Sudan University of Science and Technology

College of Engineering

School of Electrical and Nuclear Engineering

Electronic Warfare Helmet

الخوذة الحربية الإلكترونية

A Project Submitted in Partial Fulfillment for the Requirements of the Degree of B.Sc. (Honor) In Electrical Engineering.

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الآية

قال تعالى :

(وَأَعِدُّوا لَهُم مَّا اسْتَطَعْتُم مِّن قُوَّةٍ وَمِن رِّبَاطِ الْخَيْلِ تُرْهِبُونَ بِهِ عَدُوَّ اللَّهِ وَعَدُوَّكُمْ وَآخَرِينَ مِن دُونِهِمْ لَا تَعْلَمُونَهُمُ اللَّهُ يَعْلَمُهُمْ ۚ وَمَا تُنفِقُوا مِن شَيْءٍ فِي سَبِيلِ اللَّهِ يُوَفَّ إِلَيْكُمْ وَأَنتُمْ لَا تُظْلَمُونَ)

[الأنفال:60]

DEDICATION

Every challenges and difficulties we face in life cannot be overcame only by diligence and determination. It also needs prayers, guidance and cheering from those who we love and care about therefore, it is our honor to dedicate this humble work to our parents who have been the source of our strength throughout the years , to our brothers, our sisters and our friends who always supported us and to all those who kept praying for us continuously until we reached this success. Without their motivation this project would have never came to life.

ACKNOWLEDGEMENT

We would like to take this opportunity to express our deep appreciation to our supervisor **Dr. Awadallah Taifour Ali** for his absolute and continues support throughout this project. Without him having faith on us during the process this project might never been completed.

ABSTRACT

Soldiers limited capabilities in conflict zones have been a point of concern for several years especially for countries with small armies. Soldiers not being able to adapt to all tough conditions may unfortunately lead to losing their lives when it can be saved. Therefore, an electronic system was created to increase soldier's overall efficiency and to monitor their present conditions. The electronic warfare helmet is an electrically operated helmet that provides soldiers with advanced features that increases their chances of survival and their performance during action. In this study the electronic warfare helmet consists of a thermal imaging camera that provides seeing capabilities for the surrounding environment according to objects temperature in it , the thermal images are displayed in a small display attached to the helmet .A night vision camera used for surveillance is attached to the helmet to give the military base informations about what is going on in the warzone during night and day. The soldier's conditions are monitored using a heartrate sensor to detect his heart pulses for different health conditions, a gas sensor to indicate the existence of hazardous gases in the surrounding area and a GPS system that provides the military base with the solider current location at all circumstances.

مستخلص

لقد كانت القدرات المحدودة للجنود في مناطق الصراع مصدر قلق لعدة سنوات خصوصا للبلدان ذات الجيوش الصغيرة. عدم قدرة الجنود على التكيف مع جميع الظروف الصعبة قد تؤدي إلى فقدان حياتهم عند وجود إمكانية لإنقاذها. لذلك ، تم بناء نظام إلكتروني لزيادة الكفاءة العامة للجندي ومراقبة ظروفه الحالية. الخوذة الحربية الإلكترونية هي خوذة تعمل بالكهرباء تزود الجنود بميزات متقدمة تزيد من فرصهم في البقاء على قيد الحياة وأدائهم أثناء العمل. في هذه الدراسة تتكون الخوذة الحربية الإلكترونية من كاميرا تصوير حراري توفر إمكانيات رؤية للبيئة المحيطة حسب درجة حرارة الأجسام المتواجدة فيها ، ويتم عرض الصور الحرارية في شاشة عرض صغيرة متصلة بالخوذة ، كما تم إرفاق كاميرا للرؤية الليلية بالخوذة تستخدم للمراقبة لإعطاء القاعدة العسكرية معلومات عن ما يجري في منطقة الحرب أثناء الليل والنهار. تتم مراقبة ظروف الجندي باستخدام حساس معدل ضربات القلب للكشف عن نبضات قلبه في اللظروف الصحية المختلفة ، وحساس استشعار الغاز للإشارة إلى وجود غازات خطرة في المنطقة المحيطة ونظام تحديد الموقع الذي يوفر للقاعدة العسكرية موقع الجندي الحالي في جميع الظروف.

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LIST OF ABBREVIATIONS

EWH	Electronic Warfare Helmet
GPS	Global Positioning System
IT	Information Technology
ACH	Advance Combat Helmet
US	United States
SVSC	Soldier Vision System Components
PC	Personal Computer
ROM	Read Only Memory
EPROM	Erasable Programable Read Only Memory
RAM	Random Access Memory
RX (RXD)	Receiver
TX (TXD)	Transmitter
LED	Light Emitting Diode
LCD	Liquid Crystal Display
ITU	International Telecommunications Union
EHF	Extremely High Frequency
SHF	Super High Frequency
UHF	Ultra-High Frequency
VHF	Very High Frequency
HF	High Frequency
MF	Medium Frequency
LF	Low Frequency
VLF	Very Low Frequency
WLAN	Wireless Local Area Network
TV	Television

LMR	Land Mobile Radio
CB	Citizens Band
RF	Radio Frequency
AM	Amplitude modulation
FM	Frequency Modulation
PM	Phase Modulation
ADC (A/D)	Analog to Digital Converter
DAC (D/C)	Digital to Analog Converter
ASK	Amplitude Shift Keying
FSK	Frequency Shift Keying
PSK	Phase Shift Keying
LNA	Low Noise Amplifier
FHSS	Frequency-Hopping Spread-Spectrum
GSM	Global System for Mobile Communication
3G	Third Generation
4G	Fourth Generation
5G	Fifth Generation
RFID	Radio Frequency Identification
PANs	Personal Area Networks
IR	Infrared
VIS	Visible Light
UV	Ultra Violet
EM	Electromagnetic Wave
CRT	Cathode Ray Tube
NIR	Near Infrared
BPM	Beats Per Minutes
PPG	Photoplethysmography

TFT	Thin Film Transistor
IDE	Integrated Development Environment
USB	Universal Serial Bus
LABVIEW	Laboratory Virtual Instrument Engineering Workbench
AVR	Automatic Voltage Regulator
EEPROM	Electrical Erasable Programmable Read Only Memory
SRAM	Static Random Access Memory
PWM	Pulse Width Modulation
CO2	Carbon Dioxide
SnO2	Stannic Oxide
AC	Alternating Current
DC	Direct Current
LDR	Light Decreasing Resistance
GND	Ground
CLK	Clock
SPP	Serial Port Protocol
TTL	Transistor-Transistor Logic
UART	Universal Asynchronous Receiver Transmitter
SD	Secure Digital
EDR	Enhanced Data Rate
RST	Reset
NC	No Connection
NMEA	National Marine Electronics Association
$GPGLL	Geographic Longitude and Latitude

LIST OF SYMBOLS

c	Speed of light, m/sec
λ	Wave length, m
ν	Frequency, hertz
N	Period time, sec
E (λ, T)	Emitted Radiation, Watt/m^2
π	Constant pi
h	Planck's constant, $6.626x10^{-34}$ J-s
k_B	Boltzmann's constant, 1.3806 X 10^{-23} J/K
T	Temperature, C^O
V_{out}	sensor output voltage, V
ADC	Analog reading of the sensor
V_c	Controller voltage, V

CHAPTER ONE

INTRODUCTION

1.1 General Concepts

Electronic Warfare Helmet (EWH) is an advanced low-cost device that can provide a solution to many military problems by enhancing soldier's efficiency and survivability in different military operations. The idea is to have multiple applications attached in one cheap advanced helmet. A normal helmet, fire-retardant gloves, body armor and M16 weapon cost about 570, 165, 1500 and 6275 dollars respectively, which is about 9000 dollars per soldier. Many soldiers died because of lack of vision at night, enemy attacks from behind or being lost without communication which is a waste of precious human lives and resources.

EWH will provide a solution to these problems, it is easy to use and relatively low in cost compared to other equipments. It enhances soldiers vision and their sense for risks which they cannot see such as attacks from behind. It replaces other equipment which reduces the overall load weight on the soldier. These features will help soldiers be more accurate, effective and versatile which will increase their chances of living.

Helmets have been invested on thousands of years ago for only head protection purposes, then it had evolved until it took its final shape, which is the most useful and flexible through the years, there is a lot of unexploited spaces that can be exploited for putting useful small devices in modern military helmets without affecting its main function.

1.2 Problem Statement

The problems are classified into soldiers performance problem which includes Limited vision because of natural obstacles and lack of vision at low light conditions, and soldier monitoring problem which includes Loss of communications between soldiers and the military base at war conditions and high-cost of these communication systems, inability to know the health status of the soldier continuously and the military base’s inability to determine the accurate location of each soldier .

1.3 Objectives

The main aims of this study are to:

- Build an advance military helmet.
- Design a multiple vision system.
- Design a low-cost communication system for each soldier.
- Design a health statue monitoring system.
- Design an accurate positioning system for each soldier.

1.4 Methodology

- Study all of previous studies
- Drawing the block diagram.
- Drawing the wire diagram.
- Use of Arduino as main system controller.
- Arduino code is written using ArduinoC language to interface multiple parts and control the Helmet system.

1.5 Project Layout

This project consists of five chapters: Chapter One gives an introduction about the principles, reasons, motivation and objectives of the study. Chapter Two discusses the literature review of control systems, Thermal and Night vision, microcontroller and Embedded Systems, Global positioning system, Surveillance and target acquisition and Communication Systems. Chapter Three describes the control circuit, software and hardware considerations including modules review and description. Chapter Four shows the system implementation and the experimental results. Finally, Chapter Five provides the conclusion and recommendations.

CHAPTER TWO

THEORETICAL BACKGROUND AND LITERATURE REVIEW

2.1 Introduction

Information about own and enemy forces, terrain, intentions of the adversary and so on had always been an important ingredient of national security and for successful conduct of war. However, the means of gaining information, methods of processing and media of transmission were not as effective as they are today. This dramatic advancement in the field of information technology (IT) in general has opened the way to a whole range of new weapon systems and military doctrines. Information superiority both during peace and war has become key to assured security and victory. While the developed world has made impressive progress in the field, the developing world is still struggling to bridge the gap in the face of growing demand for alleviating painful human misery of their masses [1].

2.1.1 Surveillance and target acquisition

Surveillance involves continuous and systematic watch over the battlefield to provide timely information for combat intelligence. This information in fact is raw data. This data needs to be converted into information by the process of target acquisition, which involves detection, recognition, identification and location in sufficient details to permit effective deployment of weapons. The various sub-systems of target acquisition involve various processes and technologies. Detection is the process that discovers the presence. This is the most elementary task for the sensor. Recognition involves classification into types like soldiers, tanks, guns and so on. Identification involves a comparatively difficult task of establishing the object as hostile or friendly. This process is the most vital and difficult to perform in the combat zone [1].

2.1.2 Military helmets

Combat helmets have been used for centuries to protect soldiers in battlefields. Such helmets have evolved from the first generation made of steel to the current generation made of composites. The ACH, the currently serving helmet in the US Army, is made from Kevlar K129 fibers bonded with a phenolic resin matrix which has less weight, now days helmets can provide more than head protection [2].

For some years, the US Army had the benefit of equipping their ground soldiers with advanced electronic systems including global positioning system (GPS), sensors, radio and a hands-free display to provide real-time, enhanced situational awareness in different situations using only the head gear of the soldier (helmet). All these components add weight to the soldier’s head, therefore different approaches have been made for integrating these devices into the helmet with the protection. This makes fewer compromises while reducing weight [3].

The Integrated Headgear system is relying heavily on key technologies being developed under the Soldier Vision System Components (SVSC) program, which aims to provide key technologies to helmet-mounted sensor and display programs which includes helmet-mounted infrared camera, night vision system and a high-resolution colorful display [3].

2.2 Control System

Control systems are an integral part of modern society. Numerous applications are all around us: The rockets fire, and the space shuttle lifts off to earth orbit; in splashing cooling water, a metallic part is automatically machined; a self-guided vehicle delivering material to workstations in an aerospace assembly plant glide along the floor seeking its destination. These are just a few examples of the automatically controlled systems that we can create. We are not the only creators of automatically controlled systems; these systems also exist in nature. Within our own bodies are numerous control systems, such as the pancreas, which regulates our blood sugar. In time of ‘‘fight or flight,’’ our adrenaline increases along with our heart rate, causing more oxygen to be delivered to our cells. Our eyes follow a moving object to keep it in view; our hands grasp the object and place it precisely at a predetermined location. Even the nonphysical world appears to be automatically regulated. Models have been suggested showing automatic control of student performance. The input to the model is the student's available study time, and the output is the grade. The model can be used to predict the time required for the grade to rise if a sudden increase in study time is available. Using this model, you can determine whether increased study is worth the effort during the last week of the term [4].

Automatic control is an important and integral part of space-vehicle systems, robotic systems, modern manufacturing systems, and any industrial operations involving control of temperature, pressure, humidity, flow, etc. It is desirable that most engineers and scientists are familiar with theory and practice of automatic control.

2.2.1 Control system definition

control system consists of subsystems and processes (or plants) assembled for the purpose of obtaining a desired output with desired performance, given a specified input. Figure 2.1 shows a control system in its simplest form, where the input represents a desired output [4].

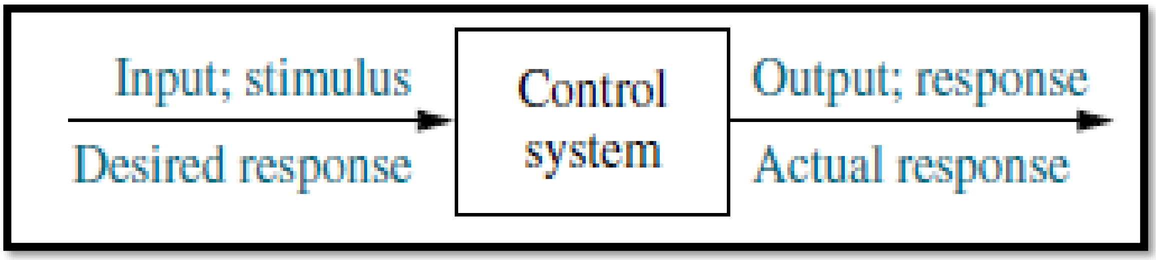


Figure 2.1: Simplified description of control system

2.2.2 Advantages of control system

With control systems we can move large equipment with precision that would otherwise be impossible. Huge antennas can be pointed toward the farthest reaches of the universe to pick up faint radio signal controlling these antennas by hand would be impossible. Because of control systems, elevators carry us quickly to our destination, automatically stopping at the right floor. The power could not require for the load and the speed, motors provide the power and control systems regulate the position and speed [4].

Control systems were built for four primary reasons:

i. Power amplification.

ii. Remote control.

iii. Convenience of input form.

iv. Compensation for disturbances.

2.2.3 Open loop control system

Those systems in which the output has no effect on the control action are called open-loop control systems as shown in Figure 2.2. In other words, in an open-loop control system the output is neither measured nor fed back for comparison with the input. One practical example is a washing machine. Soaking, washing, and rinsing in the washer operate on a time basis. The machine does not measure the output signal, that is, the cleanliness of the clothes [5].

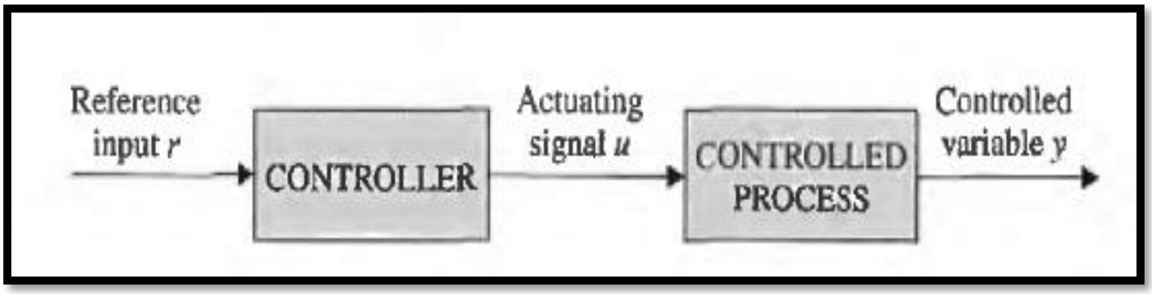


Figure 2.2: Open loop control system

2.2.4 Closed-loop control system

A system that maintains a prescribed relationship between the output and the reference input by comparing them and using the difference as a means of control is called a closed-loop control system as shown in Figure 2.3. An example would be a room temperature control system. By measuring the actual room temperature and comparing it with the reference temperature, the thermostat turns the heating or cooling equipment ON or OFF in such a way as to ensure that the room temperature remains at a comfortable level regardless of outside conditions [5].

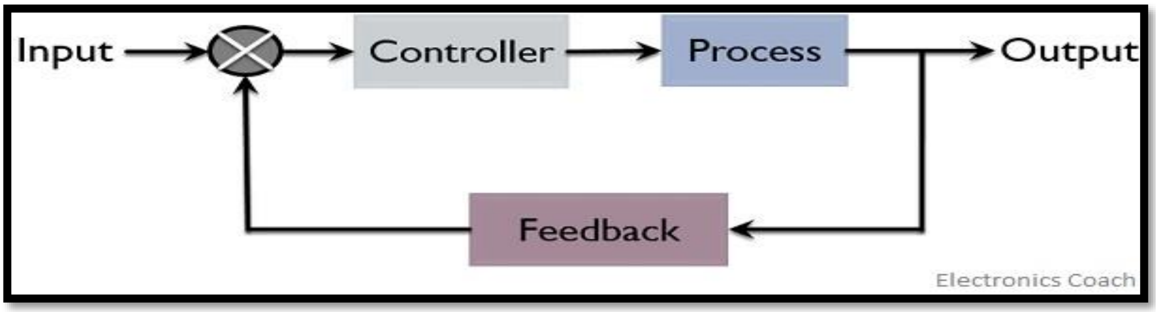


Figure 2.3: Closed-loop control system

2.3 Embedded Systems

Whenever the word microprocessor is mentioned, it conjures up a picture of a desktop or laptop PC running an application such as a word processor or a spreadsheet. While this is a popular application for microprocessors, it is not the only one and the fact is most people use them indirectly in common objects and appliances without realizing it. Without the microprocessor, these products would not be as sophisticated or cheap as they are today. The embedding of microprocessors into equipment and consumer appliances started before the appearance of the PC and consumes the majority of microprocessors that are made today. In this way, embedded microprocessors are more deeply ingrained into everyday life than any other electronic circuit that is made. A large car may have over 50 microprocessors controlling functions such as the engine through engine management systems, brakes with electronic anti-lock brakes, transmission with traction control and electronically controlled gearboxes, safety with airbag systems, electric windows, air-conditioning and so on. With a well-equipped car, nearly every aspect has some form of electronic control associated with it and thus a need for a microprocessor within an embedded system. A washing machine may have a microcontroller that contains the different washing programs, provides the power control for the various motors and pumps and even controls the display that tells you how the wash cycles are proceeding [6].

An embedded system is a microprocessor-based system that is built to control a function or range of functions and is not designed to be programmed by the end user in the same way that a PC is. An embedded system is designed to perform one particular task albeit with choices and different options [6].

2.3.1 Embedded systems evolution

- **Replacement for discrete logic-based circuits**
  The microprocessor came about almost by accident as a programmable replacement for calculator chips in the 1970s. Up to this point, most control systems using digital logic were implemented using individual logic integrated circuits to create the design and as more functionality became available, the number of chips was reduced.

- **Provide functional upgrades**

  With much of the system's functionality encapsulated in the software that runs in the system, it is possible to change and upgrade systems by changing the software while keeping the hardware the same.
- **Provide easy maintenance upgrades**

  The same mechanism that allows new functionality to be added through reprogramming is also beneficial in allowing bugs to be solved through changing software. Again, it can reduce the need for expensive repairs and modifications to the hardware.
- **Improves mechanical performance**

  For any electromechanical system, the ability to offer a finer degree of control is important. It can prevent excessive mechanical wear, better control and diagnostics and, in some cases, actually compensate for mechanical wear and tear.

2.3.2 Embedded system components

- **Processor**

  It provides the processing power needed to perform the tasks within the system including arithmetic, logical and control operations.
- **Memory**

  Memory is an important part of any embedded system design and is heavily influenced by the software design, and in turn may dictate how the software is designed, written and developed. These topics will be addressed in more detail later on in this book. As a way of introduction, memory essentially performs two functions within an embedded system:
  - It provides storage for the software that it will run at a minimum, this will take the form of some non-volatile memory that retains its contents when power is removed. This can be on-chip read only memory (ROM) or external EPROM.

  - It provides storage for data such as program variables and intermediate results, status information and any other data that might be created temporarily throughout the operation. This can be done by a RAM.

- **Peripherals**

  An embedded system has to communicate with the outside world and this is done by peripherals. Input peripherals are usually associated with sensors that measure the external environment and thus effectively control the output operations that the embedded system performs. The main types of peripherals that are used include:

  - **Binary outputs**

    These are simple external pins whose logic state can be controlled by the processor to either be a logic zero (off) or a logic one (on). They can be used individually or grouped together to create parallel ports where a group of bits can be input or output simultaneously.

  - **Serial outputs**

    These are interfaces that send or receive data using one or two pins in a serial mode (RX and TX). They are less complex to connect but are more complicated to program.

  - **Analogue values**

    While processors operate in the digital domain, the natural world does not and tends to orientate to analogue values. As a result, interfaces between the system and the external environment need to be converted from analogue to digital and vice versa.

  - **Displays**

    Displays are becoming important and can vary from simple LEDs and seven segment displays to small alpha-numeric LCD panels.

- **Time derived outputs**

  Timers and counters are probably the most commonly used functions within an embedded system.

- **Software**

  The software components within an embedded system often encompasses the technology that adds value to the system and defines what it does and how well it does it. The software can consist of several different components:

  - Initialization and configuration.
  - Operating system or run-time environment.
  - The applications software itself.
  - Error handling.
  - Debug and maintenance support.

- **Algorithms**

  Algorithms are the key constituents of the software that makes an embedded system behave in the way that it does. They can range from mathematical processing through to models of the external environment which are used to interpret information from external sensors and thus generate control signals.

2.4 Radio Frequency Communication

Radio is the use of unguided propagating electromagnetic fields in the frequency range 3 kHz and 300 GHz to convey information. Propagating electromagnetic fields in this frequency range are more commonly known as radio waves.

Radio waves main properties are speed, wavelength and frequency. Wavelength is the distance between successive peaks in an electromagnetic wave or it distance a wave takes to complete one cycle. Wavelength governs many properties of how electromagnetic radiation interacts with its environment. Frequency is the number of cycles, or times that a wave repeats in a second. Radio waves travel at the speed of light.

Relationship between wavelength and frequency is given by:

$$\text{Wavelength} = c\ /\ \text{Frequency} \tag{2.1}$$

Where: c = The speed of light.

In a radio communication system, a transmitter converts information in the form of analog signals (e.g., voice) or digital signals (i.e., data) to a radio wave, the radio wave propagates to the receiver, and the receiver converts the signal represented by the radio wave back into its original form [7].

2.4.1 Radio frequency spectrum

The radio segment of the electromagnetic spectrum covers eight orders of magnitude in frequency (or wavelength), with significant variation in properties and utilization over that span. Therefore, it is useful to further subdivide the radio spectrum into bands. One common scheme for defining and naming the bands is the scheme promulgated by the International Telecommunications Union (ITU), shown in Table 2.1.

Table 2.1: Frequency bands and their applications.

Band	Frequencies	Wavelengths	Typical Applications
EHF	30-300 GHz	10-1 mm	WLAN (60 GHz), Data Links
SHF	3-30 GHz	10-1 cm	Satellite Data Links, Radar
UHF	300-3000 MHz	1-0.1 m	TV Broadcasting, Cellular, WLAN

VHF	30-300 MHz	10-1 m	FM and TV Broadcasting, LMR
HF	3-30 MHz	100-10 m	Global terrestrial communications, CB Radio
MF	300-3000 kHz	1000-100 m	AM Broadcasting
LF	30-300 kHz	10-1 km	Navigation, RFID
VLF	3-30 kHz	100-10 km	Navigation

2.4.2 Propagation characteristics

Propagation is the way a wave travels through a medium. Electromagnetic waves and radio waves respectively have different propagation modes, with the type of mode generally depending upon wavelength and environmental characteristics.

The general line-of-sight propagation mode can be more thought of as allowing one to communicate with something that one could see in the absence of any obstacles, that is, something not blocked by the curvature of the Earth or large geographic features like mountains. The three general wave properties that govern line-of-sight propagation are diffraction, reflection, and absorption.

- Diffraction is a general wave property that occurs when a wave meets a sharp transition. Upon meeting such a transition, the wave will spread out, or diffract, around the edge. In the context of radio communications, this means that a receiver shaded by some obstacle, such as a hill, can still receive signals from a distant transmitter. An example of diffraction is shown in Figure 2.4.

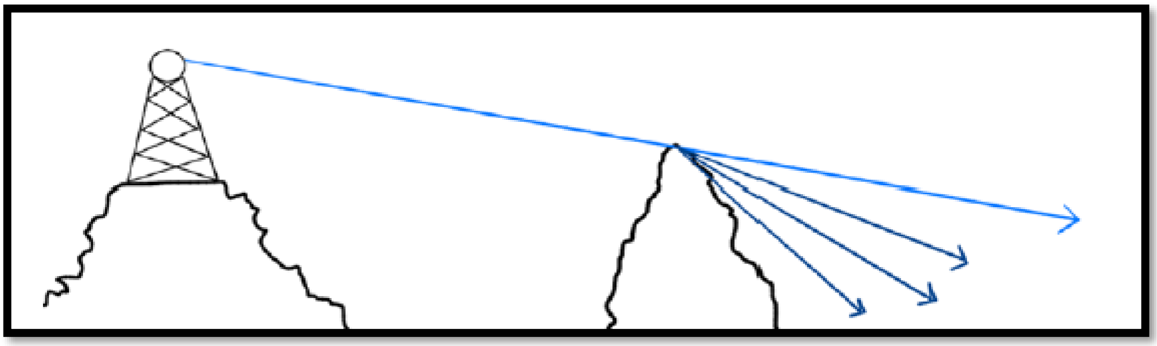


Figure 2.4: Diffraction

- Reflection is a wave property that allows a receiver to communicate with an occluded transmitter. If a wave propagating through one medium reaches a different medium, the second medium will reflect back a portion of the wave's energy. Radio waves can reflect easily off of many large objects.
- In Absorption the energy will not be reflected by a medium but will pass into the medium. Some materials allow electromagnetic radiation to pass through them without attenuation better than others do. Radio waves can travel through most nonconductive materials.

Diffraction, reflection and absorption are all frequency dependent, for example, lower frequency (400 MHz and less) waves are better at diffracting around large obstacles.

Noise can be defined as any unwanted signals, random or deterministic, errant noise around the same frequency at which one is transmitting, it can vastly limit data transmission rates and force transmitters to use more power [8].

2.4.3 Modulation

Modulation is defined as representation of information in a form suitable for transmission because usually the information signal in its normal form cannot be transmitted. A carrier, which is a sinusoidal signal of high frequency is added and modified by the information signal. Modulation can be either analog or digital.

- **Analog modulation**

Analog modulation is used when information is sent in analog form. The three main types of analog modulation are AM, FM and PM.

i. Amplitude Modulation (AM), where the amplitude of the carrier varies in accordance to the information signal.
ii. Frequency Modulation (FM), where the frequency of the carrier varies in accordance to the information signal.
iii. Phase Modulation (PM), where the phase of the carrier varies in accordance to the information signal.

- **Digital modulation**

Digital modulation is used when information is sent in digital form. One of its major types is Shift Keying Modulation, which can be subdivided into:

- Amplitude Shift Keying (ASK)
- Frequency Shift Keying (FSK)
- Phase Shift Keying (PSK)

At the receiver end a process called demodulation must be done to separate the information signal from the carrier.

2.4.4 Digital transmitters and receivers

The conceptual diagram below illustrates the basic transmitting and receiving process.

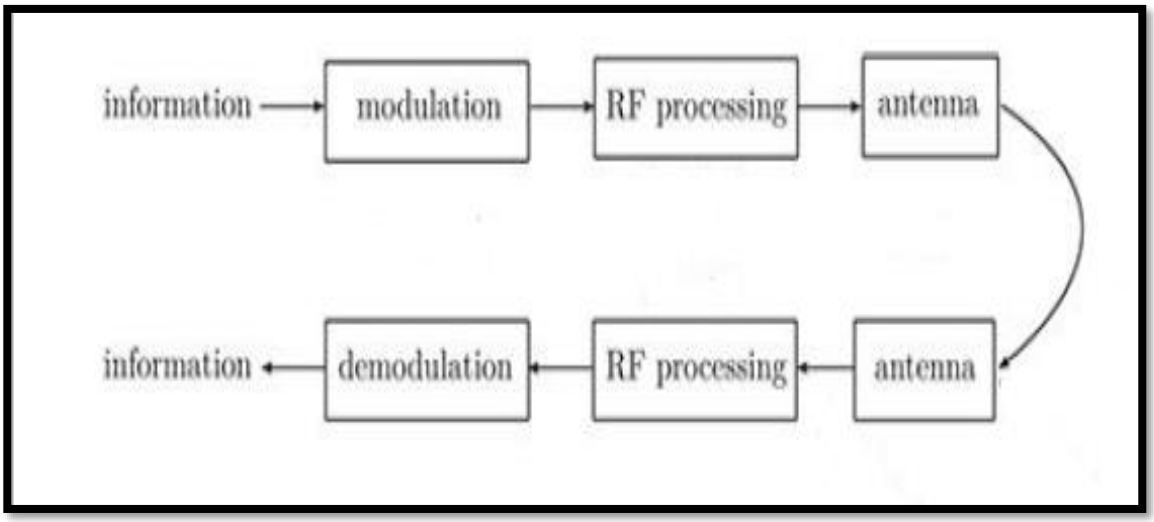


Figure 2.5: The main transmitting and receiving process

Figure 2.5 shows the elements that commonly appear in a radio link. The transmitter accepts the information and generates a representation of that information that is suitable for radio transmission. This process is known as modulation, and then the antennas are used to convert the resulting electrical signals to radio waves and transmit it through a suitable communication channel. The antenna in the receiver end can also receive the transmitted radio wave and convert it back to its electrical signal form. The receiver then receives the electrical signal and demodulate the received signal to recognizable information [7].

- **Transmitter**

The Transmitter input is digital information. To get a radio frequency signal in the analog domain, the digital representation of the modulator output is converted to an analog signal using a digital-to-analog converter (DAC or D/A). It is usually not possible to do the D/A conversion at radio frequencies; in this case, the conversion is performed at a lower frequency and then upconverted to the RF frequency at which it will be transmitted. The upconverter accomplishes this by combining the signal with one or more local oscillator signals. The digital transmitter elements are shown in Figure 2.6.

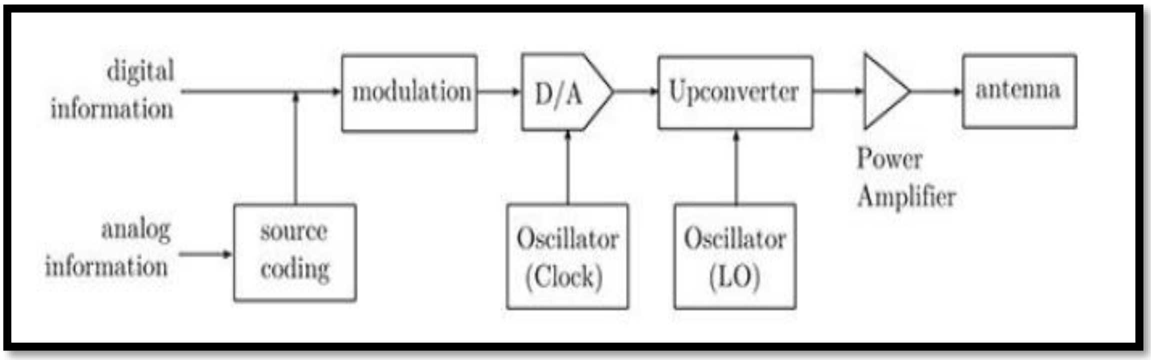


Figure 2.6: Digital transmitter elements

- **Receiver**

After receiving the signal, a low-noise amplifier (LNA) is used to overcome propagation loss while not adding too much additional internal noise, Then the signal id down converted that is, shift the center frequency from the radio band to a lower frequency that is easier to process. Like up conversion, this is done by combining the input signal with a radio frequency signal generated by an oscillator, then digitize the signal using an analog-to-digital converter (ADC or A/D) and perform the demodulation digitally. Digital receiver elements are shown in Figure 2.7.

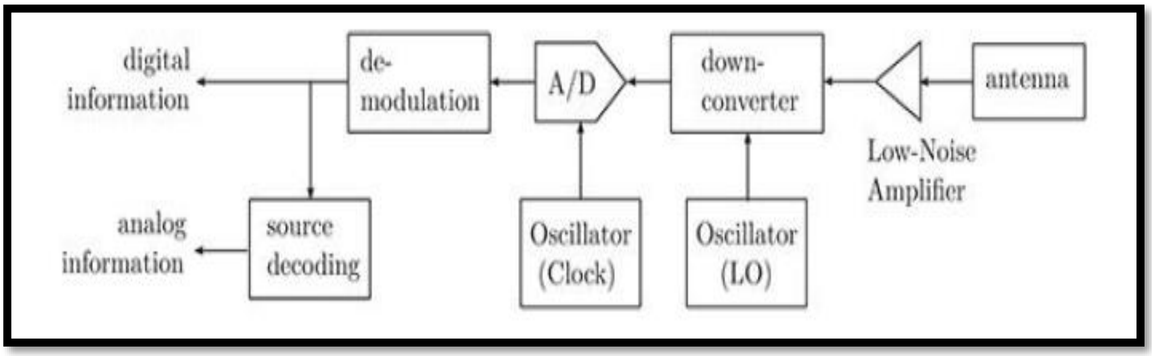


Figure 2.7: Digital receiver elements

2.4.5 Applications of radio frequency

Today, at home or on the move, Radio frequency-based applications that employ wireless technology to are increasing rapidly to an extent that it became a part of one's daily life, these applications include:

- Wireless Local Area Network (WLAN).
- Global Positioning System.
- Global System for Mobile Communication (GSM).
- The famous 3G,4G and 5G networks.
- Short Range Data Communication:
  1. Radio Frequency Identification (RFID)
  2. Bluetooth

2.5 Bluetooth Communication

Bluetooth is a wireless technology that can be used to send and receive information between devices. It is a scheme for point-to-point networking in support of devices such as wireless computer peripherals, wireless microphones and headphones; and for connections between smart phones, computers, and other devices. Such systems are sometimes referred to as personal area networks (PANs).

Bluetooth operates in the 2.4 GHz unlicensed band, using frequency-hopping spread-spectrum (FHSS) multiple access at 1600 frequency hops per second, which transmits data over different frequencies at different time intervals. This is accomplished by making ‘‘hops’’ to different frequencies through the 2.4GHz band. Unlike most devices, Bluetooth enabled devices communicate with each other automatically. There is no need to specify what type of action to take place or when it should to happen. When two devices are within range of each other, they will communicate back and forth to determine if there is any information to be passed. During initial communication, it is necessary to create a relationship between unknown devices, this process is referred to as pairing. During the paring process, a secret PIN is created that is only known by the two devices that are communicating.

2.6 Global Positioning System

The GPS is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellite. The system is made up of a network of 24 satellites placed into orbit by the U.S. Department of Defense. It was originally intended for military applications, but in the 1980s, the government made the system available for civilian use.

2.6.1 GPS working principle

GPS receivers are able to identify their location when three GPS satellites triangulate and measure the distance to the receiver and compare the measurements. A fourth satellite measures the time to the receiver. The information from all four satellites is compiled to determine the location. The sophistication of a GPS receiver impacts the reliability and accuracy of the GPS data received [9].

2.6.2 GPS technology components

According to The Aerospace Corporation and Trimble, GPS technology can be described in terms of three segments:

- **Space component**

  Consists of twenty-four satellites orbiting 11,000 nautical miles above the earth.

- **Control component**

  Consists of 5 ground stations around the globe that manage the operational health of the satellites by transmitting orbital corrections and clock updates.

- **User component**

  Consists of various types of GPS receivers that can vary in complexity and sophistication. This component is what most people are familiar with such as the navigation system in a car, or the GPS device in a cell phone.

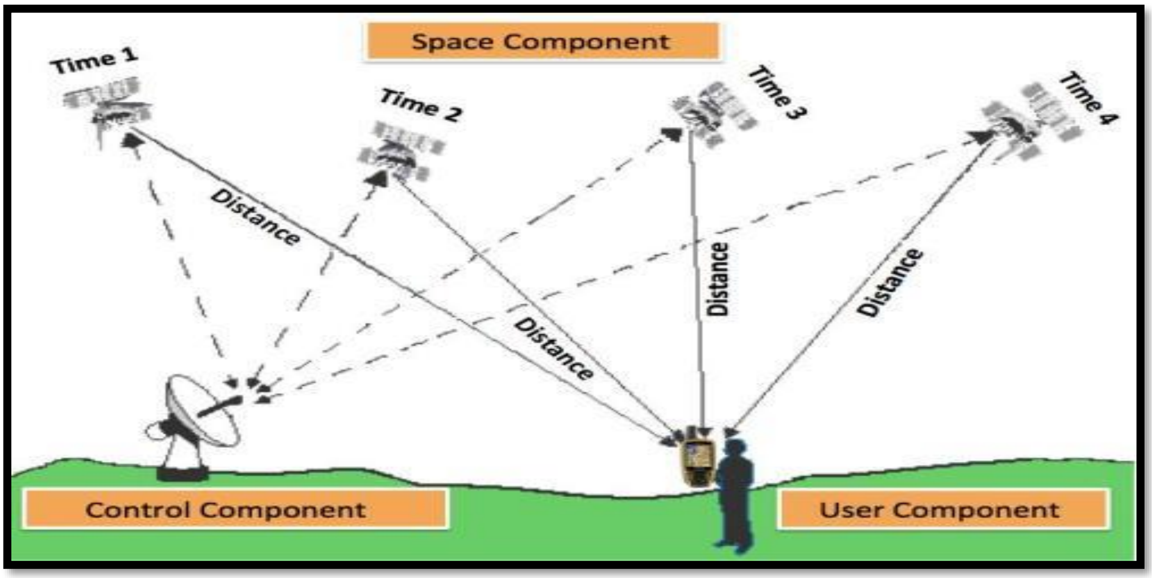


Figure 2.8: GPS system components and working principle

2.6.3 GPS system equipments

- **GPS receiver**

GPS receiver technology consists of a receiver for receiving location data points, a memory for storing the points, a rechargeable battery, RF technology for ensuring proximity to the tamper-resistant bracelet, and for Active units, cellular phone technology for transmitting GPS data points near real-time. Some vendors also provide GPS receivers that have voice communication capability.

- **Tamper-resistant bracelet**

This piece of equipment is familiar to users of RF technology. It typically consists of a bracelet worn on the client's ankle. It contains a battery and utilizes RF technology to verify its proximity to the GPS receiver. The bracelet will transmit an alert via the GPS receiver if tampering occurs.

- **GPS charging unit**.

This equipment is used daily to recharge the GPS receiver. Some charging units are connected to a land-line phone, by which the daily GPS data points are transmitted to the vendor software.

2.6.4 GPS applications

- Location determining in different parts of the world.
- Navigation while traveling from one location to another.
- Tracking and monitoring moving objects or people.
- Creating maps of the world to simplify geographical studies.
- Bringing precise timing to the world using longitudes and latitudes.

2.7 Thermal Imaging

Infrared (IR) thermal imaging, also often called thermography for short, is the technique of using the thermal radiation given off by an object to produce an image of it or to locate it [10].

The human vision is extended by the use of thermal imaging to far IR region as it utilizes the light emitted by warm objects. The human eye lacks response in the absence of light in the 0.4μm to 0.7μm range, hence the device that can create the image by generating the dominant energy in low light conditions is needed [10].

2.7.1 Electromagnetic waves

In physics, visible light (VIS), ultraviolet (UV) radiation, IR radiation, can be described as Electromagnetic (EM) waves. Waves are periodic disturbances that keep their shape while progressing in space as a function of time. The spatial periodicity is called wavelength, λ measured in meters, the transient periodicity is called the period of oscillation, T (in seconds), and its reciprocal is the frequency, ν = 1⁄N (in s^{-1} or Hertz). Both are connected via the speed of propagation c of the wave by:

$$c = \nu \cdot \lambda \tag{2.2}$$

Light and IR radiation are EM waves. In EM waves, the disturbances are electric and magnetic fields. They are perpendicular to each other and also perpendicular to the propagation direction, that is, EM waves are transverse waves. The maximum disturbance (or elongation) is called the amplitude [10].

The EM wave is shown in Figure 2.9 below.

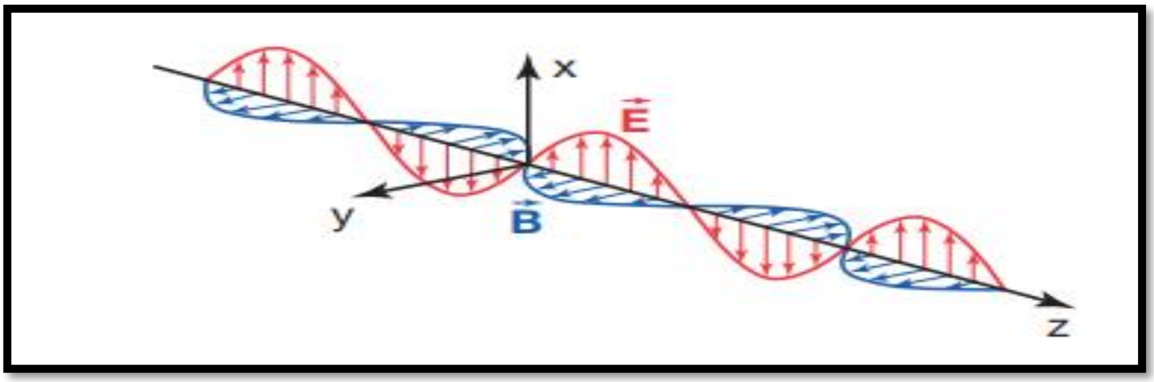


Figure 2.9: Electromagnetic waves

2.7.2 Electromagnetic spectrum

The electromagnetic spectrum is the range of frequencies of electromagnetic radiation and their respective wavelengths and photon energies.

The electromagnetic spectrum covers electromagnetic waves with frequencies ranging from below one hertz to above 10^{25} hertz, corresponding to wavelengths from thousands of kilometers down to a fraction of the size of an atomic nucleus. The amount of energy in a light wave is related to its wavelength: Shorter wavelengths have higher energy. Of the visible light, violet has the most energy, and red has the least amount of energy. Just next to the visible light spectrum, on the red end, is the infrared spectrum. Infrared light can be split into three ranges:

- Near-infrared (near-IR) - Closest to visible light, near-IR has wavelengths that range from 0.7 to 1.3 microns, or 700 billionths to 1,300 billionths of a meter.
- Mid-infrared (mid-IR) - Mid-IR has wavelengths ranging from 1.3 to 3 microns. Both near-IR and mid-IR are used by a variety of electronic devices, including remote controls.
- Thermal-infrared (thermal-IR) - Inhabiting the largest part of the infrared spectrum, thermal-IR has wavelengths ranging from 3 microns to more than 30 microns.

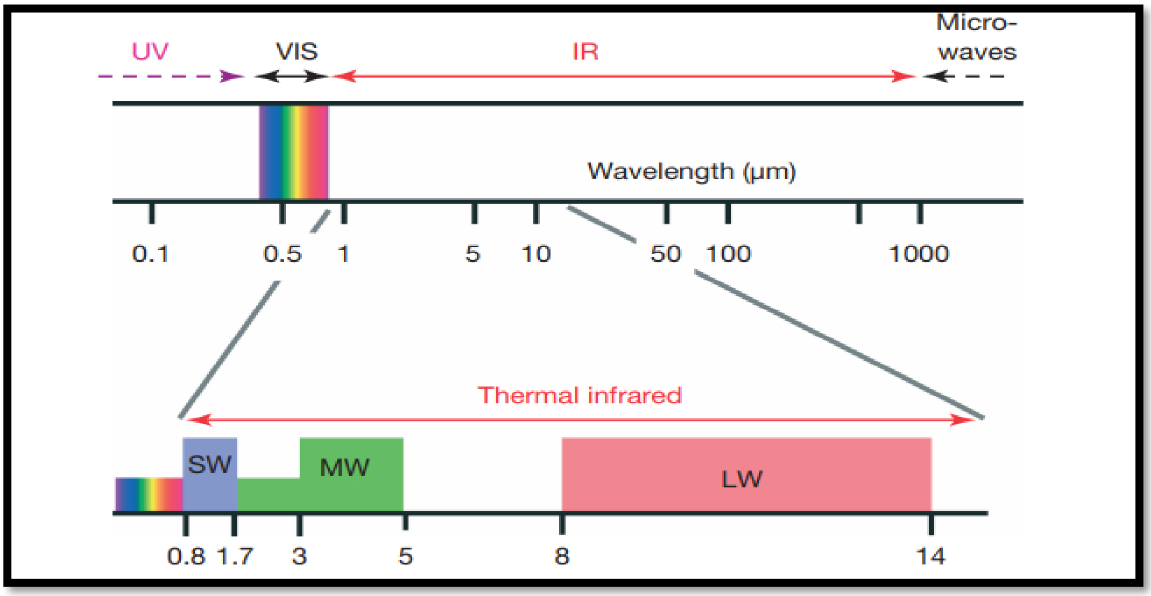


Figure 2.10: Electromagnetic spectrum

The key difference between thermal-IR and the other two is that Thermal-IR is emitted by an object instead of reflected off it. Infrared light is emitted by an object because of what is happening at the atomic level.

Commercial cameras are available for these three ranges. The restriction to these wavelengths follows firstly from considerations of the amount of thermal radiation to be expected, secondly from the physics of detectors, and thirdly from the transmission properties of the atmosphere. The origin of naturally occurring EM radiation is manifold.

The most important process for thermography is thermal radiation. In brief, the term thermal radiation implies that every body or object at a temperature $T > 0K$ (-273.15 °C) emits EM radiation. The amount of radiation and its distribution as a function of wavelength depend on temperature and material properties. For temperatures in the range of natural and technological processes, this radiation is in the thermal IR spectral region [10].

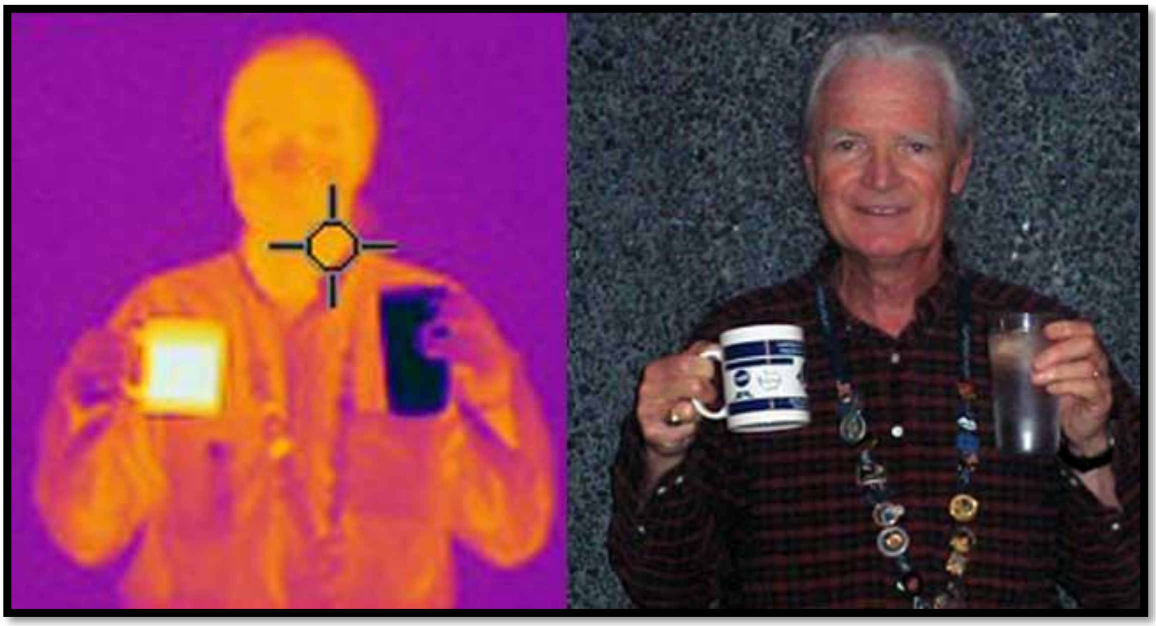


Figure 2.11: Thermal image vs Normal image

The amount of radiation emitted by an object having a temperature T can be described using Planck's wavelength distribution function as follow:

$$E(\lambda,T) = \frac{2\pi hc^2}{\lambda^5\left(e^{hc/\lambda kBT} - 1\right)} \quad (2.3)$$

Where λ is the wavelength, *h* is the Planck's constant ($6.626\text{x}10^{-34}$ J-s), *c* is the speed of light (2.99x108 m/s) and k_B is the Boltzmann's constant ($1.3806 \text{ X } 10^{-23}$ J/K) [11].

2.7.3 Thermal imaging applications

- Electrical maintenance and equipment checking
- Inspect sites of possible leaks, mainly through walls and pipes.
- Analyses a building's structure and spot faults.
- Transport navigation particularly when travelling at night.
- Healthcare and medicine to spot fevers and temperature anomalies.
- Firefighting help them see through smoke, particularly in rescue missions when they're searching for people in an otherwise obscured and dangerous environment.

2.8 Night Vision

Night vision signifies the ability to see in dark (night). This capability is normally possessed by owls and cats, but with the development of science and technology devices has been develop which enables human being to see in dark as well as in adverse atmospheric conditions such as fog, rain, dust etc. The muscles in the human eye have the ability to stretch or contract automatically, depending upon the intensity of light falling on the eye. Because of this human eye have limitations. The muscles of the eye cannot increase the aperture indefinitely. Therefore, in poor light humans are unable to see the objects because the image cannot be formed on the retina clearly. The capability to detect and identify targets at night and under poor visibility conditions has been an essential military requirement. The modern army's need to operate at night and under conditions of extremely poor visibility, Since the soldiers have to often fight in the dark at night, they have to face a severe stress as far as the location of target is concerned. Also, various wild life observer has to face problems of low light because many wild animals are more active during night time than day Therefore, to give humans the ability to see in dark by technological means, night vision technology has been developed [12].

2.8.1 Night vision technologies

Night vision technologies are divided into three main categories:

i. **Image intensification system**

Image intensification systems support direct observations by amplifying low levels of available light. They do not turn night into day nor do they overcome the problems that affect vision in low light environments.

The image intensifier is a vacuum-tube based device that converts invisible light from an image to visible light so that objects in the dark can be viewed by a camera or the naked eye. When light strikes a charged photocathode plate, electrons are emitted through a vacuum tube that strike the micro channel plate that cause the image screen to illuminate with a picture in the same pattern as the light that strikes the photocathode, this is much like a CRT television, but instead of color guns the photocathode does
the emitting. The intensified image is, typically, viewed on a phosphor screen that creates a monochrome, video-like image, on the user's eyepieces [12].

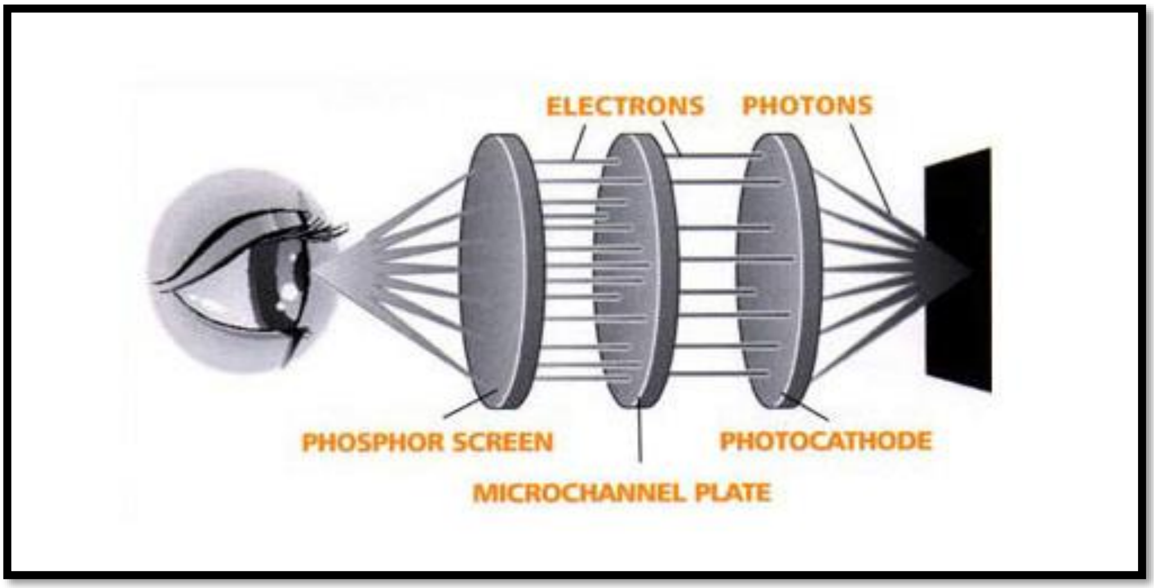


Figure 2.12: Image intensification systems

- **Advantages**
  - Excellent low-light level sensitivity.
  - Excellent recognition and identification performance.
  - High resolution.
  - Low power and cost.
  - Ability to identify people.
- **Disadvantages:**
  - Some light is required. This method is not useful when there is essentially no light.
  - Inferior daytime performance when compared to daylight-only methods.
  - Possibility of blooming and damage when observing bright sources under low-light conditions.

ii. Active illumination

Active illumination technologies work on the principle of coupling imaging intensification with an active source of illumination in the near infrared (NIR) band. Infrared is used in night vision technology when there is insufficient visible light to see, active illumination involves conversion of ambient light photons into electrons which are then amplified by a chemical and electrical process and then converted back into visible light. Active infrared night vision combines infrared illumination in spectral range 0.7–1 μm. Due to which the scene, which appears dark to a human observer now appears as a monochrome image on a normal display device. Since active infrared night vision systems can incorporate illuminators that produce high levels of infrared light, the resulting images are typically higher resolution than other night vision technologies [12].

Active illumination night vision is shown in Figure 2.13 below.

Figure 2.13: Active illumination night vision

iii. Thermal imaging

Thermal imaging technology functions by capturing the upper portion of the infrared light spectrum. It is emitted as heat by objects instead of simply reflected as light. Hotter objects such as warm bodies emit more of this light than cooler objects like trees or buildings.

The use of infrared light and night vision devices should not be confused with thermal imaging which creates images based on differences in surface temperature by detecting infrared radiation (heat) that emanates from objects and their surrounding environment

2.8.2 Night vision applications

- Law enforcement during the hours of darkness and low light situations and help them detect, deter and prevent the disruption of an enemy.
- Wildlife Observation after the sun has set and the chance to see elusive creatures that are less active during the day.
- Security and surveillance during night or low light condition and thus prevents the chances of theft, terrorists attack etc.

2.9 Gas Sensing

Gas sensor is a transducer that typically converts the presence of certain molecules into an electrical signal. It includes a filter that ensures that the sensor only responds to the gas to be measured and not to other gases or other variables. It may be a physical filter, permitting the flow of only certain molecules into the capture zone, or a more fundamental means of identifying the target gas by some unique property such as its optical absorption wavelength.

The output of the sensor may be a single value, or a more complex, time dependent signal, and may be electronically filtered or otherwise processed. The most basic performance criteria of a gas sensor are. The ratio of signal-to-noise in the output is often used to characterize performance [13].

Gas sensing basic principle is shown in Figure 2.14 below.

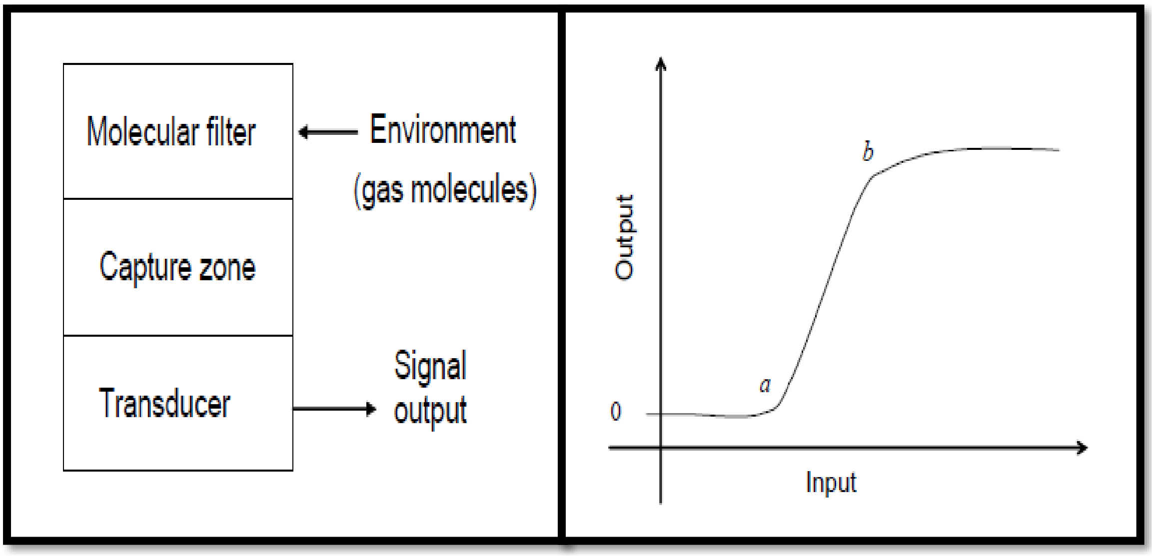


Figure 2.14: Gas sensing principle

2.10 Heart Rate Sensing

The heartbeat is a unit for counting the intensity of the heart function, whose unit is the beats per minute (BPM). The heart has pacemaker cells, which, by creating electrical waves, these cells cause heart rhythm from the right atrium with its spread throughout the heart, blood pumping occurs [14].

The heartbeat monitor is a smart wearable device that detects heartbeat from the body. This smart instrument uses photoplethysmography (PPG) technology and also has two sensors. The first sensor is for detecting light and another for determining motion. Its function is that the light is irradiated by the skin with a Light Emitting Diodes (LED) and then the light reflected from the body hits the detector and changes in heartbeat and body movement are measured. Using this method the device can be used during activity, exercise and rest, or at any other time. The problems with these optical monitors are the presence of noise in the received signals because they have similar frequencies. Also, in some cases, measuring heartbeat is wrong, which depends on the physical body and the intensity of the user's activity [14].

CHAPTER THREE

SYSTEM HAEDWARE AND SOFTWARE CONSIDERATION

3.1 System Control Circuit

System control circuit can be described by using block and wiring diagram, which declares the hardware consideration.

3.1.1 Block diagram

Describes how the helmet's controller receives data from thermal camera, night-vision camera, GPS module, gas sensor, heart rate sensor and display the outputs from the thermal camera on a small screen mounted on the helmet. Then send the rest of the data to the military base system.

The military base system displays the data received from the helmet on a monitor.

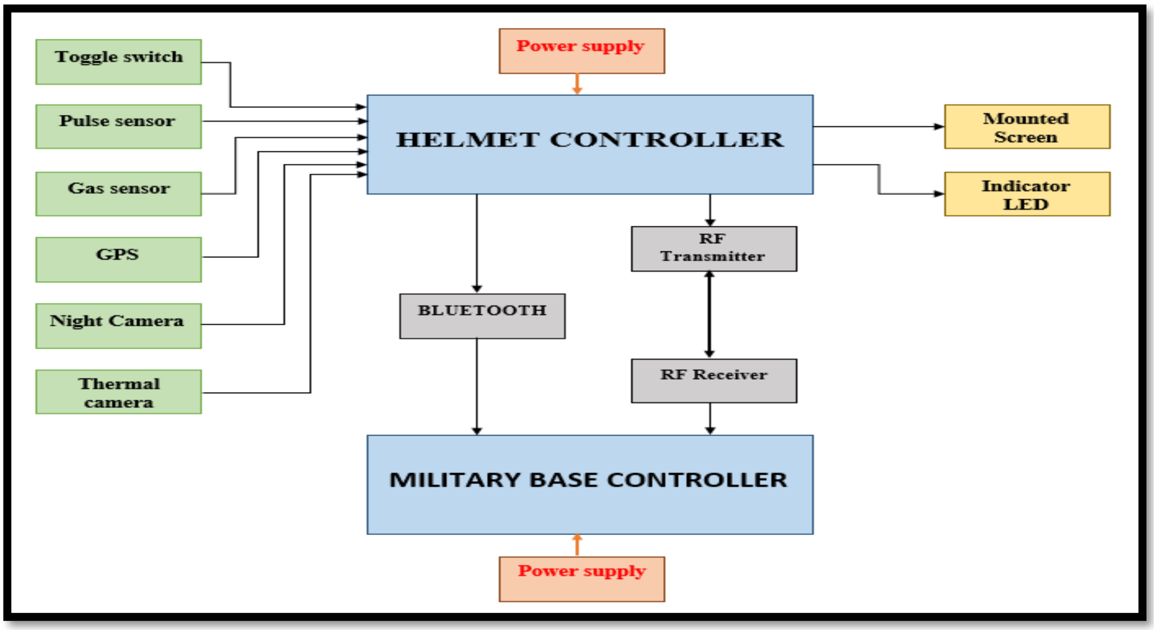


Figure 3.1: System block diagram

3.1.2 Wiring diagram

Wiring diagram is a network of wires showing how to connect the circuit components, it explains the signals requirement for communication and the ON/OFF control, also it declares the power feeding lines for the circuit. Wire diagram describe how all wires connected between the system circuit components. Microcontroller (Arduino) pins were used to receive data from thermal camera, night-vision camera, GPS module, gas sensor, heart rate sensor. The signals received from the thermal camera is sent to a small Thin Film Transistor (TFT) display after processing. The Arduino microcontroller receives power from an external power supply using two wires, one is the (+5V) DC and the other is ground. Input and output modules receive power and control signals from Arduino microcontroller using jumper wires. Bluetooth and RF modules transmits data to the PC wirelessly. The wiring diagram is shown in Figure 3.2.

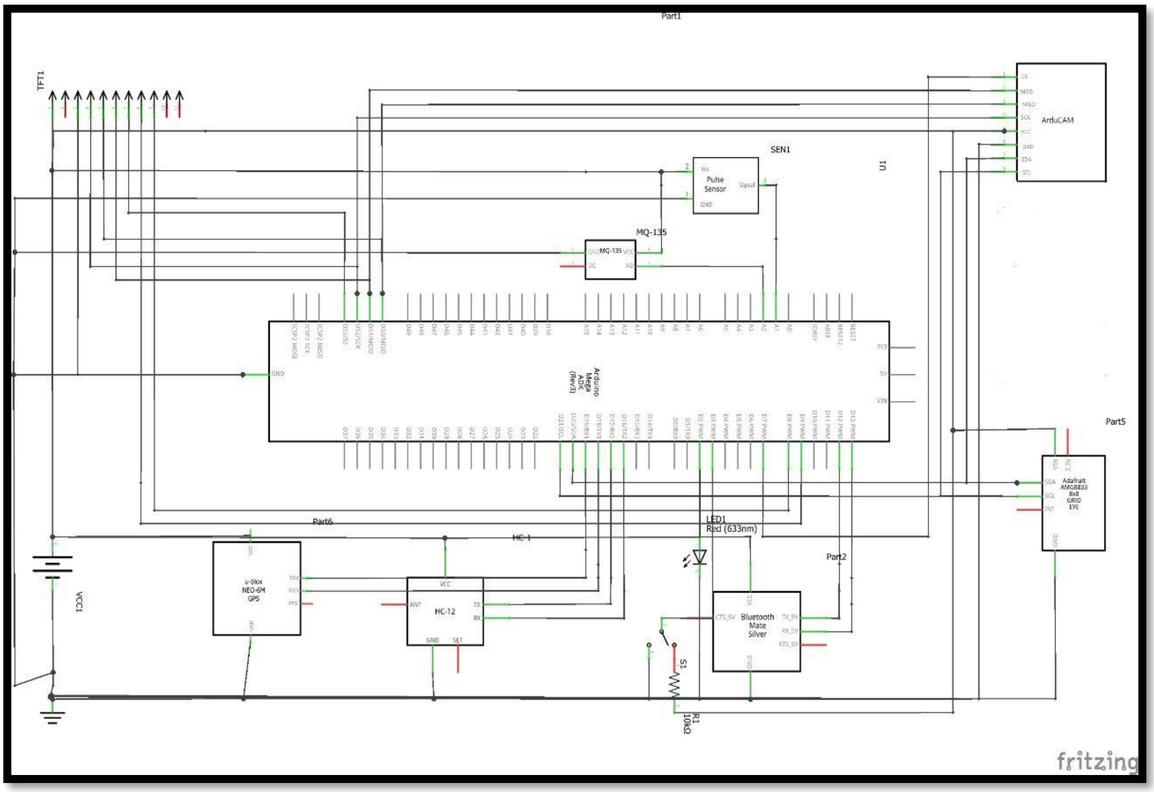


Figure 3.2: Wiring diagram

3.2 Hardware Considerations

Electronic warfare helmet consists of electrical components such as Arduino controller, night-vision camera, thermal camera, GPS module, gas and heart rate sensors, TFT display, Bluetooth, RF radio transceiver and power supply.

3.2.1 Microcontroller (Arduino)

Arduino is a small microcontroller board with a USB plug to connect to your computer and a number of connection sockets that can be wired up to external electronics, such as motors, relays, light sensors, laser diodes, loudspeakers, microphones, etc. Arduino can either be powered through the USB connection from the computer or from a 9V battery, Figure 3.8 shows different types of Arduino controller. Arduino can be controlled from the computer or programmed by the computer and then disconnected and allowed to work independently. The hardware consists of an open source hardware board that is designed around the ATMEL AVR Microcontroller. The intention of Arduino was to make the application of interactive components or environments more accessible. Arduino is programmed via an Integrated Development Environment (IDE) and run on any platform that supports Java like LABVIEW. An Arduino program is written in either C or C++ and is programmed using its own IDE.

The Arduino MEGA 2560 is designed for projects that require more I/O lines, more sketch memory and more RAM. It is suitable for the complex projects like 3D printers and robotics projects. It's features as follow:

- 64K/128K/256KBytes of In-System Self-Programmable Flash.
- 4Kbytes EEPROM.
- 8Kbytes Internal SRAM.
- Four 8-bit PWM Channels.
- 16 analog I\O pins.

- 54 digital I/O with 8 RX, TX pins.
- Operating Voltage of 1.8 - 5.5V.

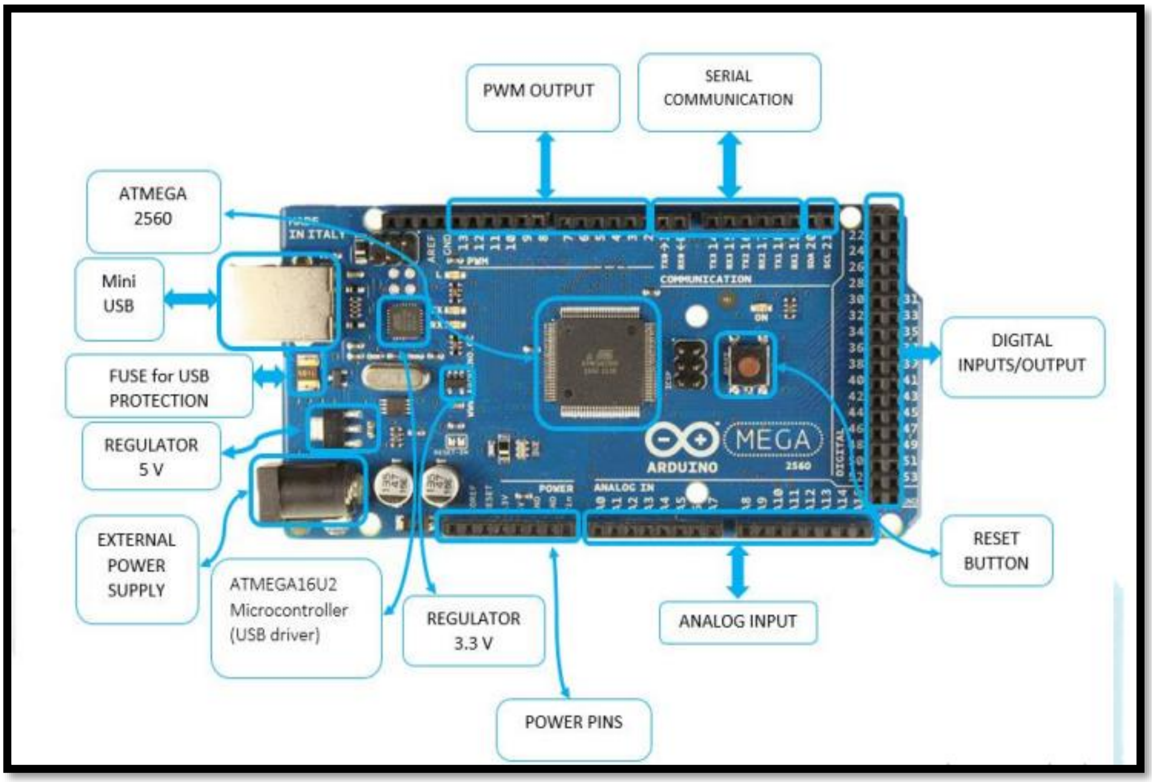


Figure 3.3: Arduino ATmega 2560

3.2.2 System input

i. Pulse sensor

The sensor used for this task is pulse sensor (SEN-11574) which is very small in size and can be worn or wrapped around the index finger or on ear lobe. This sensor module consists of light source photo detector and infra-red LED's. The idea behind the concept is the optical detection of changes in the blood volume. Changes in light intensity are used to check the changes in volume level of blood. Output voltages from this sensor module during the cardiac cycles will be converted into beats per minute to using the microcontroller Arduino board through three jumper wires.

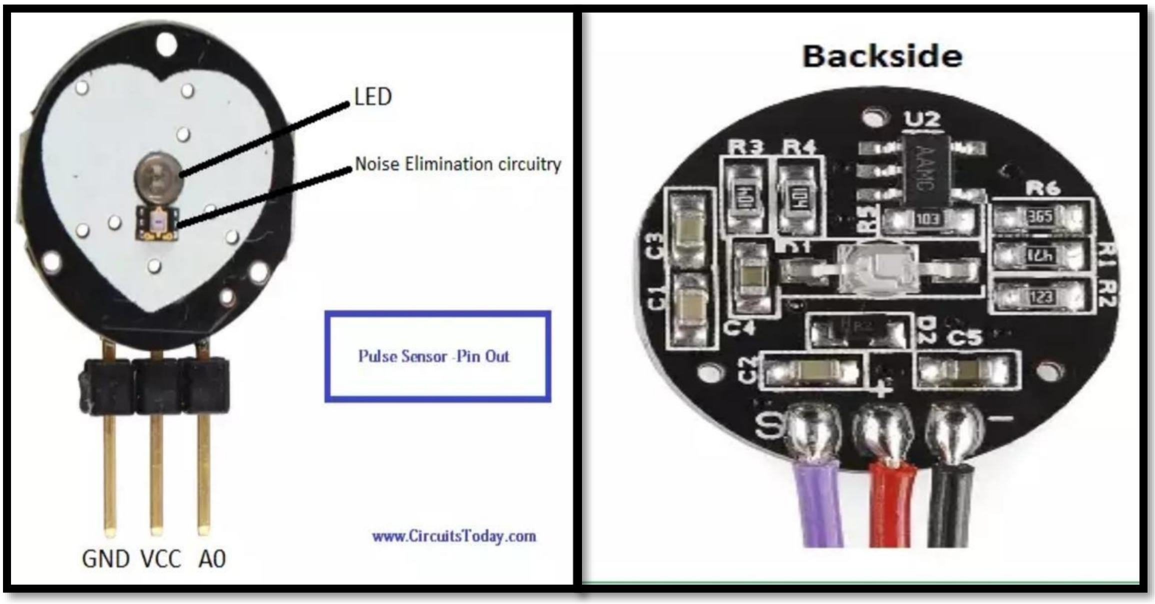


Figure 3.4: Pulse sensor (SEN-11574)

ii. Gas Sensor

The sensor used for this task is MQ 135. The Sensitive material used in the sensor is SnO2(stannic oxide). The conductivity of this material is lower in clean air. The sensor conductivity increases with the increasing concentration of target pollution gas. MQ135 can monitor different kinds of toxic gases such as sulphide, ammonia gas, benzene series steam and CO2. The detection range is 10-10,000 ppm with the voltage rate of about 5.0V±0.1V AC or DC. The important features are long life span, low cost, simple driver circuit and good sensitivity to toxic gases. MQ135 gas sensor is widely used in industrial gas portable gas detector and domestic gas alarm as shown in Figure 3.6 below.

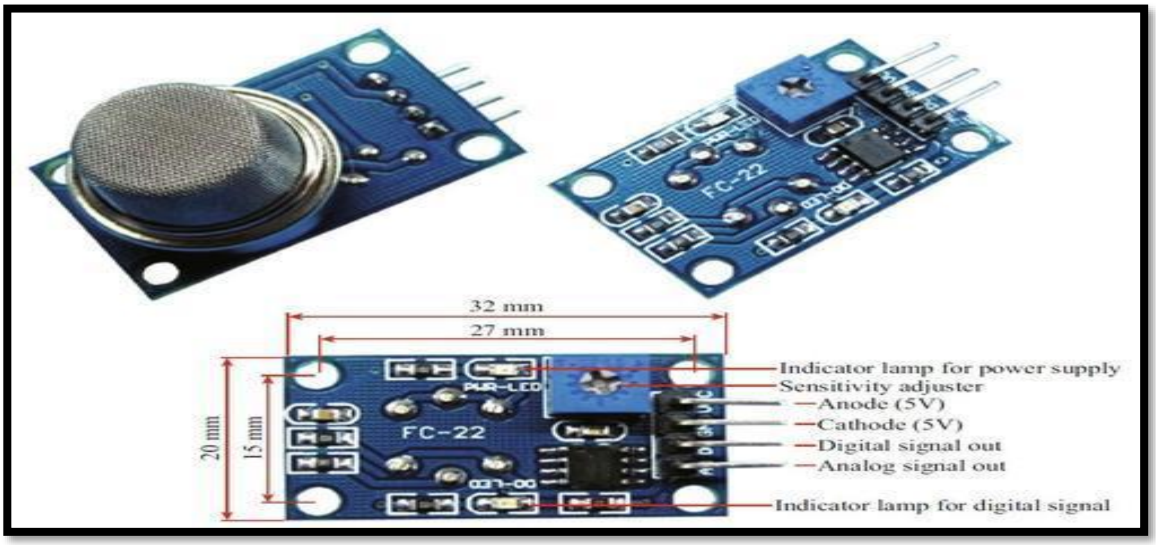


Figure 3.5: MQ135 gas sensor

3.2.3 Thermal camera system

Thermal camera system is used to identify objects and materials temperatures based on their heat signatures (which part has the highest temperature and which part has the lowest), each signature is represented by a different color ranging from purple (highest temperature area) to white (lowest temperature area).

The module use in this system is amg8833 IR thermal camera from Panasonic.

i. Module overview

The amg8833 module has a configurable interrupt pin that can fire when any individual pixel goes above or below a threshold that you set. This sensor from Panasonic is an 8x8 array of IR thermal sensors. When connected to your Microcontroller (Arduino) it will return an array of 64 individual infrared temperature readings over I^2C. It is compact and simple to use for easy integration. This part will measure temperatures ranging from 0°C to 80°C (32°F to 176°F) with an accuracy of ± 2.5°C (4.5°F). It can detect a human from a distance of up to 7 meters (23 feet) with a maximum frame rate of 10Hz.

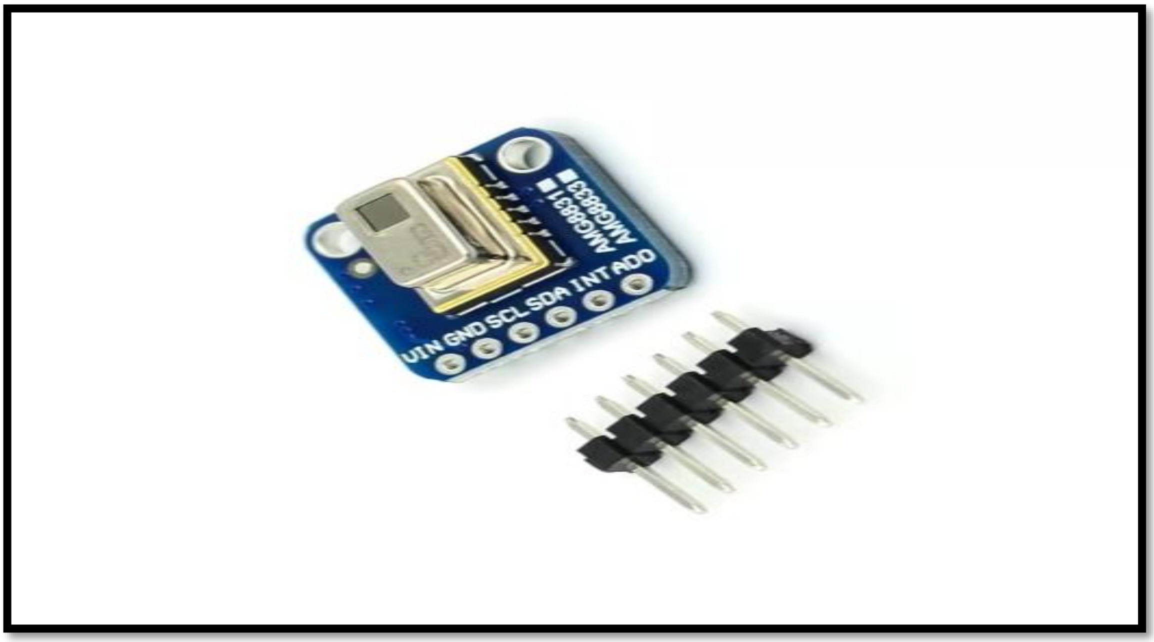


Figure 3.6: AMG8833 thermal camera module

i. **Module specifications**

- Frame rate 10 frames/sec.
- Temperature Output Resolution 0.25℃.
- Applied voltage 3.3V±0.3V or 5.0V±0.5V.
- Operating temperature 0℃～80℃.
- Rated detection distance 5 meter（Max 7 meter).
- Temperature Accuracy Within Type. ±2.5℃.
- Dimensions 10.9 x 7.8 x 4.3 mm.
- Pixel number 64 (8×8 Matrix).

ii. **Module advantages**

The amg8833 thermal camera module has many advantages such as being small in size, easy to use and install, compatible with all types of controllers and has a very low price compared to other thermal cameras.

3.2.4 Nigh vision system

Night-vision system is used to provide the ability of seeing in dark environments and in the total absence of light using a camera and an IR light illuminator.

i. IR illuminator

Infrared Illuminators are devices which emit light in infrared spectrum. They can be active devices which emit their own infrared light like various objects or passive devices which reflect the infra-red light which falls on them. One of the major applications is in night vision cameras. The infrared illuminator incorporated in the night vision camera is actually an IR LED which emits light in infrared band. This infrared light is reflected by objects and is collected by the camera lens.

A set of three IR LEDs rated at 12V DC were used. The three LEDs are connected in series with LDR sensor to operate automatically at low light.

The IR LEDS are shown in Figure 3.7 below.

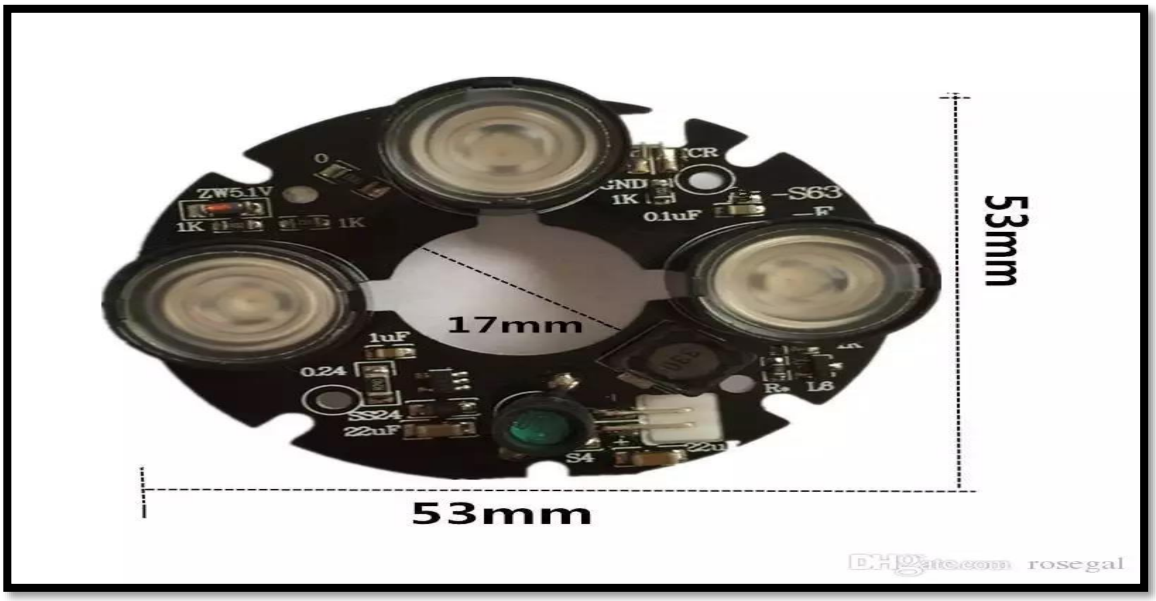


Figure 3.7: IR LED module

ii. Camera module

The camera module used in this study is shown in Figure 3.8 below

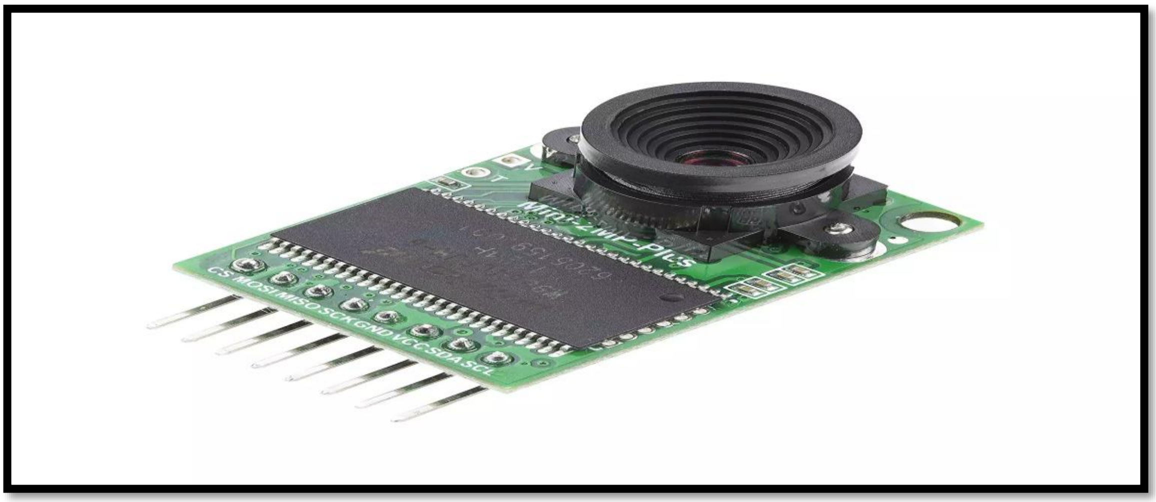


Figure 3.8: OV2640 module

- **Module overview**

  The OV2640 image sensor is a low voltage device that provides the full functionality of a digital camera and image processor in a small footprint package. The OV2640 provides full-frame, sub-sampled, scaled or windowed 8-bit/10-bit images in a wide range of formats, controlled through the serial camera control bus (SCCB) interface.

- **Module features**
  - High sensitivity for low light operation.
  - Low operating voltage.
  - Image quality control including saturation, sharpness and noise canceling.
  - Zooming, panning and windowing functions.
  - Support scaling and compression.

3.2.5 Helmet screen

The helmet's screen is used to display livestream videos from thermal camera.

The module used in the helmet is shown in Figure 3.9.

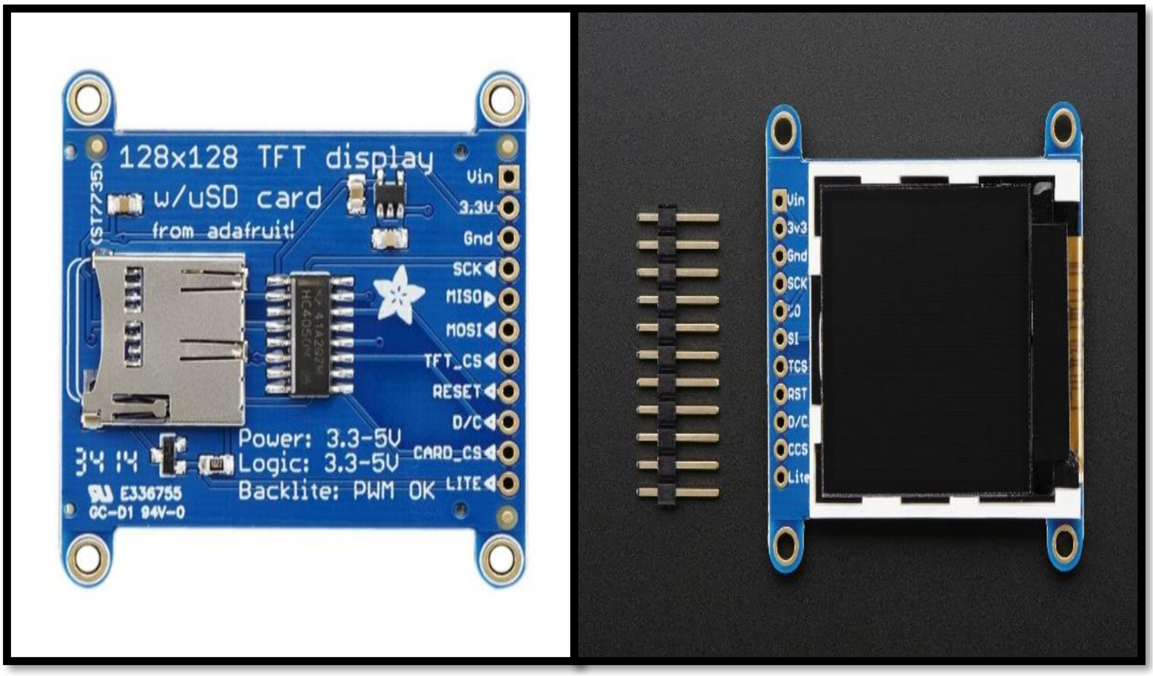


Figure 3.9: 1.5inch TFT module

- **Module interfaces**

  The interfaces and pin configurations are shown in Table 3.1.

Table 3.1: TFT screen interfaces

Pin	Description
VCC	3-5 V
GND	Ground
CLK	SPI Clock input pin
MISO	SPI Master in Slave Out pin
MOSI	SPI Master Out Slave In pin
TFT_CS	TFT SPI chip select pin
RST	TFT reset pin
D/C	TFT SPI data (command) select pin
CS/CCS	SD card chip select
LITE	PWM input for backlight control

- **Module specifications**
    - Built-in SD card slot.
    - Display driver ST7735R.
    - Interface: 4-wire SPI.
    - Pixels: 128*128.
    - Display area:1.44 inch (diagonal).
    - Dimensions: 33mm*45mm*7mm.
    - Weight: 10 gm.

3.2.6 Communication system

The communication system provides the transfer of information between the helmet and the military base via Bluetooth and radio wave modules.

- **Bluetooth HC-05 module**

  HC-05 module is an easy to use Bluetooth Serial Port Protocol (SPP) module, with UART Connector, TTL interface, & Indicators. It is designed for transparent wireless serial connection setup. It is a fully qualified Bluetooth V2.0 along with Enhanced Data Rate (EDR) & complete 2.4GHz radio transceiver and baseband. The Bluetooth module consists of four pins these pins are Vcc, GND, TXD and RXD. The TXD and RXD pins are used to transfer the data.

  mode, it will follow the default way set lastly to transmit the data automatically.

    i. **Module hardware**

       HC-05 Bluetooth module hardware and pins layout are shown in Figure 3.10.

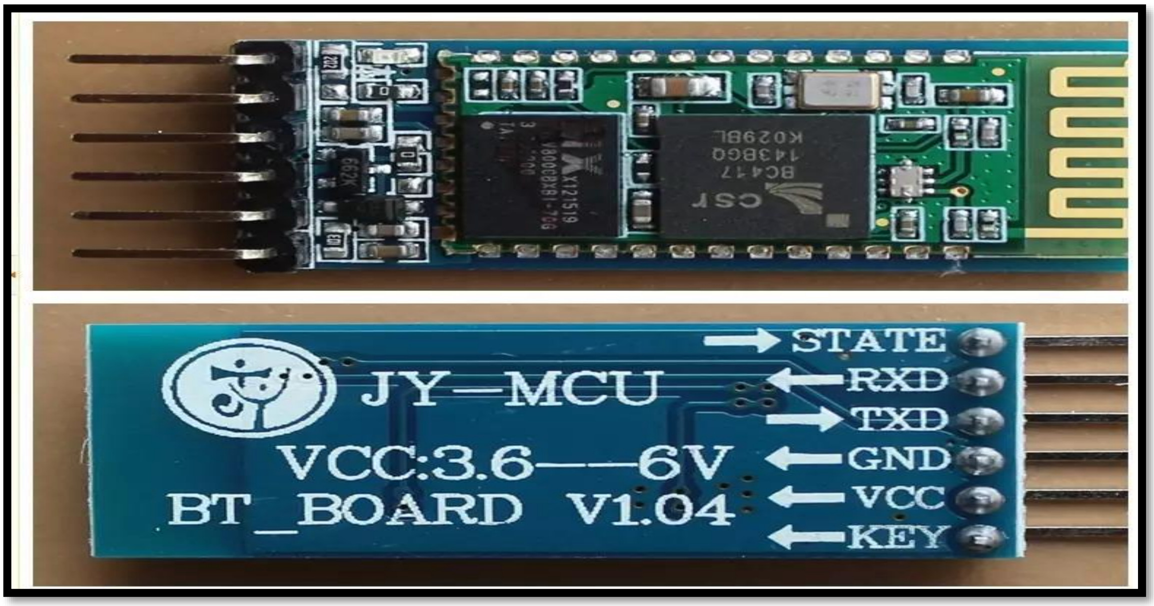


Figure 3.10: HC-05 bluetooth module

ii. **Module specifications**

- Typical -80dBm sensitivity.
- Low Power 1.8V Operation ,1.8 to 3.6V I/O.
- Supported baud rate: 9600,19200,38400,57600,115200,230400,460800.
- Auto-reconnect in 30 min when disconnected
- integrated antenna.
- 10 meters' maximum range.
- Dimensions 1mm*12.7mm*27mm.

- **Radio wave transceiver HC-12 modules**

HC-12 transceiver Modules are a wireless communication Modules with serial port that can transmit and receive serial data with a 433 MHz frequency and a distance up to 1000 meter on open space. HC-12 Modules cannot transmit and receive data in the same time because only a half-duplex link is available between the Modules. These modules can be used as a physical cable replacement to substitute communication cable junction of serial half-duplex that carry TTL (Transistor-Transistor Logic) signal.

i. Module hardware

HC-12 module and internal connection are shown in Figure 3.11 below.

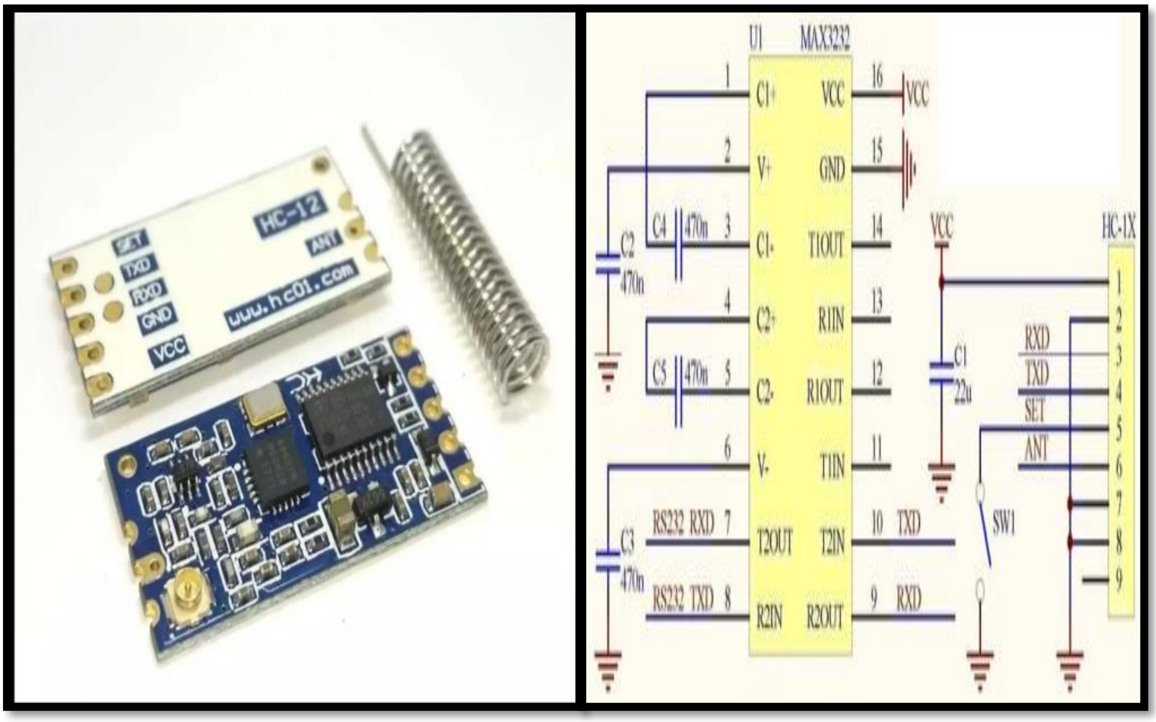


Figure 3.11: HC-12 module

ii. Module specifications

- Long-distance wireless transmission (1,000m in open space/baud rate 5,000bps in the air).
- Working frequency range (433.4-473.0MHz, up to 100 communication channels).
- Maximum 100mW (20dBm) transmitting power.
- Built-in MCU, performing communication with external device through serial port.
- Dimensions 1mm*14.4mm*27.4mm.
- External Antenna.

Table 3.2: HC-12 pin description

Pin	Description
VCC	Power pin (3.2V-5.5V DC)
GND	Ground
RXD	Receiver pin
TXD	Transmitter pin
SET	Parameter setting pin
NC	No connection (used for fixing position)

The serial transmitted data from the helmet is being received using HC-12 module mounted on a serial to USB adapter in order to be displayed on the military base's monitor.

The serial to USB adapter used in this study is USB to ESP -01 is shown in Figure 3.12.

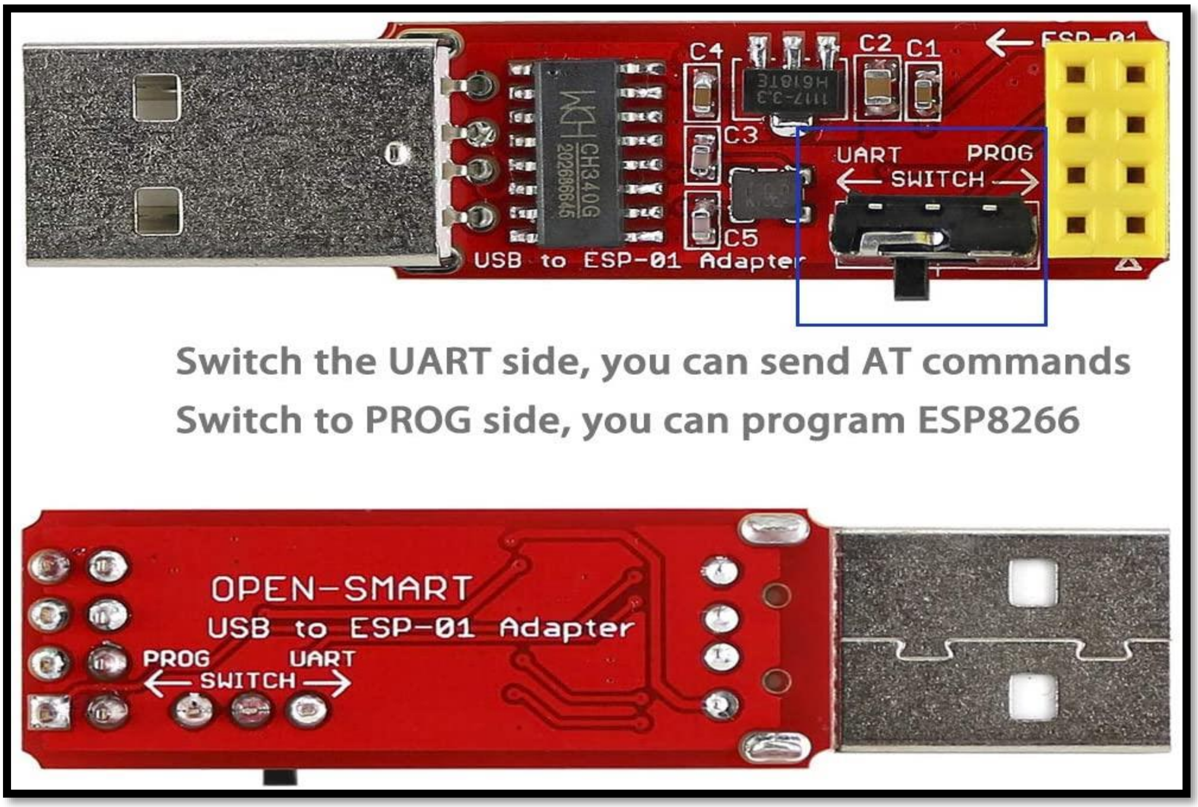


Figure 3.12: USB to ESP-01

3.2.7 GPS system

The GPS system is used to locate the current position of the helmet.

The module used for this purpose is U-blox NEO-6M.

- **Module overview**

  The NEO-6 module is a stand-alone GPS receiver with high speed and accuracy. NEO-6 module is designed for use with passive and active antennas. The minimum gain and maximum gain are 15dB and 50 dB respectively and maximum noise figure is 1.5dB. GPS receivers use a constellation of satellites and ground stations to compute position and time almost anywhere on earth. The positions of the satellites are constructed in a way that the sky above your location will always contain at most 12 satellites which allows GPS receiver to accurately calculate its position and time.

- **Module hardware**

  GPS module consists of U-blox NEO 6M module and GPS antenna as shown in Figure 3.13.

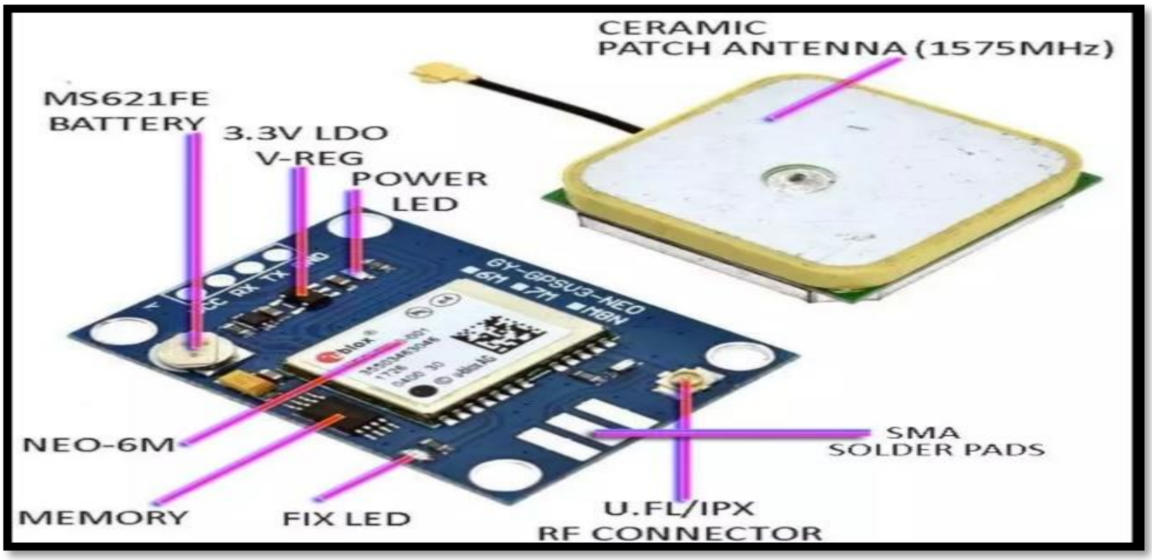


Figure 3.13: GPS module and antenna

- **Module specifications.**
  - Time-To-First-Fix 27 s.
  - Sensitivity of Tracking & Navigation -161 dB.
  - Maximum Navigation update rate 5Hz.
  - Heading accuracy 0.5 degrees.
  - Altitude limit 10 50,000 m.
  - Horizontal position accuracy 2.5 m.
  - Velocity accuracy 0.1m/s.
  - Module Dimensions 22 x 30 x 3 mm.
  - Antenna Dimensions 25 x 25 x 10 mm.
  - Wight 12gm.
- **NMEA sentences**

  NMEA sentence is a line of data called a sentence that is totally self-contained and independent from other sentences. Each sentence begins with a '$' and ends with a carriage return/line feed sequence and can be no longer than 80 characters of visible text. Most computer programs that provide real time position information understand and expect data to be in NMEA sentence format. The position latitude and longitude are defined by the sentence $GPGLL.

3.2.8 Breadboard

The board as shown in Figure 3.14 is used to easily create prototype circuits without having to solder. This is good for quickly building prototypes and test ideas without having to solder a new circuit each time. The holes in the horizontal negative and positive lines (blue and red lines) and the vertical black lines are internally connected and separated from each other.

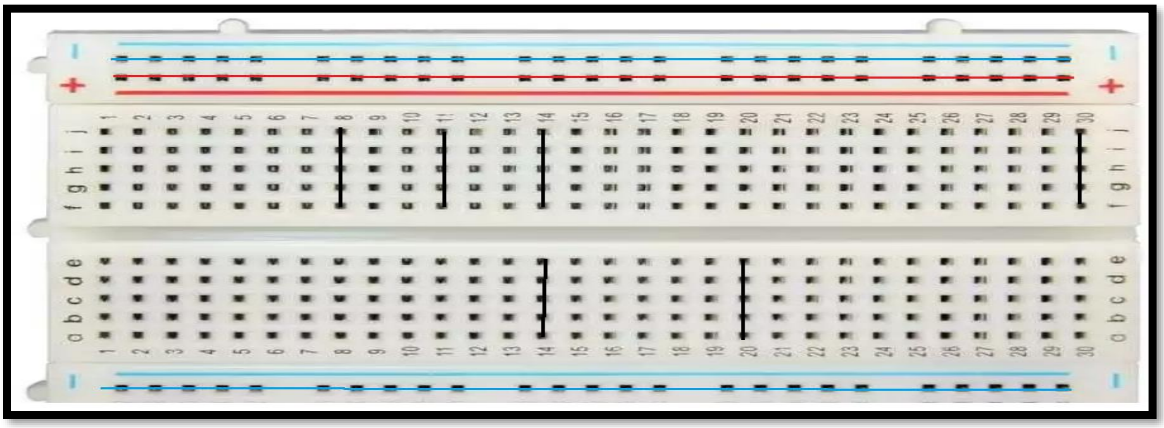


Figure 3.14: Breadboard

3.2.9 Jumper wires

One of the most important parts of the helmet is the cables used for the Connections of the helmet's module with the controller. A jumper wire is a small cable used to connect two points together. The lead of the jumper wire can be either male (has a metal tip) or female (with a pin) hence, the jumper wire combinations (male-male, male-female and female-female).

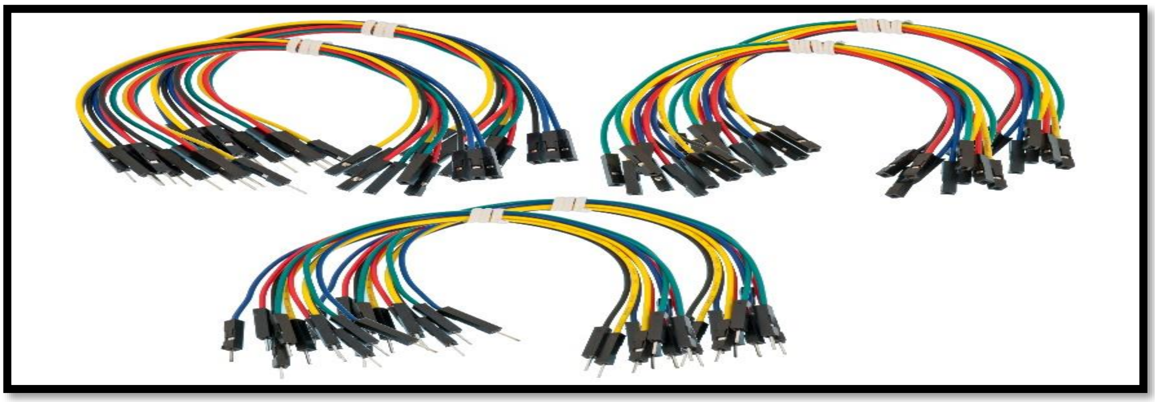


Figure 3.15: Jumper wires

3.2.10 Power supply

A power supply is a circuit that provides continuous DC power source to operate the system's controller and different components. All power supplies consist of two wires (pins). one is the source pin (V_{cc}) and the other one is the ground pin (GND).

The Power supply used in this study is a 12v Li-ion battery cell that is used to supply the IR LED module with 12v.The rest of the components are supplied from a 5v voltage regulator circuit which has a 12v input voltage from the same battery cell.

The voltage regulator circuit and the battery cell are shown in Figure 3.16.

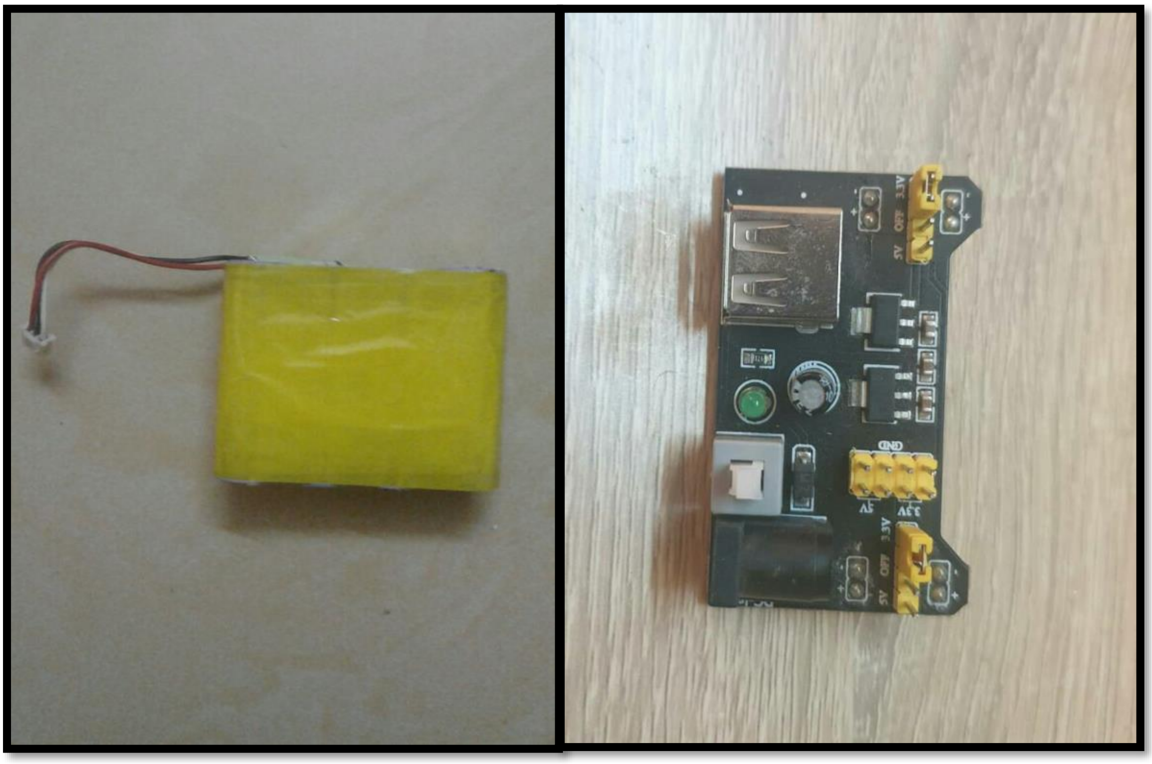


Figure 3.16: Battery cell and voltage regulator circuit

3.3 Software Considerations

System software explains the computer programs used to code and implement the functions of the EWH.

3.3.1 Coding and compiling

- **Arduino IDE**
  is an open source coding platform that uses ArduinoC language which is based on C language the program provides the ability of controlling different modules and components connected to the Arduino microcontroller by the use of specific codes and coding libraries.

- **Processing IDE**

  Processing 3 IDE is an open source coding platform which is compatible with many coding languages. The main purpose of this program is to represent the numerical data received from sensors and different modules, as graphs and diagrams to simplify dealing with them.

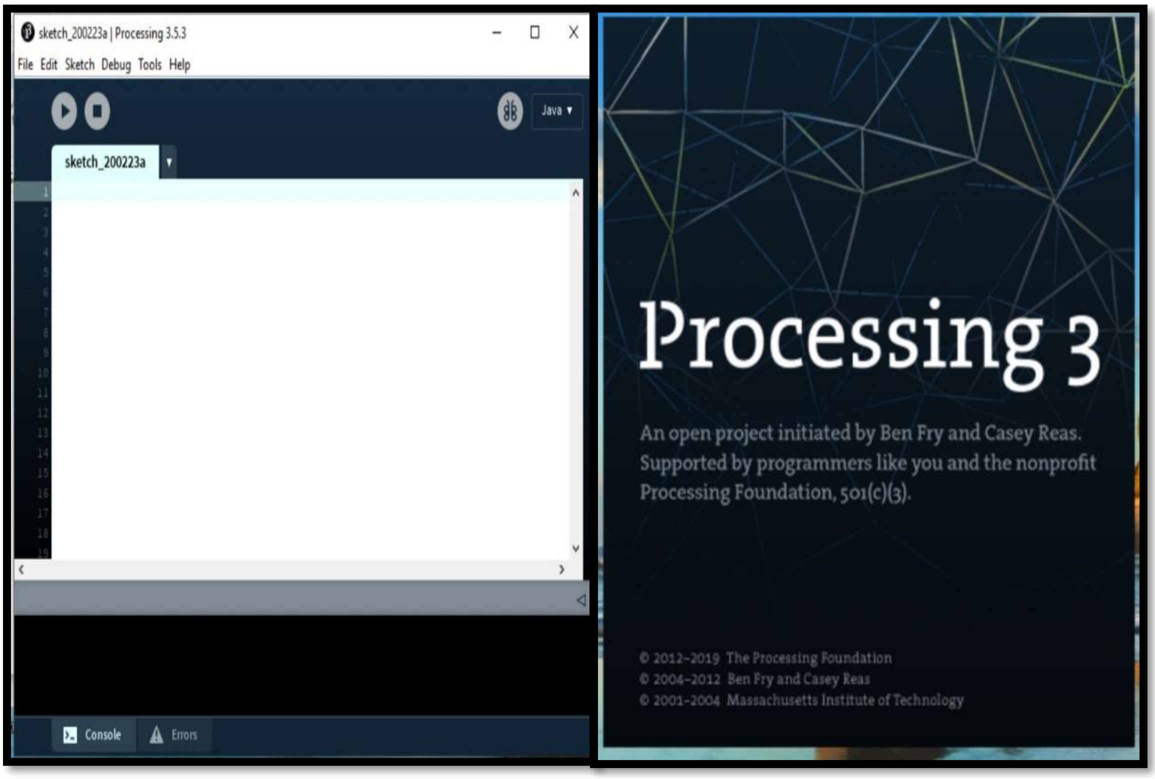


Figure 3.17: Processing 3 IDE program

3.3.2 Observation and monitoring

ArduCam Host is a simple PC program that can receive data from the camera module wirelessly. It provides the ability to take photos, record videos, or live stream videos remotely.

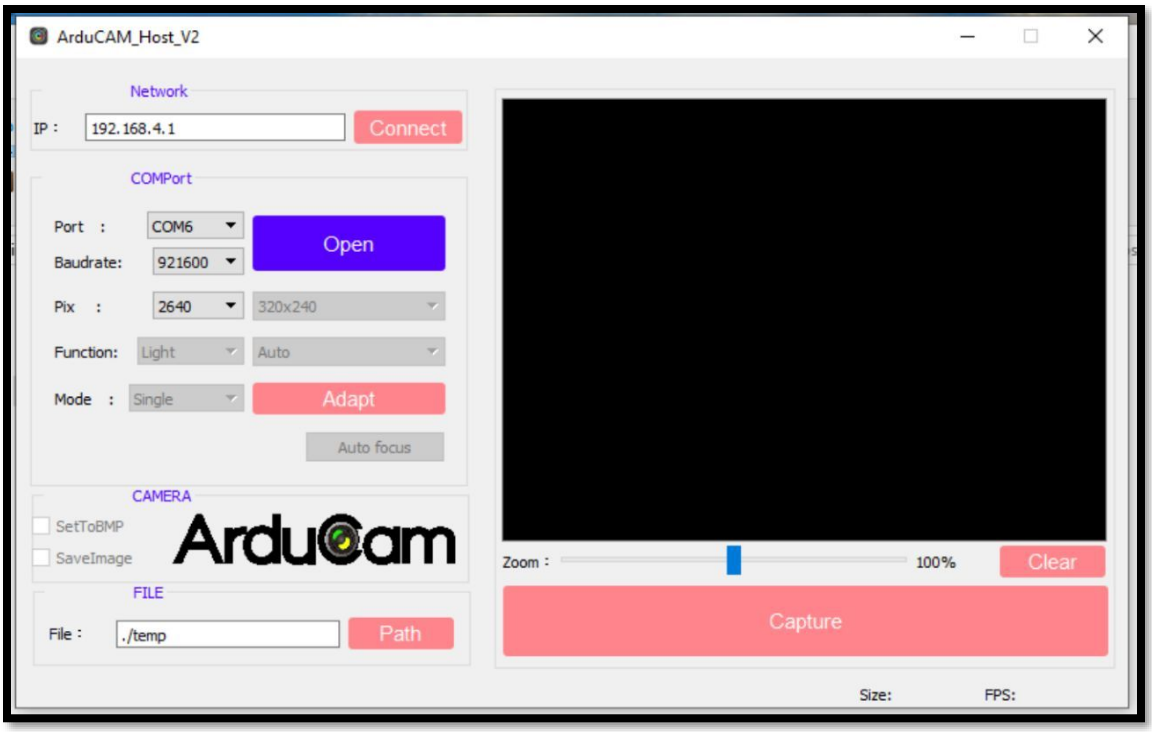
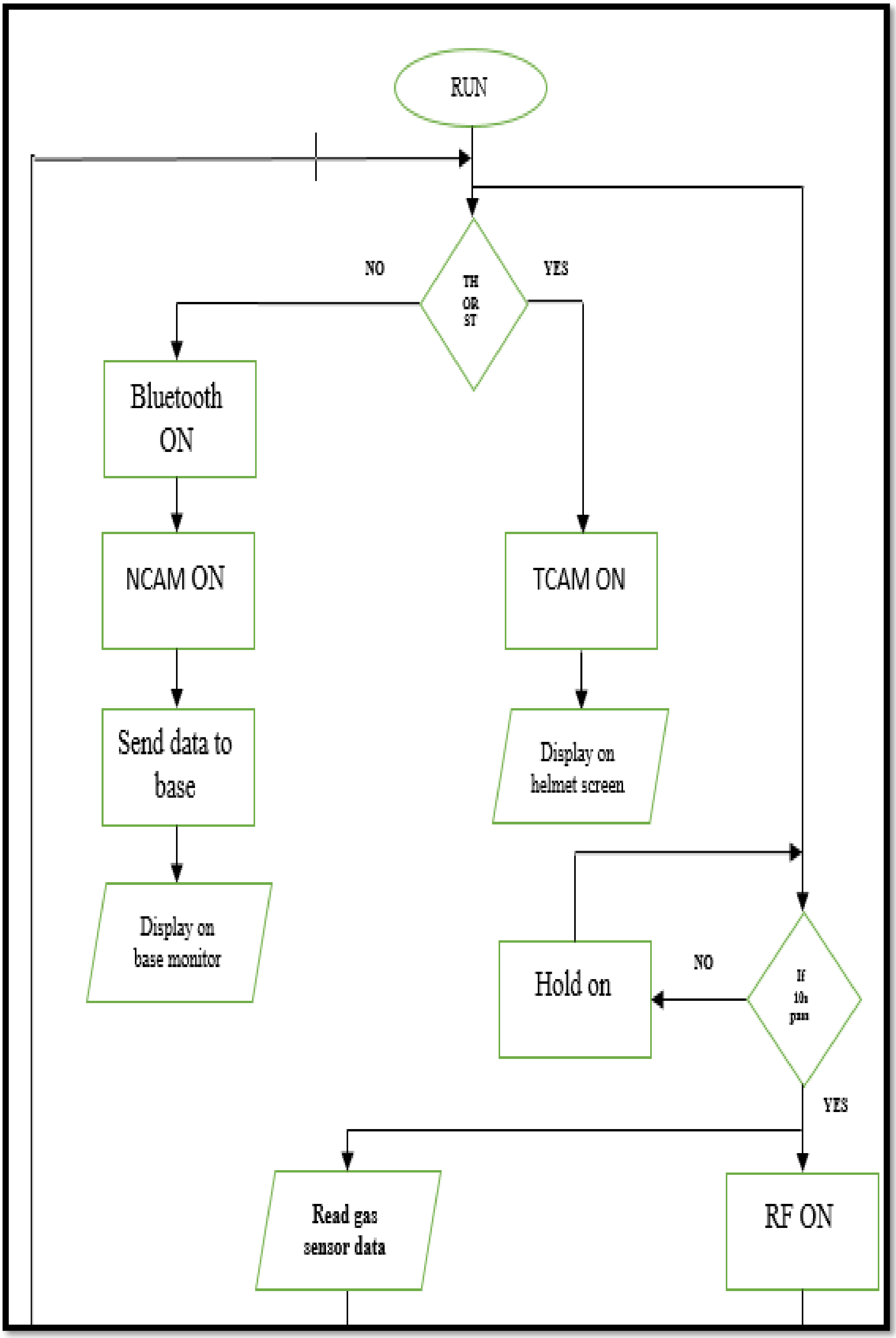


Figure 3.18: ArduCam Host program

3.3.3 System flow chart

The system sequence of the operation is illustrated in flow chart of Figure 3.19.



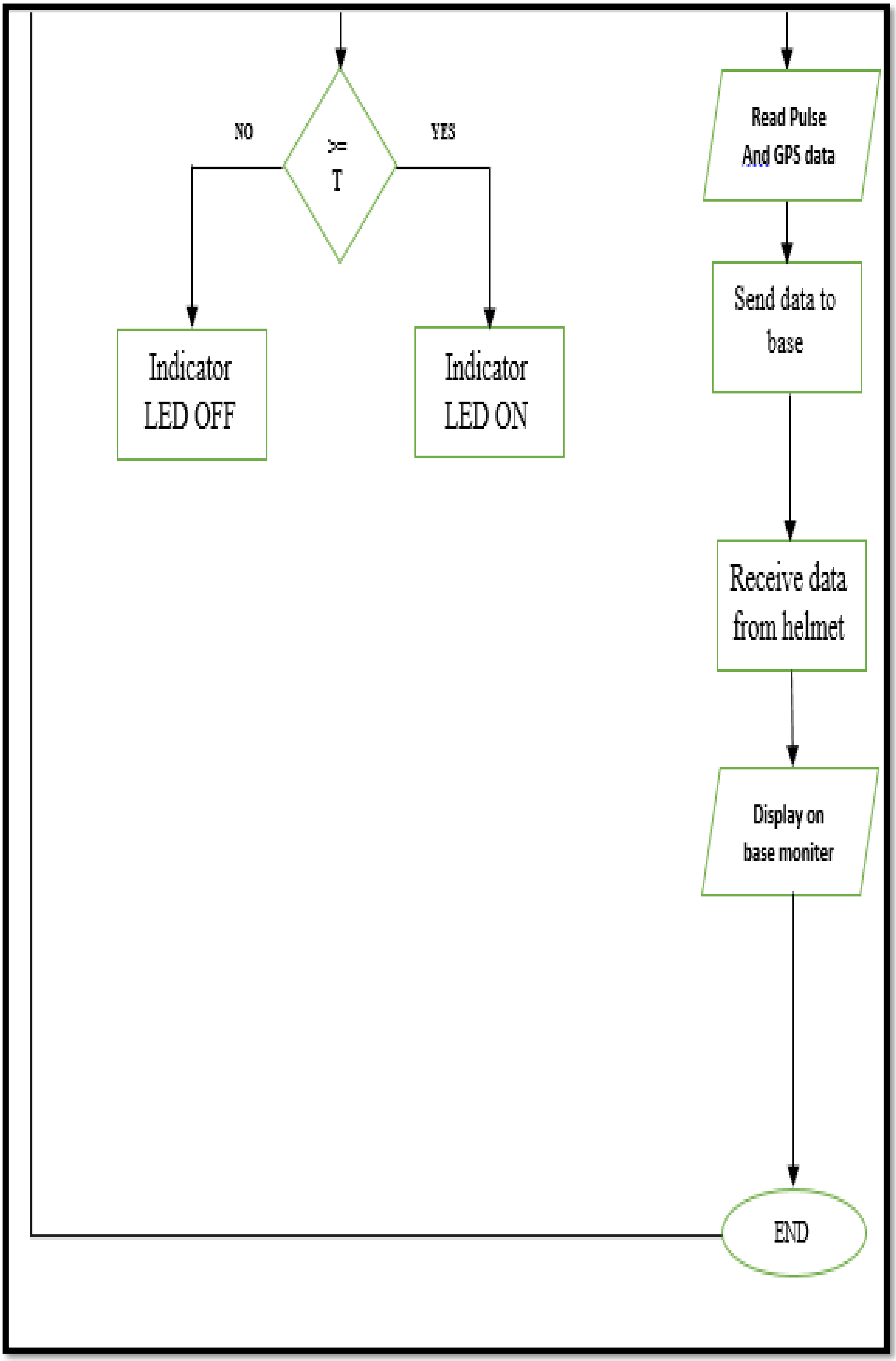


Figure 3.19: System flow chart

Where:

TH: thermal vision.

ST: live stream.

NCAM: night camera.

TCAM: thermal camera.

T: gas sensor threshold

CHAPTER FOUR

SYSTEM IMPLEMENTATION

AND RESULTS

4.1 System Implementation

Electronic warfare helmet contains a metal arm, screen holder, observation camera, thermal camera and a sensing circuit which were combined together to produce the final design.

4.1.1 Mechanical design

The mechanical design of the EWH system is designed as shown in Figure 4.1.

Figure 4.1: Electronic warfare helmet

According to the design which made as shown in Figure 4.1, the following steps had been done to get the best design of the EWH.

The helmet used to hold all the parts is a sturdy hard plastic helmet which was chosen to have a good fitting space and to provide good protection as shown Figure 4.2.

Figure 4.2: Hard plastic helmet

- The screen holder was made entirely from light wood and it consists of one 7x6.5x1 cm, one 4.5x1x1 cm, and two 6.5x1x1 cm that were fixed together using wood glue and six 1.5 cm wood nails. The screen holder was painted in black to match the overall helmet scheme as shown in Figure 4.3.

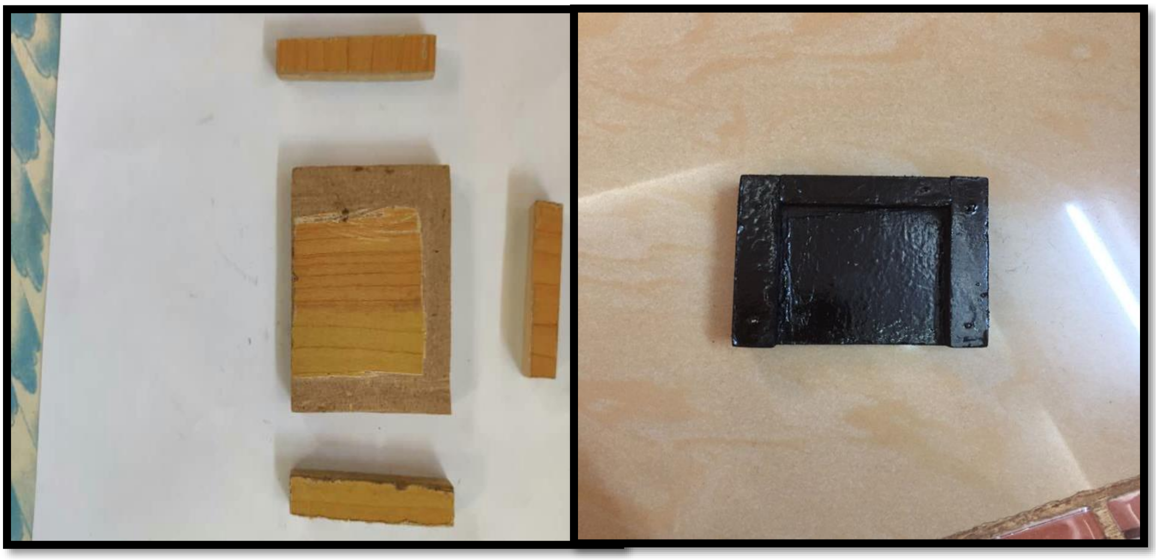


Figure 4.3: TFT screen holder.

- the screen holder was attached to 25 cm metal arm which was bent in a 90-degree angle to match the helmet curve using two 0.75 inch screws as shown in Figure 4.4.

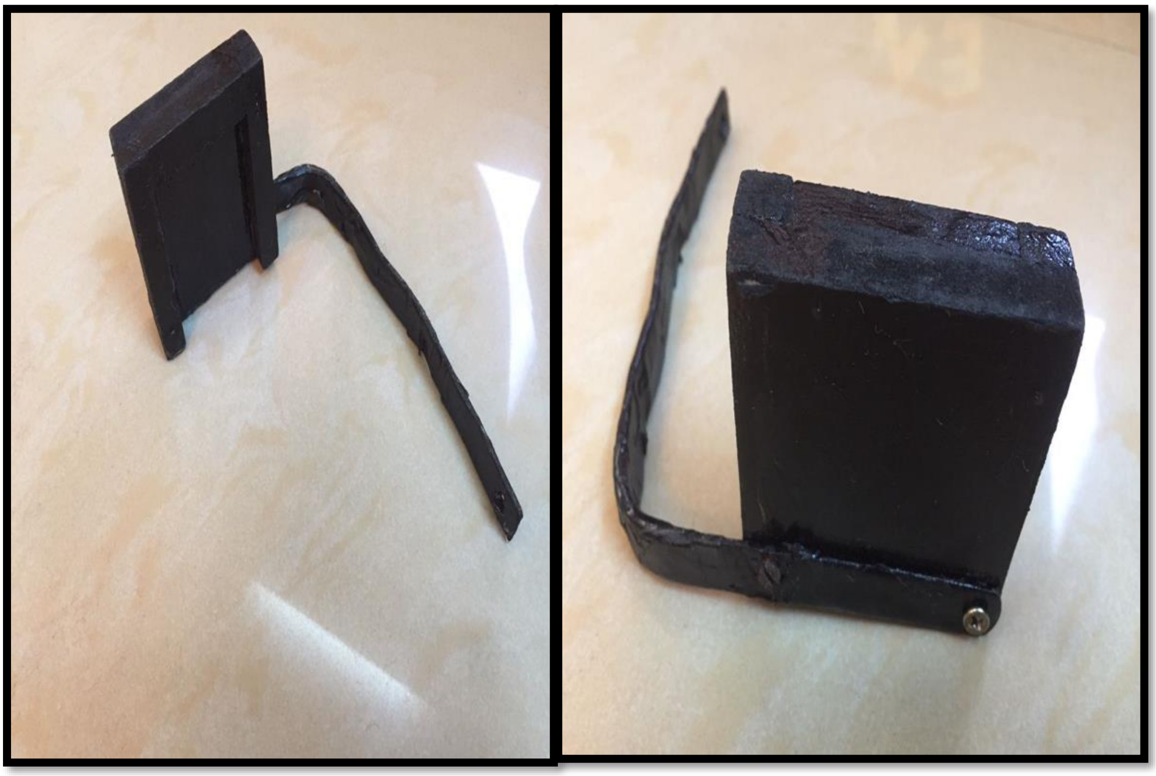


Figure 4.4: Screen holder attached to a metal arm.

- The metal arm was screwed to the left side of the helmet using a one-inch screw and a nut in a way that allows full rotation as shown in Figure 4.5.

Figure 4.5: Metal arm attached to the helmet

- The night vision camera and the thermal camera were fixed inside a casing made of foam and the casing was glued in the front side of the helmet as shown in Figure 4.6.

Figure 4.6: Night and thermal camera attachment.

- The TFT display was glued inside of the screen holder using plastic glue as shown in Figure 4.7.

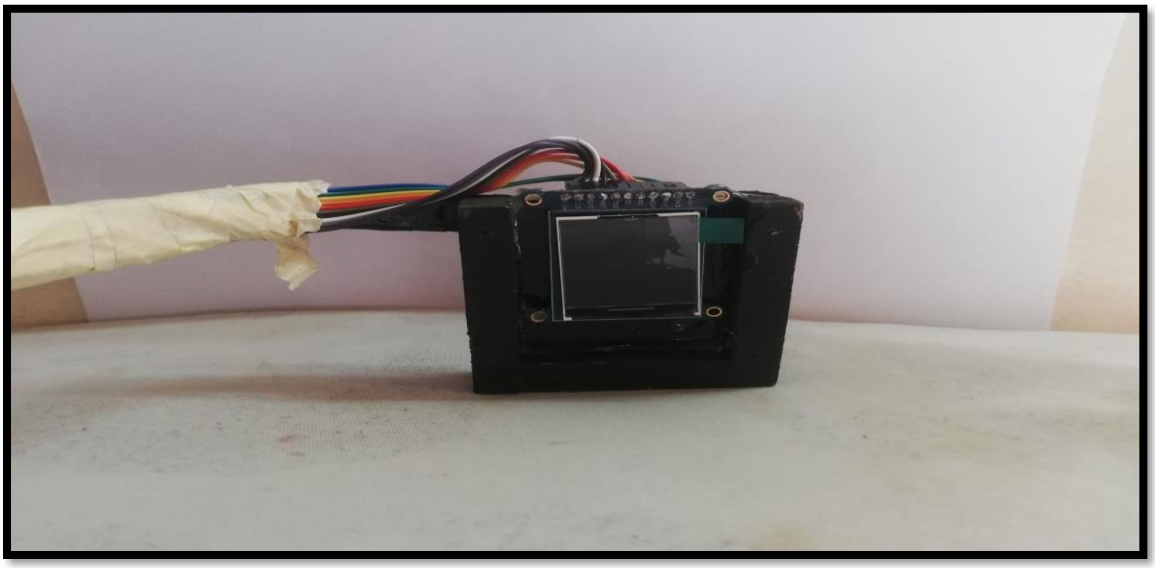


Figure 4.7: TFT screen fixing.

- The GPS module was fixed on top of the helmet and the gas sensor, heart rate, sensor, radio transceiver and Bluetooth module were fixed on the left and right sides as shown in Figure 4.8.

Figure 4.8: Communications modules, sensors and GPS fixing

- Finally, the two cameras, display, GPS, Radio transceiver, Bluetooth and sensors were connected to the main controller using jumper wires which transfer signals and power from and to the control circuit.

4.1.2 Control circuit

The control circuit was created by using a power supply and Arduino microcontroller. The Arduino sends and receive signals from helmet components and provides them with 5v DC to operate. The control circuit is shown in Figure 4.9 below.

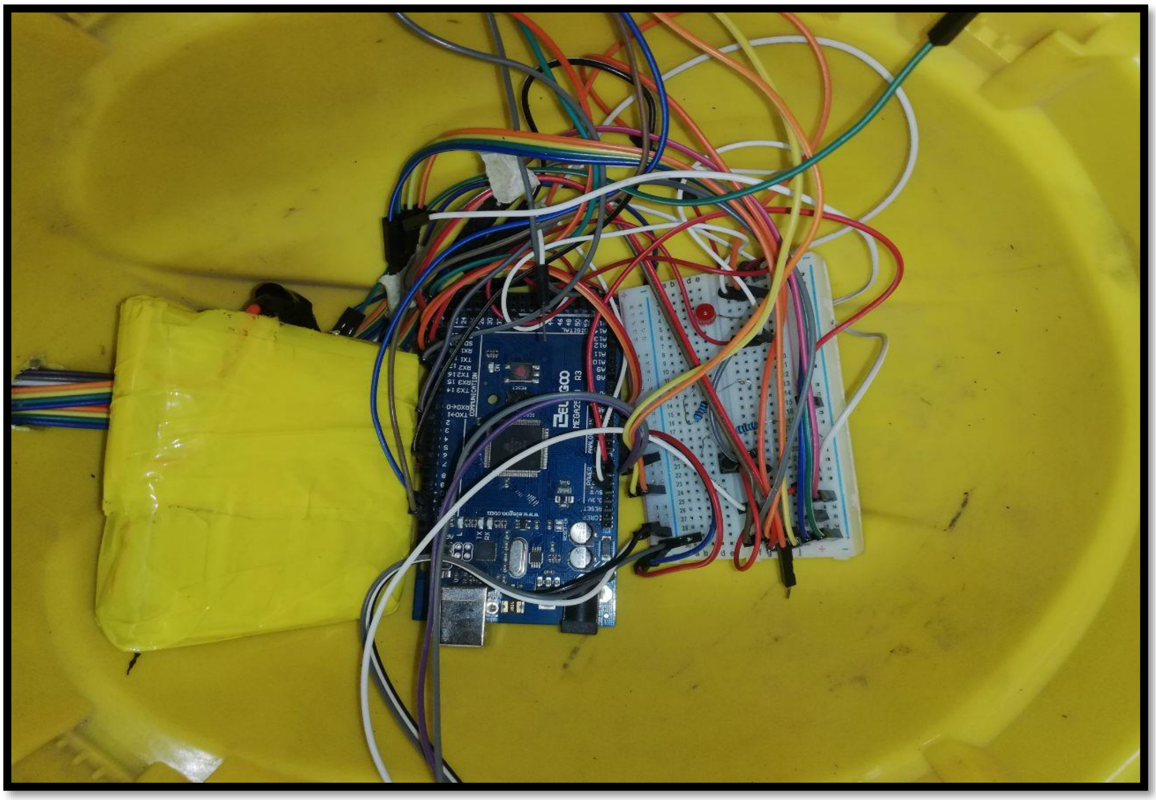


Figure 4.9: Control circuit.

4.2 Testing and Results

An important and significant part of the helmet construction is observing and testing. Whenever a component or program phase was completed there would be a test to check for proper functionality. There were three types of tests namely visual test, sensory test and location test.

4.2.1 Visual test

Visual test was done to assure that the cameras were optimized correctly to give the best possible resolution to give clear images. It has been divided into two tests. The first test was the night vision test and the second test was the thermal imaging test. Both tests were done in a closed room.

- For The night vision test, the camera was turned on and pointed at a wooden bowl placed at 20 cm distance from the night camera. The night camera testing was divided into low light test and normal light test.
    - In normal light test all the lights where turned on then a picture was taken using ArduCam host program
    - In low light test, the lights of the room were turned completely off and the IR LED was turned on automatically then a picture was taken in the dark.

      The results of the normal and low light tests were both displayed on computer screen as shown in Figure 4.10 below.

Figure 4.10: Low light vs Normal light

- For thermal imaging test the thermal camera was turned on and it was pointed at different objects with different heat signatures to ensure it was functioning properly.

  Thermal imaging test was done in two steps as follows

  - In the first step, two cups were filled with boiling hot and cold ice water respectively and they were placed side by side as shown in Figure 4.11 below.

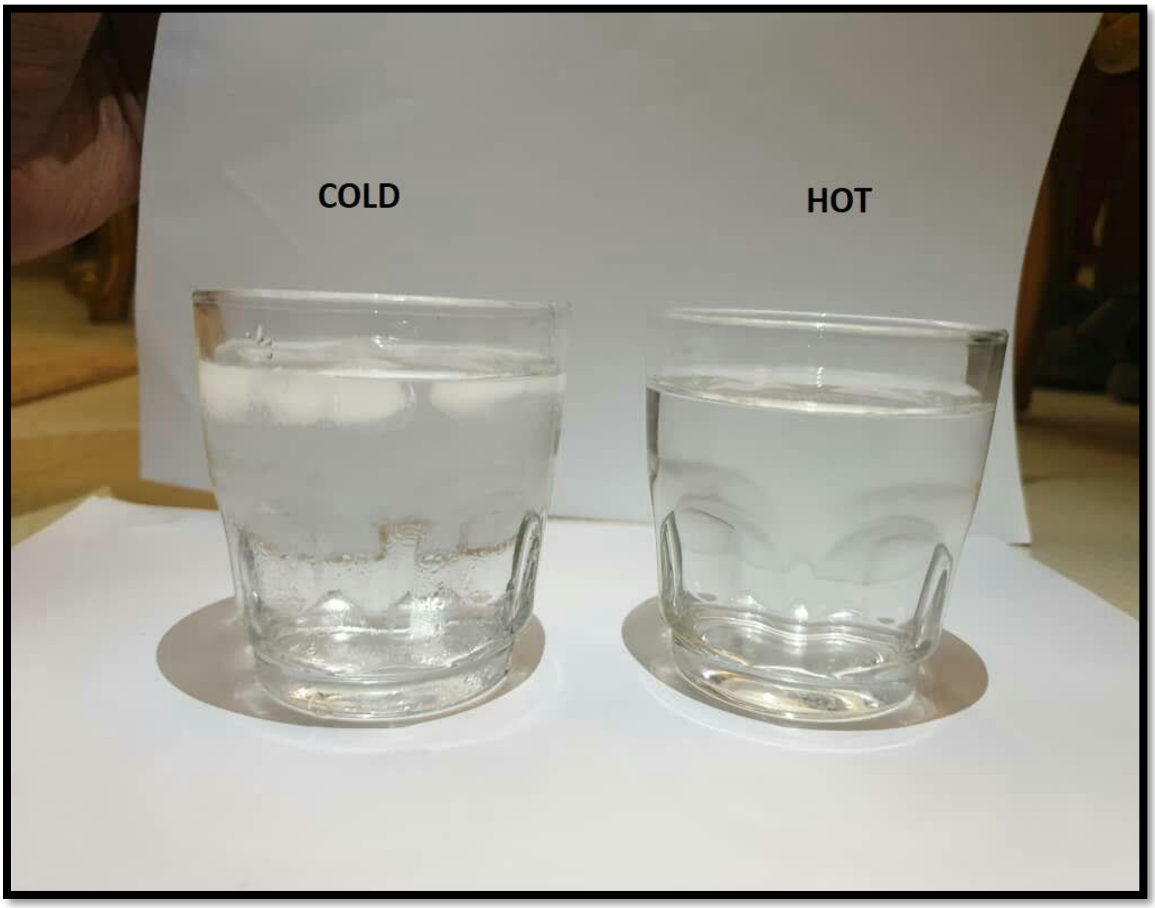


Figure 4.11: Cold and hot water cups

  - In the second step, the thermal camera was pointed at the two cups from a 20 cm distance. The heat emitted from the two cups were captured by the thermal camera and displayed on the helmet screen as shown in Figure 4.12.

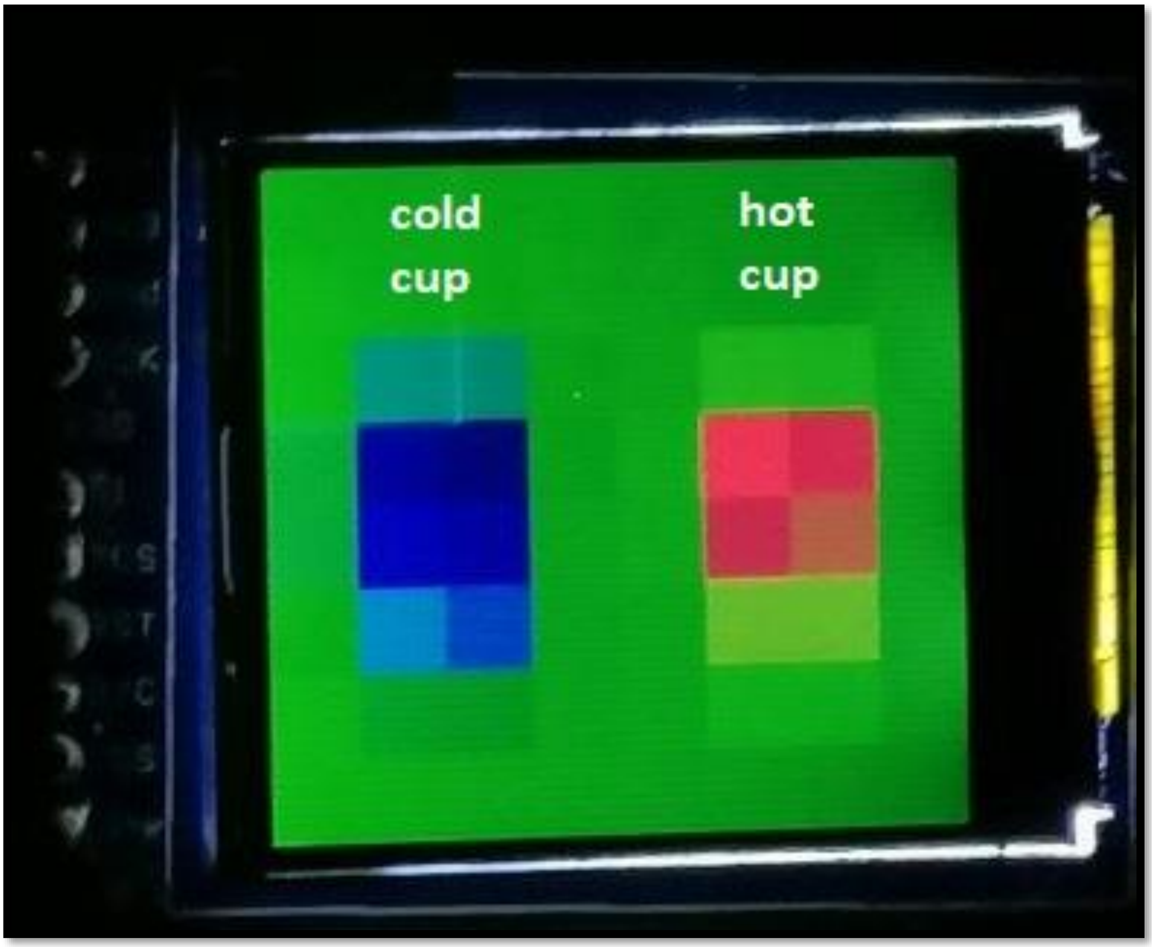


Figure 4.12: Heat comparison results

4.2.2 Sensory test

The word “Sensory” implies the tests that were done using the helmet’s sensors to measure different parameters.

Sensory test was done in two part. The first part was the vital conditions test and the second part was area toxicity level test.

- For the first part, the heart pulse sensor was attached to the neck of a human being using a plastic patch. Each heart beat was recorded by the sensor and was graphically represented and displayed in the computer screen as shown in Figure 4.13.

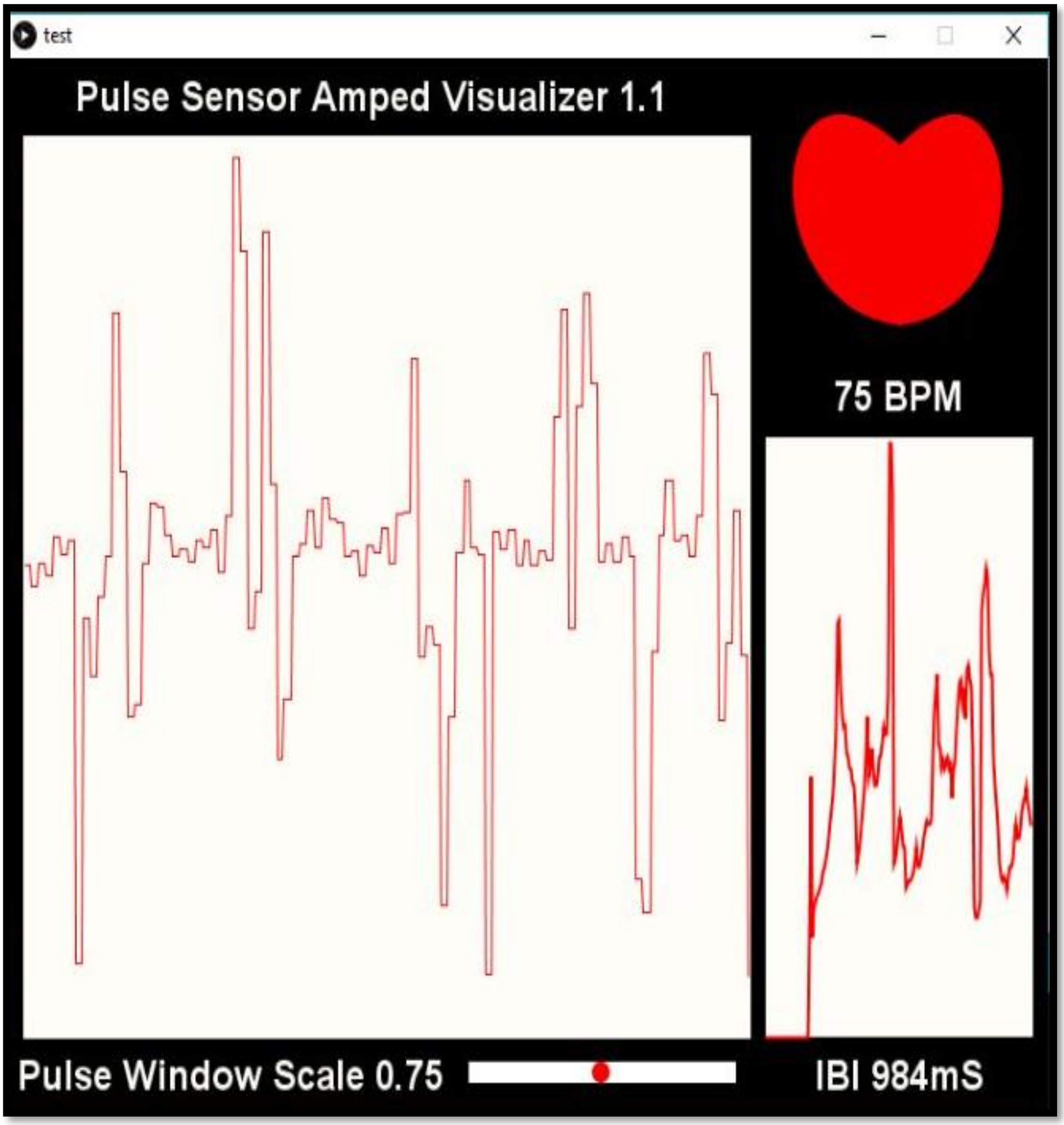


Figure 4.13: Heart rate (BPM) vs Time

- In the second part, a piece of paper was burnt to produce smoke containing different gases.

  The burnt paper was placed in 100 cm distance from the gas sensor, the distance was decreased by 10 cm each time until it reached zero cm.

The output voltage of the sensor was calculated using the following equation:

$$V_{out} = \frac{ADC \times Vc}{1023} \quad (4.1)$$

Whereas:

V_{out} = sensor output voltage.

ADC = the analog reading of the sensor.

V_c =Controller voltage (5V).

The relation between the distance and gas sensor output voltage was plotted to produce a curve as shown in Figure 4.14.

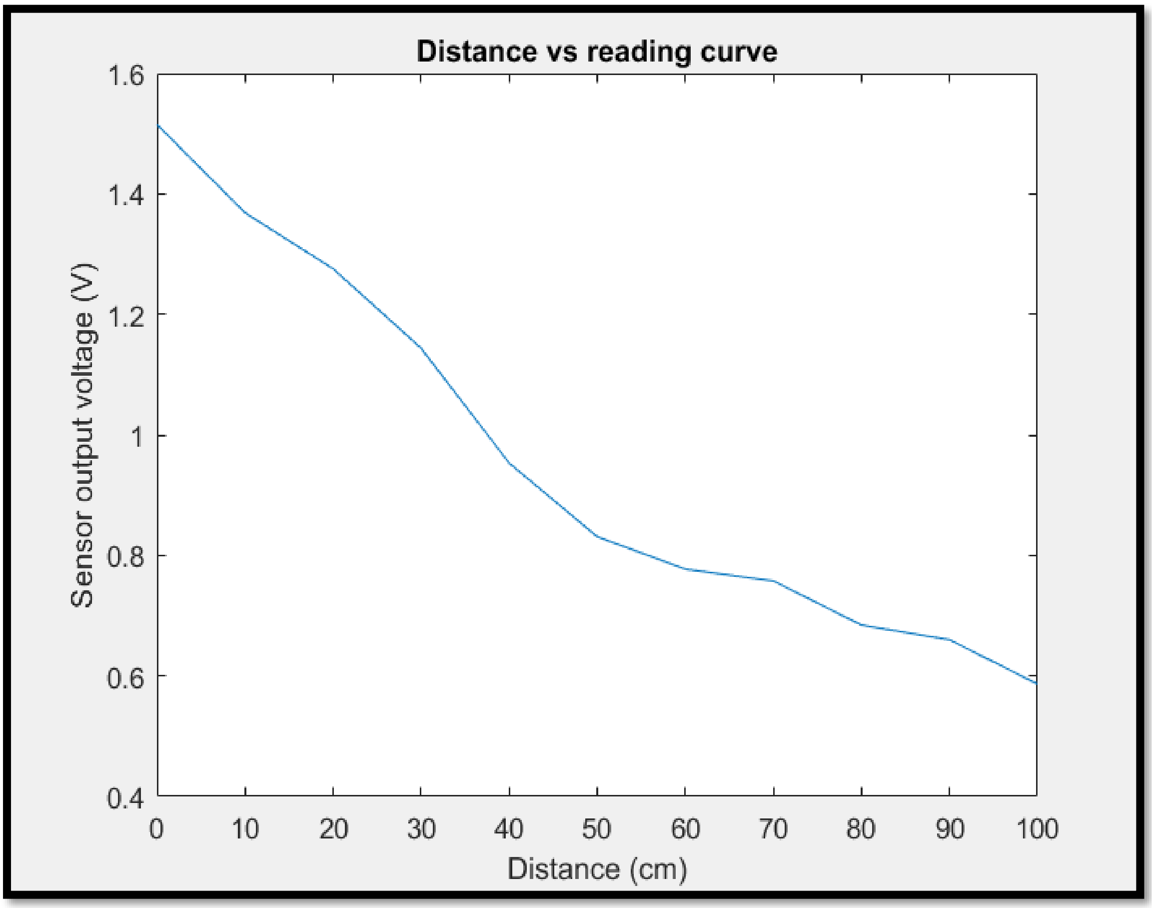


Figure 4.14: Gas sensor distance vs Voltage curve

4.2.3 Location test

The location test describes the helmet's capability of determining the accurate position of the solider using GPS. The test was done in two steps, accurate location testing and helmet location testing. The tests took place in Nile street in Omdurman.

- The accurate position of the solider was recorded using a standard GPS device. A laptop with integrated GPS chip was used for this study.

  The accurate position of the solider is given by altitudes and longitudes using google maps as shown Figure 4.15.

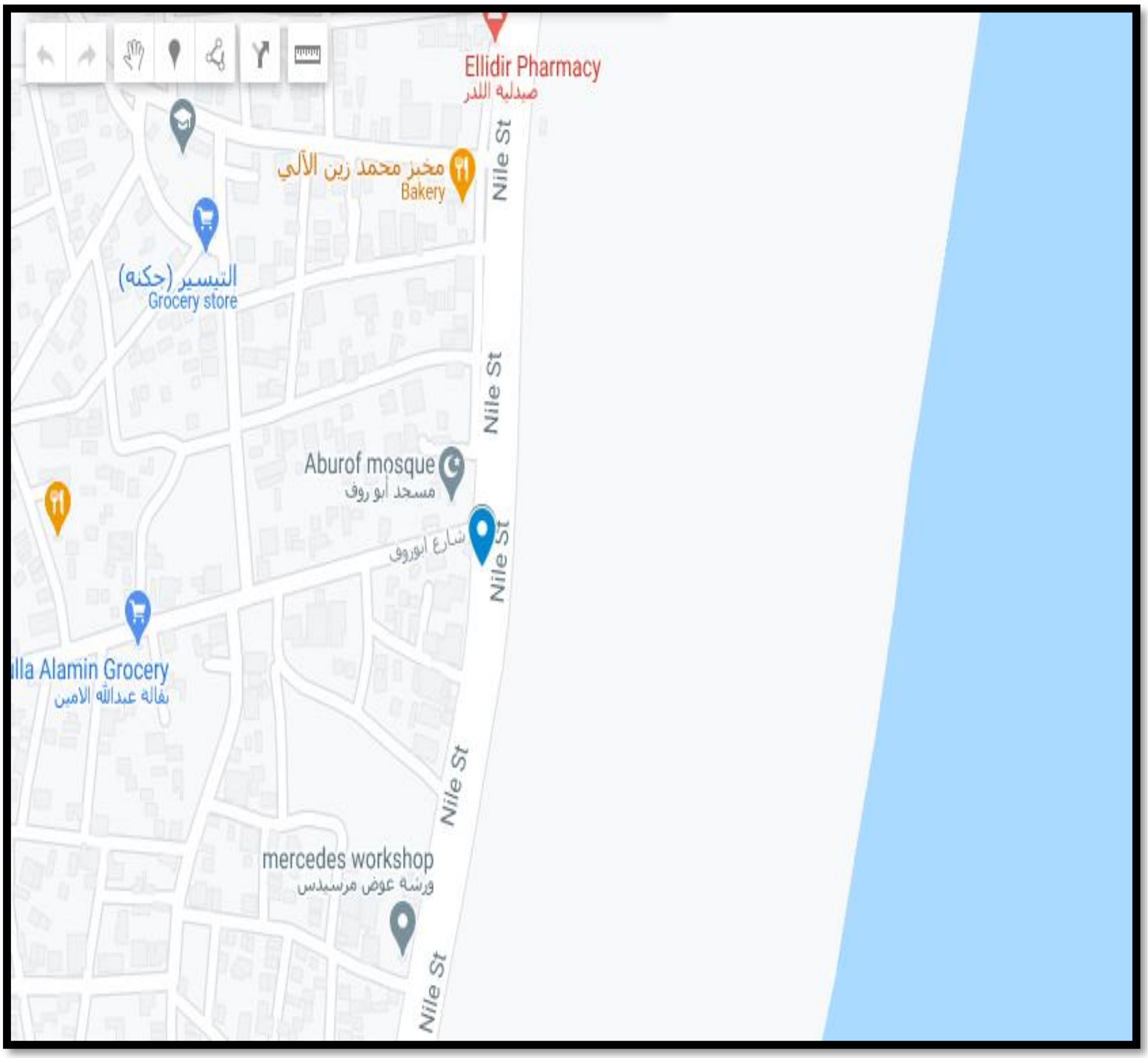


Figure 4.15: Accurate location

- The helmet's location was recorded using the GPS module and it showed to be within a range of 200-450 meters from the actual location. Helmet location was displayed in google maps as shown in Figure 4.16.

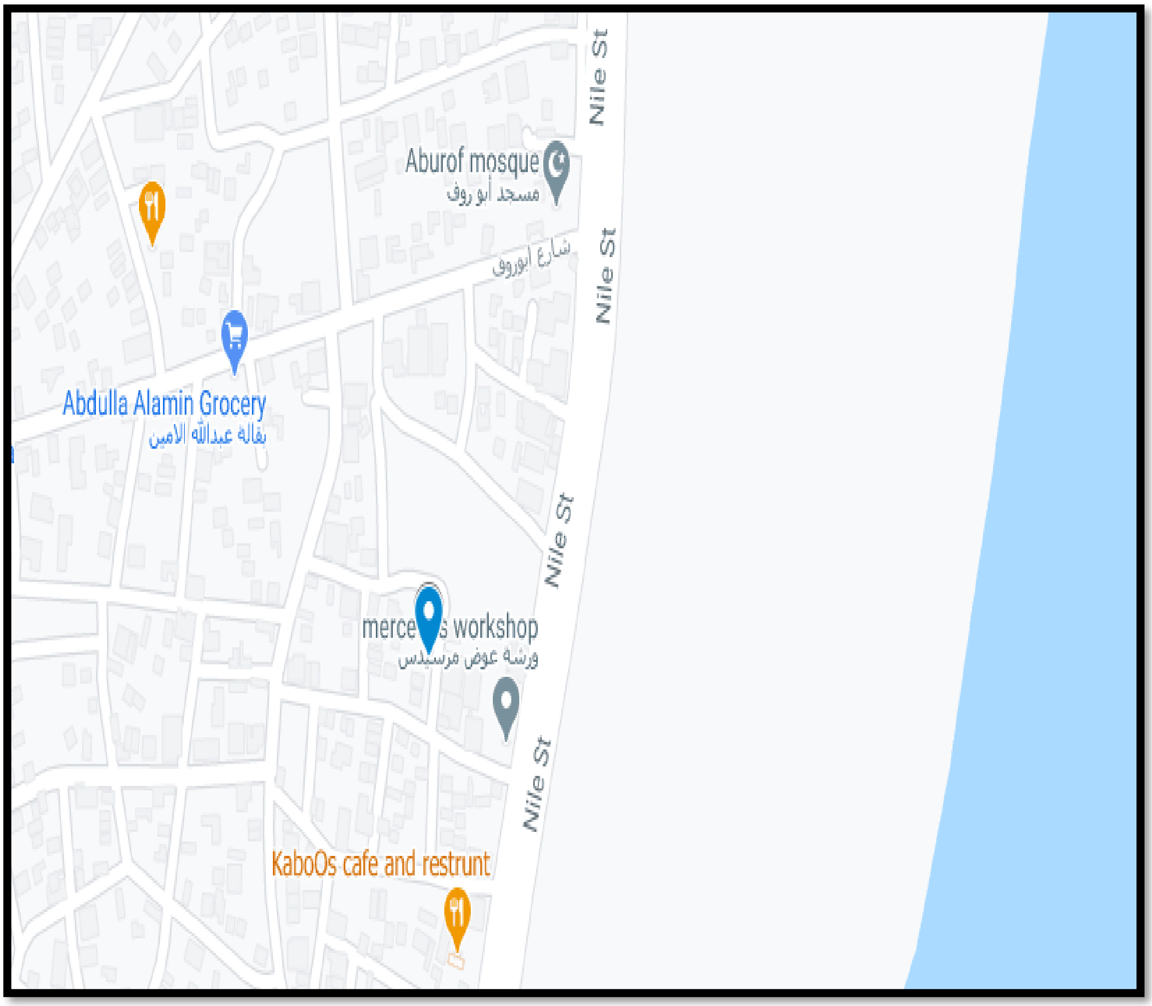


Figure 4.16: Helmet location.

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CHAPTER FIVE
CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

An electronic warfare helmet, is created for the main and specific purposes of assisting the soldier in many tasks and enhancing his efficiency and ability during military operations, using the Arduino controller.

This project was chosen because of the many difficulties faced by soldiers, namely the loss of communication, the difficulty of determining the exact geographical location of the soldier during war, limited vision and possible inhalation of some toxic gases. To solve these problems, a thermal camera, night camera and a monitoring system were developed and installed on the helmet. The thermal camera was able to give acceptable thermal images which are displayed in the helmet's screen. As for the night camera and the monitoring system, the data sent to the military base showed to be almost accurate. Weight, sturdiness and handling of all conditions were considered in making this project.

5.2 Recommendations

During this project creation, several problems where noticed. Most of them were solved, but not all of them. Therefore, the project has a large capacity for further improvements

- Using a servo motor to automatically move the metal arm up and down when using the thermal camera.
- Using a more advanced controller with higher processing speeds for performance increase.

- Increasing the sensors to gain more information about the solider conditions.
- Adding Voice communication capabilities between the soldiers and the military base.
- Encrypting the information between the helmet and the military base.
- Adding the ability of viewing the night camera outputs in the helmet screen.
- Develop an operating system for the military base to manage multiple helmets.

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APPENDIX A

Arduino microcontroller code for the EWH operations

```
#include <Adafruit_GPS.h>
#define GPSSerial Serial1
Adafruit_GPS GPS(&GPSSerial);
int smokeA0 = A2;
int sensorThres = 50;
#define GPSECHO false
int pulsePin = 0;
pin 0
volatile int analogSensor; volatile int BPM; volatile int Signal;
volatile int IBI = 600; volatile boolean Pulse = false;
volatile boolean QS = false; volatile char c;
uint32_t timer = millis(); int state;
#include <Adafruit_GFX.h>
#include <Adafruit_ST7735.h>
#include <Adafruit_AMG88xx.h>
#define TFT_CS     53
#define TFT_RST    9
#define TFT_DC     8
#define MINTEMP 22
#define MAXTEMP 34
const uint16_t camColors[] = {0x480F,
0x400F,0x400F,0x400F,0x4010,0x3810,0x3810,0x3810,0x3810,0x3010,0x3010,
0x3010,0x2810,0x2810,0x2810,0x2810,0x2010,0x2010,0x2010,0x1810,0x1810,
0x1811,0x1811,0x1011,0x1011,0x1011,0x0811,0x0811,0x0811,0x0011,0x0011,
```

0x0011,0x0011,0x0011,0x0031,0x0031,0x0051,0x0072,0x0072,0x0092,0x00
B2,

0x00B2,0x00D2,0x00F2,0x00F2,0x0112,0x0132,0x0152,0x0152,0x0172,0x0
192,

0x0192,0x01B2,0x01D2,0x01F3,0x01F3,0x0213,0x0233,0x0253,0x0253,0x0
273,

0x0293,0x02B3,0x02D3,0x02D3,0x02F3,0x0313,0x0333,0x0333,0x0353,0x
0373,

0x0394,0x03B4,0x03D4,0x03D4,0x03F4,0x0414,0x0434,0x0454,0x0474,0x
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0x05AD,0x05AC,0x05AC,0x05AB,0x05CB,0x05CB,0x05CA,0x05CA,0x05
CA,0x05C9,

0x05C9,0x05C8,0x05E8,0x05E8,0x05E7,0x05E7,0x05E6,0x05E6,0x05E6,0x
05E5,

0x05E5,0x0604,0x0604,0x0604,0x0603,0x0603,0x0602,0x0602,0x0601,0x0
621,

0x0621,0x0620,0x0620,0x0620,0x0620,0x0E20,0x0E20,0x0E40,0x1640,0x1
640,

0x1E40,0x1E40,0x2640,0x2640,0x2E40,0x2E60,0x3660,0x3660,0x3E60,0x3
E60,

0x3E60,0x4660,0x4660,0x4E60,0x4E80,0x5680,0x5680,0x5E80,0x5E80,0x6
680,

0x6680,0x6E80,0x6EA0,0x76A0,0x76A0,0x7EA0,0x7EA0,0x86A0,0x86A0,
0x8EA0,

0x8EC0,0x96C0,0x96C0,0x9EC0,0x9EC0,0xA6C0,0xAEC0,0xAEC0,0xB6E
0,0xB6E0,

0xBEE0,0xBEE0,0xC6E0,0xC6E0,0xCEE0,0xCEE0,0xD6E0,0xD700,0xDF
00,0xDEE0,

0xDEC0,0xDEA0,0xDE80,0xDE80,0xE660,0xE640,0xE620,0xE600,0xE5E
0,0xE5C0,

```
0xE5A0,0xE580,0xE560,0xE540,0xE520,0xE500,0xE4E0,0xE4C0,0xE4A0,
0xE480,
0xE460,0xEC40,0xEC20,0xEC00,0xEBE0,0xEBC0,0xEBA0,0xEB80,0xEB6
0,0xEB40,
0xEB20,0xEB00,0xEAE0,0xEAC0,0xEAA0,0xEA80,0xEA60,0xEA40,0xF2
20,0xF200,
0xF1E0,0xF1C0,0xF1A0,0xF180,0xF160,0xF140,0xF100,0xF0E0,0xF0C0,0
xF0A0,
0xF080,0xF060,0xF040,0xF020,0xF800,};
Adafruit_ST7735 tft = Adafruit_ST7735(TFT_CS,  TFT_DC, TFT_RST);
Adafruit_AMG88xx amg; unsigned long delayTime;
float pixels[AMG88xx_PIXEL_ARRAY_SIZE];
uint16_t displayPix00elWidth, displayPixelHeight;
#include <SoftwareSerial.h>
#include <Wire.h>
#include <ArduCAM.h>
#include <SPI.h>
#include "memorysaver.h"
SoftwareSerial mySerial(12, 13); // RX, TX
#if !(defined OV2640_MINI_2MP)
#endif
#define BMPIMAGEOFFSET 66
const char bmp_header[BMPIMAGEOFFSET] PROGMEM ={
0x42, 0x4D, 0x36, 0x58, 0x02, 0x00, 0x00, 0x00, 0x00, 0x00, 0x42, 0x00,
0x00, 0x00, 0x28, 0x00,
0x00, 0x00, 0x40, 0x01, 0x00, 0x00, 0xF0, 0x00, 0x00, 0x00, 0x01, 0x00,
0x10, 0x00, 0x03, 0x00,
0x00, 0x00, 0x00, 0x58, 0x02, 0x00, 0xC4, 0x0E, 0x00, 0x00, 0xC4, 0x0E,
0x00, 0x00, 0x00, 0x00,
0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0xF8, 0x00, 0x00, 0xE0, 0x07,
0x00, 0x00, 0x1F, 0x00,0x00, 0x00};
const int CS = 7; bool is_header = false; int mode = 0;
```

```
uint8_t start_capture = 0;
#if defined (OV2640_MINI_2MP)
ArduCAM myCAM( OV2640, CS );
#else
ArduCAM myCAM( OV5642, CS );
#endif
uint8_t read_fifo_burst(ArduCAM myCAM);
void setup(){
Serial.begin(115200);  mySerial.begin(115200);
interruptSetup();
pinMode(2, INPUT_PULLUP);
pinMode(smokeA0, INPUT);
pinMode(A0,INPUT);
pinMode(4, OUTPUT);
GPS.begin(9600);
delay(100);
GPS.sendCommand(PMTK_SET_NMEA_OUTPUT_RMCGGA);
delay(100);
RMC+GGA since
GPS.sendCommand(PMTK_SET_NMEA_UPDATE_1HZ);
delay(1000);
GPSSerial.println(PMTK_Q_RELEASE);
uint8_t vid, pid;
uint8_t temp;
#if defined(__SAM3X8E__)
Wire1.begin();
Serial2.begin(115200);
#else
Wire.begin();
Serial2.begin(115200);
```

```
#endif
Serial2.println(F("ACK CMD ArduCAM Start! END"));
pinMode(CS, OUTPUT);
digitalWrite(CS, HIGH);
SPI.begin();
myCAM.write_reg(0x07, 0x80);
delay(100);
myCAM.write_reg(0x07, 0x00);
delay(100);
while(1){
myCAM.write_reg(ARDUCHIP_TEST1, 0x55);
temp = myCAM.read_reg(ARDUCHIP_TEST1);
if (temp != 0x55){
Serial2.println(F("ACK CMD SPI interface Error! END"));
delay(1000);continue;  }
else{
Serial2.println(F("ACK CMD SPI interface OK. END"));break; } }
#if defined (OV2640_MINI_2MP)
while(1){
myCAM.wrSensorReg8_8(0xff, 0x01);
myCAM.rdSensorReg8_8(OV2640_CHIPID_HIGH, &vid);
myCAM.rdSensorReg8_8(OV2640_CHIPID_LOW, &pid);
if ((vid != 0x26 ) && (( pid != 0x41 ) || ( pid != 0x42 ))){
Serial2.println(F("ACK CMD Can't find OV2640 module! END"));
delay(1000);continue;  }
else{
Serial2.println(F("ACK CMD OV2640 detected. END"));break; } }
#else
while(1){
myCAM.wrSensorReg16_8(0xff, 0x01);
```

```
myCAM.rdSensorReg16_8(OV5642_CHIPID_HIGH, &vid);
myCAM.rdSensorReg16_8(OV5642_CHIPID_LOW, &pid);
if((vid != 0x56) || (pid != 0x42)){
Serial2.println(F("ACK CMD Can't find OV5642 module! END"));
delay(1000);continue;   }
else{
Serial2.println(F("ACK CMD OV5642 detected. END"));break;  }   }
#endif
myCAM.set_format(JPEG);myCAM.InitCAM();
#if defined (OV2640_MINI_2MP)
myCAM.OV2640_set_JPEG_size(OV2640_320x240);
#else
myCAM.write_reg(ARDUCHIP_TIM, VSYNC_LEVEL_MASK);
myCAM.OV5642_set_JPEG_size(OV5642_320x240);
#endif
delay(1000);
myCAM.clear_fifo_flag();
#if !(defined (OV2640_MINI_2MP))
myCAM.write_reg(ARDUCHIP_FRAMES,0x00);
#endif
 Serial.println(F("AMG88xx thermal camera!"));
pinMode(TFT_CS,OUTPUT); digitalWrite(TFT_CS,HIGH);
tft.initR(INITR_144GREENTAB);  tft.fillScreen(ST7735_BLACK);
 displayPixelWidth = tft.width() / 8;  displayPixelHeight = tft.height() / 8;
bool status;  status = amg.begin();
if (!status) {
Serial.println("Could not find a valid AMG88xx sensor, check wiring!");
while (1){
delay(100); }
void sendDataToProcessing(char symbol, int data ){
```

```
mySerial.print(symbol); mySerial.println(data);  }
void loop(){
state= digitalRead(2);
if(state==0){
uint8_t temp = 0xff, temp_last = 0; bool is_header = false;
if (Serial2.available()){
temp = Serial2.read();
switch (temp){
case 0:
#if defined (OV2640_MINI_2MP)
myCAM.OV2640_set_JPEG_size(OV2640_160x120);delay(1000);
Serial2.println(F("ACK CMD switch to OV2640_160x120 END"));
#elif defined (OV3640_MINI_3MP)
myCAM.OV3640_set_JPEG_size(OV3640_176x144);delay(1000);
Serial2.println(F("ACK CMD switch to OV2640_160x120 END"));
#else
myCAM.OV5642_set_JPEG_size(OV5642_320x240);delay(1000);
Serial2.println(F("ACK CMD switch to OV5642_320x240 END"));
#endif
temp = 0xff;  break;
case 1:
#if defined (OV2640_MINI_2MP)
myCAM.OV2640_set_JPEG_size(OV2640_176x144);delay(1000);
Serial2.println(F("ACK CMD switch to OV2640_176x144 END"));
#elif defined (OV3640_MINI_3MP)
myCAM.OV3640_set_JPEG_size(OV3640_320x240);delay(1000);
Serial2.println(F("ACK CMD switch to OV3640_320x240 END"));
#else
myCAM.OV5642_set_JPEG_size(OV5642_640x480);delay(1000);
Serial2.println(F("ACK CMD switch to OV5642_640x480 END"));
```

```
#endif
temp = 0xff; break;
case 2:
#if defined (OV2640_MINI_2MP)
myCAM.OV2640_set_JPEG_size(OV2640_320x240);delay(1000);
Serial2.println(F("ACK CMD switch to OV2640_320x240 END"));
#elif defined (OV3640_MINI_3MP)
myCAM.OV3640_set_JPEG_size(OV3640_352x288);delay(1000);
Serial2.println(F("ACK CMD switch to OV3640_352x288 END"));
#else
myCAM.OV5642_set_JPEG_size(OV5642_1024x768);delay(1000);
Serial2.println(F("ACK CMD switch to OV5642_1024x768 END"));
#endif
temp = 0xff; break;
case 3: temp = 0xff;
#if defined (OV2640_MINI_2MP)
myCAM.OV2640_set_JPEG_size(OV2640_352x288);delay(1000);
Serial2.println(F("ACK CMD switch to OV2640_352x288 END"));
#elif defined (OV3640_MINI_3MP)
myCAM.OV3640_set_JPEG_size(OV3640_640x480);delay(1000);
Serial2.println(F("ACK CMD switch to OV3640_640x480 END"));
#else
myCAM.OV5642_set_JPEG_size(OV5642_1280x960);delay(1000);
Serial2.println(F("ACK CMD switch to OV5642_1280x960 END"));
#endif
break;
case 4: temp = 0xff;
#if defined (OV2640_MINI_2MP)
myCAM.OV2640_set_JPEG_size(OV2640_640x480);delay(1000);
Serial2.println(F("ACK CMD switch to OV2640_640x480 END"));
```

```
#elif defined (OV3640_MINI_3MP)
myCAM.OV3640_set_JPEG_size(OV3640_800x600);delay(1000);
Serial2.println(F("ACK CMD switch to OV3640_800x600 END"));
#else
myCAM.OV5642_set_JPEG_size(OV5642_1600x1200);delay(1000);
Serial2.println(F("ACK CMD switch to OV5642_1600x1200 END"));
#endif
break;
case 5:
temp = 0xff;
#if defined (OV2640_MINI_2MP)
myCAM.OV2640_set_JPEG_size(OV2640_800x600);delay(1000);
Serial2.println(F("ACK CMD switch to OV2640_800x600 END"));
#elif defined (OV3640_MINI_3MP)
myCAM.OV3640_set_JPEG_size(OV3640_1024x768);delay(1000);
Serial2.println(F("ACK CMD switch to OV3640_1024x768 END"));
#else
myCAM.OV5642_set_JPEG_size(OV5642_2048x1536);delay(1000);
Serial2.println(F("ACK CMD switch to OV5642_2048x1536 END"));
#endif
break;
case 6:
temp = 0xff;
#if defined (OV2640_MINI_2MP)
myCAM.OV2640_set_JPEG_size(OV2640_1024x768);delay(1000);
Serial2.println(F("ACK CMD switch to OV2640_1024x768 END"));
#elif defined (OV3640_MINI_3MP)
myCAM.OV3640_set_JPEG_size(OV3640_1280x960);delay(1000);
Serial2.println(F("ACK CMD switch to OV3640_1280x960 END"));
#else
```

```
myCAM.OV5642_set_JPEG_size(OV5642_2592x1944);delay(1000);
 Serial2.println(F("ACK CMD switch to OV5642_2592x1944 END"));
#endif
break;
case 7:
temp = 0xff;
#if defined (OV2640_MINI_2MP)
myCAM.OV2640_set_JPEG_size(OV2640_1280x1024);delay(1000);
Serial2.println(F("ACK CMD switch to OV2640_1280x1024 END"));
#else
myCAM.OV3640_set_JPEG_size(OV3640_1600x1200);delay(1000);
Serial2.println(F("ACK CMD switch to OV3640_1600x1200 END"));
#endif
break;
case 8: temp = 0xff;
#if defined (OV2640_MINI_2MP)
myCAM.OV2640_set_JPEG_size(OV2640_1600x1200);delay(1000);
Serial2.println(F("ACK CMD switch to OV2640_1600x1200 END"));
#else
myCAM.OV3640_set_JPEG_size(OV3640_2048x1536);delay(1000);
Serial2.println(F("ACK CMD switch to OV3640_2048x1536 END"));
#endif
break;
case 0x10: mode = 1; temp = 0xff; start_capture = 1;
Serial2.println(F("ACK CMD CAM start single shoot. END"));break;
case 0x11:  temp = 0xff; myCAM.set_format(JPEG);
myCAM.InitCAM();
#if !(defined (OV2640_MINI_2MP))
myCAM.set_bit(ARDUCHIP_TIM, VSYNC_LEVEL_MASK);
#endif
```

```
break;
case 0x20:  mode = 2; temp = 0xff; start_capture = 2;
Serial2.println(F("ACK CMD CAM start video streaming. END"));
break;
case 0x30: mode = 3; temp = 0xff;
start_capture = 3;
Serial2.println(F("ACK CMD CAM start single shoot. END")); break;
case 0x31:
temp = 0xff; mmyCAM.set_format(BMP);  myCAM.InitCAM();
#if !(defined (OV2640_MINI_2MP))
myCAM.clear_bit(ARDUCHIP_TIM, VSYNC_LEVEL_MASK);
#endif
myCAM.wrSensorReg16_8(0x3818, 0x81);
myCAM.wrSensorReg16_8(0x3621, 0xA7); break;
default: break;}}
if (mode == 1){
if (start_capture == 1){
myCAM.flush_fifo(); myCAM.clear_fifo_flag();
myCAM.start_capture(); start_capture = 0;}
if (myCAM.get_bit(ARDUCHIP_TRIG, CAP_DONE_MASK)) {
Serial2.println(F("ACK CMD CAM Capture Done. END"));
delay(50);  read_fifo_burst(myCAM);  myCAM.clear_fifo_flag();}}
else if (mode == 2){
while (1){ temp = Serial2.read(); if (temp == 0x21){start_capture = 0; mode =
0;
Serial2.println(F("ACK CMD CAM stop video streaming. END"));break; }
if (start_capture == 2)  { myCAM.flush_fifo(); myCAM.clear_fifo_flag();
myCAM.start_capture(); start_capture = 0;}
if (myCAM.get_bit(ARDUCHIP_TRIG, CAP_DONE_MASK)){
uint32_t length = 0;  length = myCAM.read_fifo_length();
```

```
if ((length >= MAX_FIFO_SIZE) | (length == 0)){ myCAM.clear_fifo_flag();
start_capture = 2; continue;}myCAM.CS_LOW(); myCAM.set_fifo_burst();
temp = SPI.transfer(0x00); length --;
while ( length-- )   {temp_last = temp; temp = SPI.transfer(0x00);
if (is_header == true){ Serial2.write(temp);}
else if ((temp == 0xD8) & (temp_last == 0xFF)){
is_header = true; Serial2.println(F("ACK IMG END"));
Serial2.write(temp_last); Serial2.write(temp);}
if ( (temp == 0xD9) && (temp_last == 0xFF)  break;
delayMicroseconds(15);} myCAM.CS_HIGH(); myCAM.clear_fifo_flag();
start_capture = 2;is_header = false;}}}
else if (mode == 3){if (start_capture == 3){
myCAM.flush_fifo();  myCAM.clear_fifo_flag(); myCAM.start_capture();
start_capture = 0;  }
if (myCAM.get_bit(ARDUCHIP_TRIG, CAP_DONE_MASK)){
Serial2.println(F("ACK CMD CAM Capture Done. END"));
delay(50); uint8_t temp, temp_last; uint32_t length = 0;
length = myCAM.read_fifo_length();
if (length >= MAX_FIFO_SIZE )  {
Serial2.println(F("ACK CMD Over size. END"));
myCAM.clear_fifo_flag();  return;}
if (length == 0 ) {
Serial2.println(F("ACK CMD Size is 0. END"));
myCAM.clear_fifo_flag(); return;}
myCAM.CS_LOW(); myCAM.set_fifo_burst();//Set fifo burst mode
Serial2.write(0xFF); Serial2.write(0xAA);
for (temp = 0; temp < BMPIMAGEOFFSET; temp++){
Serial2.write(pgm_read_byte(&bmp_header[temp]));}
SPI.transfer(0x00); char VH, VL;
int i = 0, j = 0;for (i = 0; i < 240; i++){
```

```
for (j = 0; j < 320; j++){VH = SPI.transfer(0x00);
VL = SPI.transfer(0x00); Serial2.write(VL); delayMicroseconds(12);
Serial2.write(VH); delayMicroseconds(12); }}
Serial2.write(0xBB); Serial2.write(0xCC);
myCAM.CS_HIGH(); myCAM.clear_fifo_flag(); }}}
if(state==1){  amg.readPixels(pixels);
for(int i=0; i<AMG88xx_PIXEL_ARRAY_SIZE; i++){
uint8_t colorIndex = map(pixels[i], MINTEMP, MAXTEMP, 0, 255);
colorIndex = constrain(colorIndex, 0, 255);
tft.fillRect(displayPixelHeight * floor(i / 8), displayPixelWidth * (i % 8),
displayPixelHeight, displayPixelWidth, camColors[colorIndex]);}
if (GPS.newNMEAreceived()) {
GPS.lastNMEA();if (!GPS.parse(GPS.lastNMEA()))  return; }
if (millis() - timer > 1000) { timer = millis();
if (GPS.fix) { mySerial.print('G');
mySerial.print(GPS.latitude/100, 4); mySerial.print(',');
mySerial.println(GPS.longitude/100, 4);  }}
analogSensor = analogRead(smokeA0);
if (analogSensor > sensorThres) { digitalWrite(4, HIGH);}
else { digitalWrite(4, LOW);}
sendDataToProcessing('S', Signal);
if (QS == true){ sendDataToProcessing('B',BPM);
sendDataToProcessing('Q',IBI);   prefix
QS = false;   }}}
uint8_t read_fifo_burst(ArduCAM myCAM){ uint8_t temp = 0, temp_last = 0;
uint32_t length = 0;length = myCAM.read_fifo_length();
Serial2.println(length, DEC);  if (length >= MAX_FIFO_SIZE) {
Serial2.println(F("ACK CMD Over size. END")); return 0; }
if (length == 0 ) {
Serial2.println(F("ACK CMD Size is 0. END")); return 0;}
```

```
myCAM.CS_LOW();  myCAM.set_fifo_burst();
temp =  SPI.transfer(0x00); length --;
while ( length-- ) { temp_last = temp;temp =  SPI.transfer(0x00);
if (is_header == true){Serial2.write(temp); }
else if ((temp == 0xD8) & (temp_last == 0xFF)){
is_header = true;
Serial2.println(F("ACK IMG END")); Serial2.write(temp_last); Serial2.write(temp); }
if ( (temp == 0xD9) && (temp_last == 0xFF) )  break;
delayMicroseconds(15); }myCAM.CS_HIGH();is_header = false;
return 1;}
volatile int rate[10]; volatile unsigned long sampleCounter = 0;
volatile unsigned long lastBeatTime = 0;
volatile int P =512; volatile int T = 512;
volatile int thresh = 525; volatile int amp = 100;
volatile boolean firstBeat = true;
volatile boolean secondBeat = false;   cli();
TCCR1A = 0x00; TCCR1B = 0x11; TCCR1C = 0x00;
TIMSK1 = 0x01; ICR1 = 16000;   TCCR2A = 0; TCCR2B = 0;
TCNT2  = 0;
OCR2A = 255;// = (16*10^6) / (1*1024) - 1 (must be <65536)
TCCR2B |= (1 << WGM22); TCCR2B |= (1 << CS22) | (1 << CS20);
TIMSK2 |= (1 << OCIE2A); sei(); }
ISR(TIMER1_OVF_vect){ cli(); Signal = analogRead(pulsePin);
sampleCounter += 2;
int N = sampleCounter - lastBeatTime;
if(Signal < thresh && N > (IBI/5)*3){
if (Signal < T){T = Signal;}}
if(Signal > thresh && Signal > P){ P = Signal; }
if (N > 250){
```

```
if ( (Signal > thresh) && (Pulse == false) && (N > (IBI/5)*3) ){
Pulse = true; IBI = sampleCounter - lastBeatTime;
lastBeatTime = sampleCounter;
if(secondBeat){ secondBeat = false;
for(int i=0; i<=9; i++){ rate[i] = IBI; }}
if(firstBeat){firstBeat = false; secondBeat = true;sei();return;}
word runningTotal = 0;  for(int i=0; i<=8; i++){rate[i] = rate[i+1];
runningTotal += rate[i]; }rate[9] = IBI; runningTotal += rate[9];
 runningTotal /= 10; BPM = 60000/runningTotal; QS = true;}}
if (Signal < thresh && Pulse == true){ Pulse = false;
amp = P - T; thresh = amp/2 + T;P = thresh;T = thresh;}
if (N > 2500){ thresh = 512;P = 512; T = 512;
lastBeatTime = sampleCounter; firstBeat = true;secondBeat = false;}sei(); }
ISR(TIMER2_COMPA_vect){cli(); c = GPS.read(); sei();}
```

APPENDIX B

Processing IDE code for receiving serial data and display it

```
import processing.serial.*
Table dataTable;
int numReadings = 5;  int readingCounter = 0; PFont font;
Scrollbar scaleBar;
Serial port;
int Sensor;int IBI; int BPM; int[] RawY;int[] ScaledY;int[] rate;
float zoom; float offset;
color eggshell = color (255, 253, 248);
int heart = 0;   // This variable times the heart image 'pulse' on screen
int PulseWindowWidth = 490; int PulseWindowHeight = 512;
int BPMWindowWidth = 180; int BPMWindowHeight = 340;
boolean beat = false;
void setup() {
dataTable = new Table(); dataTable.addColumn("id");
dataTable.addColumn("lat"); dataTable.addColumn("lng");
size(700, 600); frameRate(100);
font = loadFont("Arial-BoldMT-24.vlw");
textFont(font); textAlign(CENTER); rectMode(CENTER);
ellipseMode(CENTER);
scaleBar = new Scrollbar (400, 575, 180, 12, 0.5, 1.0);
RawY = new int[PulseWindowWidth];
ScaledY = new int[PulseWindowWidth];
rate = new int [BPMWindowWidth];zoom = 0.75;
for (int i=0; i<rate.length; i++){rate[i] = 555;  }
for (int i=0; i<RawY.length; i++){RawY[i] = height/2;
```

```
println(Serial.list());
port = new Serial(this, Serial.list()[0], 115200);port.clear();
port.bufferUntil('\n'); }
void draw() {
background(0);noStroke();fill(eggshell);
rect(255,height/2,PulseWindowWidth,PulseWindowHeight);
rect(600,385,BPMWindowWidth,BPMWindowHeight);
RawY[RawY.length-1] = (1023 - Sensor) - 212;
zoom = scaleBar.getPos(); offset = map(zoom,0.5,1,150,0);
for (int i = 0; i < RawY.length-1; i++) { RawY[i] = RawY[i+1];
float dummy = RawY[i] * zoom + offset;
ScaledY[i] = constrain(int(dummy),44,556);}
stroke(250,0,0); noFill(); beginShape();
for (int x = 1; x < ScaledY.length-1; x++) { vertex(x+10, ScaledY[x]);}
endShape();
if (beat == true){ beat = false;
for (int i=0; i<rate.length-1; i++){rate[i] = rate[i+1];}
BPM = min(BPM,200);
float dummy = map(BPM,0,200,555,215);
rate[rate.length-1] = int(dummy);}
stroke(250,0,0);strokeWeight(2); noFill(); beginShape();
for (int i=0; i < rate.length-1; i++){ vertex(i+510, rate[i]);}
endShape(); fill(250,0,0);
stroke(250,0,0); heart = max(heart,0);
if (heart > 0){strokeWeight(8); }smooth();
bezier(width-100,50, width-20,-20, width,140, width-100,150);
bezier(width-100,50, width-190,-20, width-200,140, width-100,150);
strokeWeight(1);fill(eggshell);
text("Pulse Sensor Amped Visualizer 1.1",245,30);
text("IBI " + IBI + "mS",600,585); text(BPM + " BPM",600,200);
```

```
scaleBar.update (mouseX, mouseY); scaleBar.display();
TableRow newRow = dataTable.addRow();
newRow.setInt("id", dataTable.lastRowIndex());
newRow.setFloat("lat", (sensorVals[0])*1.016789);
newRow.setFloat("lng", (sensorVals[1])*1.00621105);
readingCounter++;
if (readingCounter % numReadings ==0){
fileName = str(year()) + str(month()) +
str(day())+str(dataTable.lastRowIndex());
saveTable(dataTable, "data/new.csv");}}
if  (inData ==null){return;}
void serialEvent(Serial port){
String inData = port.readStringUntil('\n'); try{
inData = trim(inData);
if (inData.charAt(0) == 'S'){ inData = inData.substring(1);
Sensor = int(inData);}
if (inData.charAt(0) == 'B'){inData = inData.substring(1);
BPM = int(inData); beat = true; heart = 20;}
 if (inData.charAt(0) == 'Q'){
inData = inData.substring(1); IBI = int(inData);}
if (inData.charAt(0) == 'G'){inData = inData.substring(1);
float sensorVals[] = float(split(inData, ","));
TableRow newRow = dataTable.addRow();
newRow.setInt("id", dataTable.lastRowIndex());
newRow.setFloat("lat", (sensorVals[0])*1.016789);
newRow.setFloat("lng", (sensorVals[1])*1.00621105);
readingCounter++;
if (readingCounter % numReadings ==0){
fileName = str(year()) + str(month()) + str(day()) +
str(dataTable.lastRowIndex());
```

```
saveTable(dataTable, "data/new.csv");}}}
catch(Exception e){ e.printStackTrace();}}
class Scrollbar{ int x,y;
float sw, sh; float pos; float posMin, posMax;
boolean rollover;  boolean locked;
float minVal, maxVal;
x = xp; y = yp; sw = w; sh = h; minVal = miv; maxVal = mav; pos = x - sh/2;
posMin = x-sw/2; posMax = x + sw/2;  // - sh; }
void update(int mx, int my) {
if (over(mx, my) == true){rollover = true;}
else {rollover = false;}
if (locked == true){
pos = constrain (mx, posMin, posMax);}}
void press(int mx, int my){
if (rollover == true){locked = true;}
else{ locked = false;} }
void release(){locked = false; }
boolean over(int mx, int my){
if ((mx > x-sw/2) && (mx < x+sw/2) && (my > y-sh/2) && (my < y+sh/2)){
return true;}else{return false;}}
void display (){
noStroke(); fill(255); rect(x, y, sw, sh); fill (250,0,0);
if ((rollover == true) || (locked == true)){
stroke(250,0,0); strokeWeight(8); }
ellipse(pos, y, sh, sh); strokeWeight(1); }
float getPos() { float scalar = sw / sw;  // (sw - sh/2);
float ratio = (pos-(x-sw/2)) * scalar;
float p = minVal + (ratio/sw * (maxVal - minVal));
return p;}}
```