conditions due to the various sensors installed. Then it uses all the data collected via the processing unit so that it can determine the suitable speed for the safest possible driving. After that, it will display it in real time on the screen.

In our future research, we intend to concentrate on harmonizing the traffic flow and reducing exhaust emissions by proposing a cooperative VSL system as an extension of an existing VSL system. In the proposed system, communication between the infrastructure and the vehicles is used to transmit VSL to upstream vehicles before the VMS become visible to the drivers. The system is evaluated by the means of microscopic traffic simulation. Traffic efficiency and environmental effects are considered in the analysis.

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