DEVELOPMENT OF AN INTER-VEHICLE VOICE COMMUNICATION SYSTEM VIA CONTROLLER AREA NETWORK (CAN) BUS THROUGH VISIBLE LIGHT WITH BLACK BOX AS DATA STORAGE

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Bachelor of Science in Electronics Engineering

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ABSTRACT

Ever since the establishment of cars, the human-race has undergone great advancement. Remote places became accessible and mobility was attained, boosting both social and economic interactions. However, despite the great benefits, increasing number of people all around the world were killed by car accidents each year, from this information, this paper introduced the development of an inter-vehicle voice communication system through visible light rays. The project aims to reduce the possibility of a car accident to happen by sending information through voice signals to other vehicles within the surroundings.

The visible light communication device contains a transceiver circuit composed of microphone, audio amplifier, power amplifier, operational amplifier and LED in the transmitter side and a photodetector, transimpedance amplifier, power amplifier and speaker in the receiving side is used to make the voice transmission possible through the use of visible light. It also has optical filter composed of microlouver film and collimating lens to reduce the ambient light noise by blocking light noise at a certain angle and focusing the LED source to the photodetector. This study also utilizes a localization system to identify the position and distance of the other driver's car during conversation. The method used for this is the Received Signal Strength technique, wherein the light intensity of the transmitter, which is an LED, will be measured at varying distances. From a single point, the farther the distance, the weaker the light intensity of the LED. An LCD display is used to show the whereabouts of the other driver. The project also uses a Controller Area Network Bus (CAN Bus) Shield to extract various data from vehicles equipped with CAN Bus. After data gathering and statistical analysis, result showed that VLC system can help

the drivers to have another means of communication to other drivers in their surrounding where the light will able to reach and the system can help for the prevention of car accidents.

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Chapter 1

THE PROBLEM AND ITS SETTING

This chapter presents the background of the study, statement of the problem, objectives, significance, and the scope and delimitation of the study.

1.1 Introduction

Humans underwent a great advancement ever since cars were invented. Faraway places became reachable and mobility was attained, causing a rise in both social and economic interactions. But despite the great benefits, these vehicles also post danger to people, for there is an increasing number of deaths caused by car accidents each year.

In the Philippines, the Metropolitan Manila Development Authority (MMDA) showed that the number of road crashes in Metro Manila has increased from 95,615 in 2015 to 109,322 in the year 2016. 80 to 90 percent of which were caused by human error such as drunk-driving, multitasking and miscommunicating with other vehicles on the road.

The only means of inter-vehicle communication available to the majority of automobiles are car horns and turn signals. Horns are essentially for warning other vehicles and or pedestrians of the vehicle's approach or presence. Nowadays, drivers use horns for reasons like greeting familiar drivers and pedestrians, as well as expressing feelings like impatience or anger towards another individual. A typical car uses signaling lights to see the vehicle's presence, position, size, direction of travel and emergency. However, due to the rising number of cars on the road nowadays, signal lights may incur confusion to drivers and can be rendered insufficient in maintaining smooth traffic flow. A report from Florida in the year 2012 by the Society of Safety Engineers (SAE) state that drivers tend to not use their turn signals 25% of the time when making turns, and 48% of the time when they are changing lanes. A survey conducted in 2006 by the Response Insurance reveals that 57% of drivers admitted that they do not use their turn signals for various reasons.

From the previous information, the proponents have emerged with an idea to develop an inter-vehicle voice communication system through visible light rays. The project aims to reduce the possibility of a car accident to happen by sending information through voice signals to other vehicles in the vicinity.

Visible light communication (VLC) is a low-cost wireless communication system that utilizes visible light to transmit data within line of sight (LOS). Visible light can transmit data up to 500 megabits per second (mbps). It is also safe to use, for visible rays cause very little to no harm to human beings.

1.2 Background of the Study

Vehicle-to-vehicle communication is a wireless network for automobiles. Through this communication system, vehicles can transmit and receive information to other vehicles. This system enables drivers to maximize the communications of vehicles for safety in the road while the vehicles are running. By using the vehicle-to-vehicle communication, drivers can avoid the danger of road works, traffic jams and road obstacles that can lead to road accidents. Vehicles can also send critical information to other vehicles for the safety of drivers.

An existing vehicle-to-vehicle communication system is the Dedicated Short-Range Communications (DSRC). The DSRC is a two-way short-to-medium wireless communication system that is especially made for automotive use. The system is capable of high-speed data transmission. DSRC is a major research priority of the Joint Program Office (ITS JPO) at the U.S. Department of Transportation (U.S. DOT) Research and Innovative Technology Administration (RITA). DSRC uses vehicle-to-vehicle (v2v) and vehicles-to-infrastructure (v2i) communication that contributes for safer driving. This system uses radio frequency (RF) as its medium for data transmission.

The visible light communication (VLC) is a wireless communication system that uses visible light as its medium to transmit data within line of sight (LOS). Comparing to RF communications, VLC has a larger bandwidth which makes it more capable of transmitting more information than the RF communication. Some drawbacks of the RF communication system can be conquered by VLC. One of the applications of visible light communication is the light fidelity (Li-Fi). Li-fi is the transmission of data using the visible light spectrum. It has a theoretical speed is 224 Gbps. Li-fi is advantageous in terms of high security, efficiency, fast data transfer and low cost, when compared to the traditional Wi-fi technology. A research conducted by Nikshep, K.N. and Sowmya, G. on voice and data communication using li-fi showed that LED's switch on and off rapidly that it cannot be seen by the naked eye, which makes it more efficient in transmitting more data than wi-fi.

1.3 Statement of the Problem

This study proposes to develop a real-time voice communication system between vehicles that utilizes visible light as its transmission medium. The project should help reduce the number of car accidents happening everyday by improving the means of communication between vehicles. The project aims to reduce miscommunication, which is known to be one of the greatest causes of car accidents. As the project proceeds, the following questions should be of concern: (1) What should be the suitable displacement of the transceiver from the ground level for all types and designs of vehicles? (2) What is the maximum distance between vehicles to ensure the best audio quality? (3) How can the device locate the direction of the sender? (4) How can the researchers design the best optical filter to disallow all kinds of noise from entering the system?

1.4 Objectives (General and Specific)

1.4.1 General Objective

The main objective of this project is to develop a system that can transmit and receive audio and text information between vehicles using visible light communication and to centralize the electronic control unit inside the vehicle using CAN Bus.

1.4.2 Specific Objectives

1. To design a transceiver circuit that will send and receive audio information.

2. To integrate a black box that can record audio conversation in case of car accidents and utilize the Control Area Network Bus (CAN Bus) capabilities in a vehicle's electronic control.

3. To design a filter for the photodetector that can reduce the data transmission noise caused by ambient light.
4. To design a visible light-based outdoor positioning system using received signal strength technique.

1.5 Significance of the Study

The project is beneficial to our society especially to drivers for it allows them to communicate with each other in order to warn other drivers about traffic congestion, potential hazards and accidents in the road and thus prevent crashes and miscommunication. It can transmit data and information about the roads situation and drivers may directly send and receive warning or other messages concerning other drivers. Considering today's situation where accidents are prone in every road and research said that human miscommunication is one majority factor for these accidents, developing vehicle's means of communication to lessen and avoid crashes and accidents could be a big help.

Moreover, while the system boasts its safety for drivers, it also features speed of communication. A substantial amount of car crashes and other accidents caused by human error and miscommunication can be prevented by having a fast, wireless communication system for vehicles. Through this project which basically adheres to a new paradigm of wireless technology in terms of communication, the information is transmitted using visible light medium that is dashed in the front bumpers and rear side of the vehicle thus making the communication for vehicles faster with a wide range.

Furthermore, taking into consideration when it is daylight where ambient light noise is present and can affect the information to be transmitted, an optical filter will be used to block unnecessary light sources and other noise. As the driver is driving at broad daylight, the LED light is on and can still transmit messages and warnings.

1.6 Scope and Delimitation

1.6.1 Scope

The system uses visible light communication to transmit and receive information. Digital signals are sent through an array of LED's illuminating visible light in varying frequencies depending on the data being transferred. In case of analog signals such as voice, a microphone converts the data into electrical signals before transmission. On the receiver end, a photodiode senses optical signals from the LED's and converts it into electrical signal. The electrical signal is then amplified to recover the digital signal which will be converted back to analog signal as voice.

The system utilizes the fast communication capabilities of a Controller Area Network Bus. Every vehicle has its own set of sensors such as proximity, speedometer, etc. Each of these sensors are connected to an Electronic Control Unit (ECU) which controls various parts of the vehicle such as lights, horns, doors, windows, etc. With the help of CAN Bus, all ECU systems will be centralized for fast sensor-to-actuator communication and simplification of complex wirings. Information regarding vehicle's conditions will be displayed in a LCD. The LCD also serves as an interface for the drivers in sending and receiving messages.

Every vehicle will be integrated with four transceivers, mounted at one of each headlights and taillights. For information tracking and keeping, a Black Box is also added to record every voice conversation and sensor readings. Such information is critical in the events of accidents and crimes, so the durability of the Black Box should withstand extreme conditions.

1.6.2 Delimitation

Visible Light Communication is widely known for its promise of speed and safety. However, like other ways of communication, it also has its disadvantages.

The system requires a near or perfect line-of-sight to transmit data. The optical filters are integrated at the receivers to prevent light from a certain angle from coming in. In addition, lights coming from the sides of the vehicle is undetectable by the system since the transmitters are only installed near the taillights and headlights. Also, the inter-vehicle communication system may only be effective for an event of traffic congestion because of the need of near line-of-sight between transceivers.

Since the system uses light as its medium of information, opaque obstacles on pathways can foil the transmission. It also limits the system to transfer data only to adjacent receivers. Also, the maximum information transmission distance is only about ten (10) meters.

In addition, the technology itself is still new and yet to be developed for mass scale adoption.

1.7 Definition of Terms

1.7.1 Light Emitting Diode (LED)

An LED is a semiconductor diode that emits light when a voltage is applied to it and that is used especially in electronic devices as for an indicator light. (Merriam-Webster, 2006)

1.7.2 Radio Frequency

Radio Frequency (RF) is any frequency within the electromagnetic spectrum associated with radio wave propagation. When an RF current is supplied to an antenna, an electromagnetic field is created that then is able to propagate through space. Many wireless technologies are based on RF field propagation. (webopedia, 2010)

1.7.3 Optical Filter

Optical filters are used to filter out light of specific wavelengths. These are usually in the form of a glass plane or plastic and placed in the optical path. They can also be either dyed in the bulk or have interference coatings. (Wikipedia, 2018)

1.7.4 Photodiode

A photodiode is a device that converts light into electric current. Current is produced in the photodiode when photons are absorbed and a small amount of current is also produced when there is no light present. With increase of the surface area, photodiodes have slower response times. Photodiode technology has been successfully and widely used due to its simple and low-cost rugged structure. (techopedia, ----)

1.7.5 Transceiver

A transceiver is an integration of a transmitter and a receiver in one piece. Wireless communication devices which include cordless telephone sets, cellular telephones, mobile two-way radios and handheld two-way radios are examples of transceivers. (TechTarget, 2005)

Chapter 2

REVIEW OF RELATED LITERATURE

This part of the research is where the ideas from different studies come together to develop an innovative project with background that has a basis and purpose for improvement. It circles on theories and principles of related literature and studies in conceptualizing ideas that are useful to the whole research.

2.1 Conceptual Literature

2.1.1 Visible Light Communication

Visible light communication is a new paradigm of wireless communication system that uses light instead of radio frequency. Most VLC systems are used indoor, but the use of VLC system outdoor is a promising application that lets you communicate using light. Most application of VLC outdoor are underwater or in vehicle communications. VLC uses visible light spectrum to transmit information between two people, infrastructure and other things that needs communication.

Advantages of VLC are listed below.

- Safety – VLC is safe to use by humans for it is not harmful to the body, unlike RF where it can affect the body if used for a long period of time.
- Security – VLC uses visible light to transmit information and makes it secured from third party interference and thus making it effective to use for privacy concerns.

- Cost-effective – Visible light communication systems use LED for data transmission and the use of photodiode/photodetector to receive the transmitted data. With a simple transmitter and receiver circuit, wireless communication through visible light can be achieved.

2.1.1.1 Theory behind Visible Light Communication

The light signals that can be detected by the human eye is in the range of 380-780 nm wavelength interval of the electromagnetic spectrum. Illumination and data transfer simultaneously through LEDs that is a prominent lighting equipment lately are possible. Wireless data transfer through the interior lighting of a room can be achieved without any need of additional communication system.

Figure 2.1. Basic VLC configuration

Visible Light Communication system uses an LED as the transmitter of data and photodetectors as receivers. Some research and studies focused on simultaneously transferring of data with the use of LED lighting equipment. Using this new wireless communication system is intended to be used indoor and most likely outdoor for its benefit and developing opportunities in our communication system without the use of RF waves but purely visible light.

2.1.1.2 Application in Inter-Vehicle Communication and Intelligent Traffic System

Traffic systems can be made smart by using VLC techniques and can help to tackle the situations that arise while driving. Vehicles, obstacles and pedestrians can be detected with the help of such systems which results in control of traffic and avoidance of accidents. Red light is used as a transmitter in such systems. Since existing techniques for traffic management have not proved their effectiveness, VLC is considered as a promising alternative to the problem. In an analog circuit is being designed with the requirements of traffic management system and it is carefully integrated with the computer data so that data can be transmitted with the help of LEDs used in traffic lights and car headlights. (Neha Yadav, 2016)

2.1.1.3 Optical Filter

The VLC systems has a future to be used in outdoor applications. However, during daytime, visible light communication is highly susceptible to ambient light noise that can affect the data transmitted. In order to achieve an efficient VLC data communication, optical filters are used to block and reduce the ambient light noise in the environment.

Optical filters are usually mounted on the light sensor to block unnecessary light sources that do not carry any data or information.

There is an existing optical filter which is a light control film that consists of a micro-louver layer. This layer has a characteristic that when varying its thickness and angle, the desired blocking performance can be achieved, thus making those light rays that is not within employed angle of the film be blocked.

The dispersed emitted light signal can be efficiently collected through using collimating lens. This optical lens can collect light from a wider angle and focus all the received light into a smaller point.

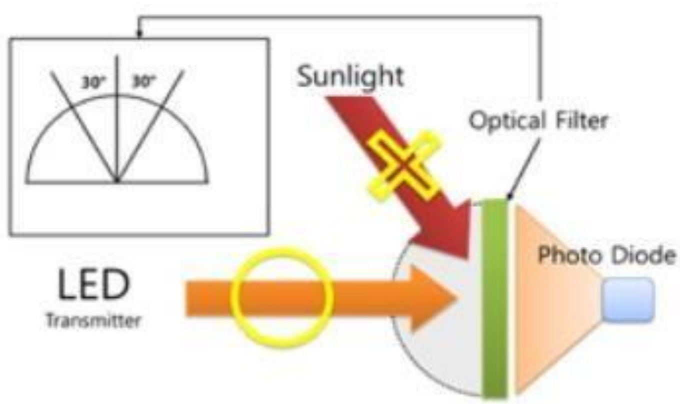


Figure 2.2 proposed filtering method against obliquely incident sunlight

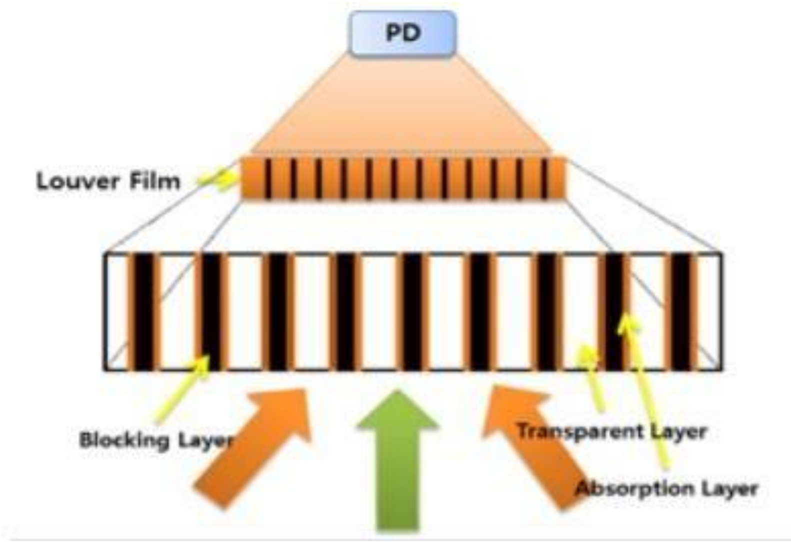


Figure 2.3 blocking effect of the optical filter

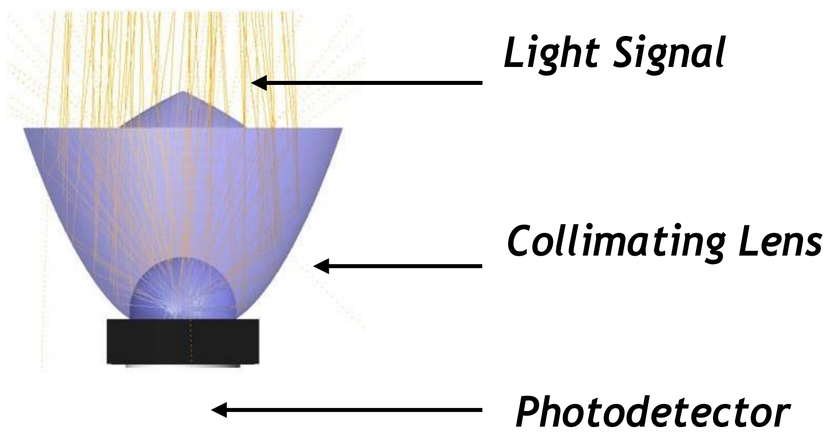


Figure 2.4 Proposed method for efficient collection of emitted light signal

2.1.1.4 Localization of Visible Light Communication

Visible Light Communications that is used in outdoor application such as for inter-vehicle communication need to consider localization techniques to identify where the transmitted data or information came from. Some localization techniques used in Visible Light Communication are Cell ID, Received Signal Strength, Time of Arrival, Time Difference of Arrival, Angle of Arrival.

A unique identifier (ID) is broadcast in the Cell ID systems for each cell. Received signal strength (RSS) is a technique used to locate the sender using the measurement of the signal power detected at the receiver. The distance can be calculated using this technique, since the signal diminishes as the distance gets further to the receiver. Time of arrival (TOA) is based on the trilateration and is useful for multiple signals sent at exactly, the same known time. This technique is used to calculate the distance of the transmitter to the receiver through the time the signal arrived the receiver (they all travel at the speed of light). Time difference of arrival or TDOA differs from TOA for it measures the time difference between the signals from different not the absolute time of arrival. Angle of arrival (AOA) is widely used for location finding using triangulation.

2.1.2 Controller Area Network (CAN) Bus

CAN is a serial communication bus defined by the International Standardization Organization (ISO), originally designed for the automotive industry to replace the complex cable harness with a two - wire bus. The specification requires high immunity against electrical interference and the ability to diagnose and repair data errors. These features led to the popularity of CAN in a variety of industries, including construction automation, medical and manufacturing. (Texas Instrument, 2014)

CAN exhibits a multi-master communication protocol. Each of its nodes are connected to the other nodes allowing fast node-to-node communication. Any system processor can send a message to any other processor. The other subsystems in the machine will continue to work and communicate with each other even if some node fails.

CAN is a low-cost serial bus network allowing communication between all Electronic Control Units (ECU's) in a vehicle through a centralized CAN interface. Direct analog signal lines from one processor to another can be minimized thus reducing errors and costs. Due to the node-to-node communication capabilities of CAN bus, error diagnosis and configuration can be achieved in a system of ECU's. In addition, failure of subsystems and electromagnetic interferences can be reduced using CAN bus making it ideal for automotive applications.

Information from each sensor of a vehicle such as proximity sensors and speedometers are recognized by CAN bus as inputs with different ID's. This capability allows the network to recognize inputs such as car keys and brakes to be high priority and non-interruptible. Every ECU connected to the CAN bus will be assigned to a chip for receiving all transmitted messages, decide priority and act accordingly which allows easy modification for the system and inclusion of additional instructions.

2.1.3 Black Box for Vehicle

Recording on what goes on in vehicles is very important to every modern car that in case of emergency, information that has been recorded can be obtained to help identify the causes during and after the accident.

A black box is a device that records all information in a system. The black box was first implemented to aircraft where all flight data and voice communication was stored in the black box. The black box was made up of very strong materials that can withstand different condition in case of an accident. However, the black box is not limited to aircraft as they can be also be implemented to other kinds of vehicles.

The black box in the vehicle will detect and collect the information from the vehicle and will be stored black box. The black box system can be implemented in any vehicle as soon as the driver runs the car the black box system will now begin saving the events and corresponding vehicle. The last are always saved in the EEPROM of the black box and if accident happened an additional 10 seconds of events after this accident will be saved. The data now can retrieved after the accident via a Keil Vision debugger that uses C programming.

2.2 Related Literature

2.2.1 Real-World Deployment of a Locally-Developed Tilt and Moisture Sensor for Landslide Monitoring in the Philippines

The study entitled Real-World Deployment of a Locally-Developed Tilt and Moisture Sensor for Landslide Monitoring in the Philippines by Joel S. Marciano Jr.∗, Mark Albert H. Zarco**, Marc Caesar R. Talampas∗, Sandra G. Catane***, Calvin G. Hilario*, Mary Ann B. Zabanal*, Catherine Ruffa C. Carreon*, Earl A. Mendoza*, Roy N. Kaimo** and Cathleen N. Cordero***. This study is about the improvement and real-world deployment of an alternative instrumentation for monitoring slope deformation and water level intended as an early warning system for landslides and slope failures. The landslide monitoring system contains a "sensor column" which consist of pipe segments, each containing capacitive sensors for water content measurements and tri-axial accelerometers for measuring tilt. Measurements taken for each segment are accessible through the Controller Area Network (CAN) communications protocol. For post processing, the GSM cellular infrastructure is used to send data from the sensor column to a remote host. Initial testing conducted for the sensor where done on a small-scale slope model which resulted to failure because of water seepage. After the failure, inspection on the column showed good agreement between the visual tilt data and the measured tilt data from the accelerometers. The whole system was deployed in a slope in Benguet province and is being monitored in real-time.

2.2.2 CAN Gateway for Fast Vehicle to Vehicle (V2V) Communication

There is a study that is entitled “CAN Gateway for Fast Vehicle to Vehicle (V2V) Communication” by Hyun-Yong Hwang, Sung-Min Oh and Jaeshung Shin. In this paper, they propose an effective gateway method for controller area network (CAN). A vehicle communicates with other wired / wireless communication technologies and/or infrastructures. In - vehicle networks consist of numerous electronic control units (ECUs) in different domains (e.g. powertrain domain, body domain, and chassis domain) depending on the type of service. Vehicle - to - vehicle (V2V) vehicle safety messages should meet the requirements of low latency. Furthermore, the information in V2V messages is linked to specific ECUs. A new method should be considered for interconnecting V2V communications and in - vehicle networks that responds to the necessary ECUs for specific V2V messages. In this paper, an effective gateway method is proposed for controller area network (CAN). When searching for a network table based on the CAN frame for V2V message, a CAN gateway is used. The proposed method can be a good solution that easily controls the ECUs due to simple structure and method and it can also deliver high - speed V2V messages.

2.2.3 Design of CAN Bus Application in the Process of Papermaking

A study entitled “Design of CAN Bus Application in the Process of Papermaking by Kaisheng Zhang, Zhijian Li, Xin Zhang and Di Fan” contains research on the design of CAN bus application in the process of papermaking. The design for an intelligent measure and control system based on the technology of CAN bus, is applied to detect and control the concentration of wood-pulp, the temperature of multistage dryer and other parameters in the process of papermaking, in order to meet the control requirements and characters for the study quality and ensure paper even and cohesive under the course of manufacturer. The intelligence of measure and control system has been predominantly researched in the article, including the proposal of intelligent control node and communication model, the design of hardware interface circuit in the intelligent measure and control node and the design of whole system.

2.2.4 Secure In-Vehicle Communication

A project entitled “Secure In-Vehicle Communication” by Marko Wolf1, André Weimerskirch, and Christof Paar, presents a study of state - of - the - art bus systems in terms of their safety from various malicious attacks. The study present feasible attacks and potential exposures for these automotive networks after a brief description of the most well - known and established vehicle communication systems. It also provides a secure automotive communication approach based on modern cryptographic mechanisms that provide confidentiality, prevention of manipulation and authentication to solve most vehicle bus safety issues.

2.2.5 Platooning Rear Vehicle Control Using Vehicle-to-Vehicle Communication

This study entitled Amada, K., Kobayashi, K., & Watanabe, K. Platooning Rear Vehicle Control Using Vehicle - to - Vehicle Communication. This paper describes a communication system for vehicle - to - vehicle (V2V) developed in the SARTRE project. The vision of the project is the development and integration of technology that allows vehicles to drive in pits. The vision of the project is the development and integration of technology that allows vehicles to drive in pits. The V2V communication system allows vehicle - to - vehicle communication to share data such as vehicle speed. The V2V communication system allows vehicle - to - vehicle communication to share data such as vehicle speed. This is an important part of the SARTRE project's platooning demonstration.

2.2.6 Black Box for Vehicles

The study called "Vehicle Black Box," by P. Ajay Kumar Reddy, P.Dileep Kumar, K. Bhaskar Reddy, E.Venkataramana and M.Chandra sekhar Reddy developed a black car diagnostic prototype that can be installed in any vehicle.. All the car's information is stored in the black box. The black box can be the source of information in the event of an accident that can help determine the cause of the accident. Embedded C programming is used in this research. This programming not only helps to record the data, but also to recover the microcontroller memory data.

2.2.7 Vehicle as a Resource

The study entitled “Vehicle as a Resource” (VaaR) by Sherin Abdel Hamid, Hoosam S. Hassanein and Glen Takahara introduces the concept of Vehicle as a Resource (Vaar) and shed light on the services a vehicle can potentially provide on the road or parked. They seek to achieve the use of intelligent vehicles as service providers for different situations. This study also introduces the concept, Vehicle as a Resource (VaaR), to show the potential of an intelligent vehicle in the parking lot or on the road. Also, it showed that a vehicle can be a resource for sensing, data storage, computing, cloud, data relaying, infotainment and a means for locating other objects. The project uses MobEyes platform which utilizes vehicles as mobile sensors to monitor surroundings, recognize objects, store data and advertise this data for potential sharing via internet.

2.2.8 A Vehicle-to-Vehicle Communication Protocol for Cooperative Collision Warning

This study entitled "A Vehicle-to-Vehicle Communication Protocol for Cooperative Collision Warning" by Xue Yang, Nitin H. Vaidya, Jie Liu, Feng Zhao proposes a Vehicular Collision Warning Communication (VCWC) protocol to improve road safety. It defines congestion control policies for emergency warning messages so that a low emergency warning message delivery delay can be achieved, and a large number of co-existing abnormal vehicles can be supported. The study focused on utilizing Dedicated Short-Range Communication (DSRC) to transmit emergency warning messages whenever a vehicle on the road acts abnormally, e.g., deceleration exceeding a certain threshold, dramatic change of moving direction, major mechanical failure, etc.

2.2.9 Vehicle-to-Vehicle-to-Infrastructure (V2V2I) Intelligent Transportation System Architecture

The study entitled "Vehicle-to-Vehicle-to-Infrastructure (V2V2I) Intelligent Transportation System Architecture" by Jeffrey Miller described the vehicle-to-vehicle-to-infrastructure that is a hybrid of vehicle-to-vehicle communication. In the V2V2I architecture, the transportation network is broken into zones in which a single vehicle is known as the Super Vehicle. Only Super Vehicles are able to communicate with the central infrastructure or with other Super Vehicles, and all other vehicles can only communicate with the Super Vehicle responsible for the zone in which they are currently traversing. The V2V architecture provides fault tolerance in a highly distributed environment, whereas the V2I architecture provides fast queries and accuracy given an abundance of speed and location data. The study utilizes Vehicular Ad-hoc Network (VANET) technology. This network uses vehicles in the road as a router node in order to communicate at a distance of 100-300m using several protocols. The network basically relies on WiFi, WIMax and DSRC technologies in addition to 3G networks.

2.2.10 Potentialities and challenges of VLC based Outdoor Positioning

This study entitled "Potentialities and challenges of VLC based Outdoor Positioning" by Trong-Hop Do, Myungsik Yoo compares existing indoor positioning techniques using visible light and evaluate the potentialities and challenges of applying them to outdoor positioning. This study uses different visible light-based indoor positioning system and use it for outdoor application.

2.2.11 Outdoor Visible Light Communication for Inter-Vehicle Communication using Controller Area Network

The study entitled "Outdoor Visible Light Communication For InterVehicle Communication Using Controller Area Network" by Deok-Rae Kim, Se-Hoon Yang, Hyun-Seung Kim, Yong-Hwan Son and Sang-Kook Han implemented the outdoor Visible Light Communication (VLC) system based on Controller Are Network (CAN) that is normally used in a car, plane, ship, product line control system, medical device and industrial device. They used the visible light spectrum for communicating of vehicles and utilize the controller area network (CAN) of vehicles installed.

Chapter 3

METHODOLOGY

3.1 Research Design

3.1.1 Input-Process-Output Model

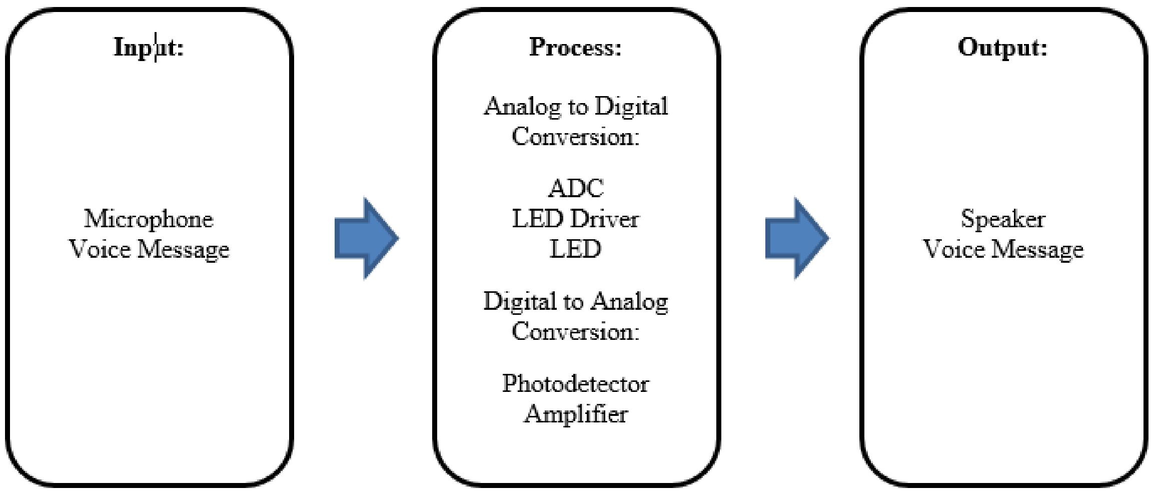


Figure 3.1. Input-Process-Output Model

Figure 3.1 shows the Input-Process-Output model. This model shows the components used in the system. The input must be in the form of a voice signal is then fed to the microphone where it will be converted into an electrical signal. In the transmitter section, the electrical signal will be converted into digital form using analog-to-digital converter. In the receiver section, the digital signal will be converted into electrical form using photodetector and amplifier. The output will be an electrical signal coming from amplifier and is then converted into audible form using speaker.

3.1.2 Gathering of the Related Facts/Information

- Research for local and international studies related to Vehicle-to-Vehicle system.
- Interview with drivers in which necessary queries can be answered reliably.
- Research the process of using visible light communication in V2V system.
- Research for the localization technique such as received signal strength.

3.1.3 Block Diagram

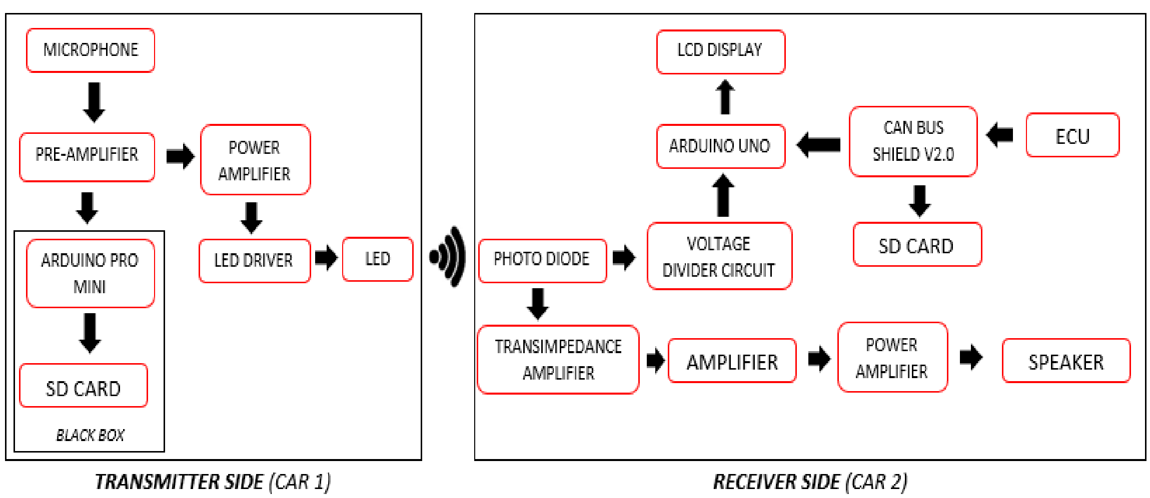


Figure 3.2 Block Diagram of the Transceiver

Figure 3.2 shows the block diagram of the vehicle-to-vehicle communication system. On the transmitter side of the first vehicle, a voice signal will be fed to the microphone where it is converted into an electrical signal. This signal then goes through amplifiers before it is fed to the LED driver. The LED driver needs the signal to be amplified so that it gives an output with pulse-like characteristics. Otherwise, the output will be distorted and show now significant change when a voice signal is going through. From here, the received signal takes form of a digital signal. This signal is then fed to the LED which will transmit the signal to the receiver of the other vehicle.

On the receiver side of the other vehicle, the photodiode senses the signal from the LED. The photodiode will receive or detect only the variation of the signal. The detected message signal coming from the transmitter will be in analog form. However, a photodiode gives current output rather than voltage, hence a transimpedance amplifier is used to convert the current into voltage, as well as to amplify the signal. This signal then goes through more amplifiers before it is fed to the speaker of the other vehicle, so that the output signal is less distorted and audible. The speaker consists of electro magnets which converts the electrical signal into audible form.

The whole conversation can be recorded through a push of a button. While talking, the digitally converted signal goes through the Arduino Pro Mini microcontroller, which is programmed to save the signal to .wav form. These files are then stored in the micro SD card. An SD card module is used for this. The microcontroller is programmed to have a FIFO (First in, First Out) system wherein it overwrites the oldest file and saves the new one. The maximum limit of files depends on the storage capacity of the micro SD card used. The file size per minute of conversation is around 2 microbits.

The localization method used for this project is the Received Signal Strength (RSS) Technique. The distance between vehicles is measured through the amount of voltage received at the receiver. The higher the voltage, the lesser the distance in meters. This information is then shown on the LCD Display.

The CAN Bus Shield module in this project is used to retrieve various information from the CAN Bus of the vehicle. These information, such as RPM, speed, throttle and engine temperature can be uses as additional information for safety purposes.

3.1.4 Flow Charts

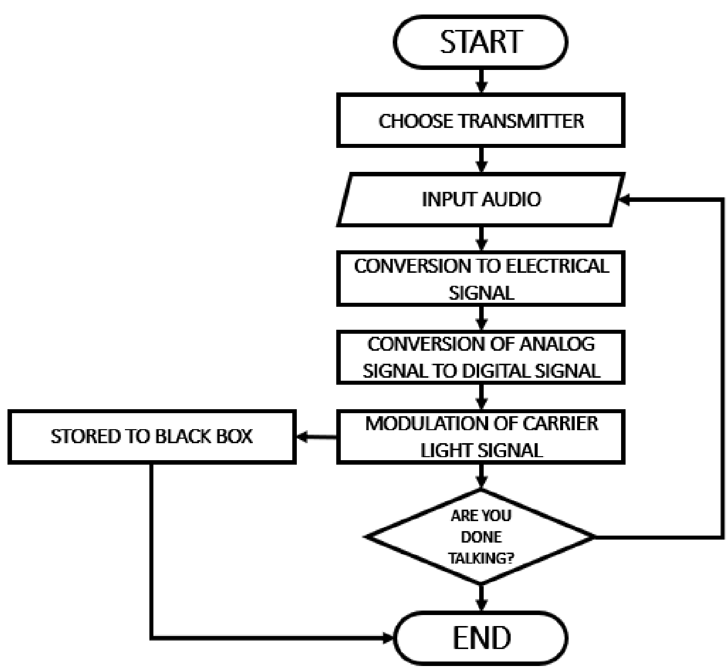


Figure 3.3 (a) Transmitter Section

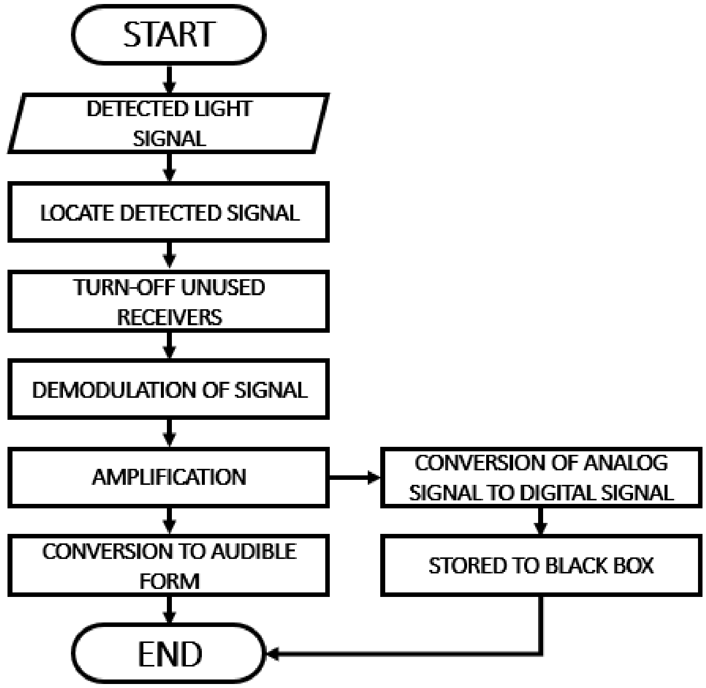
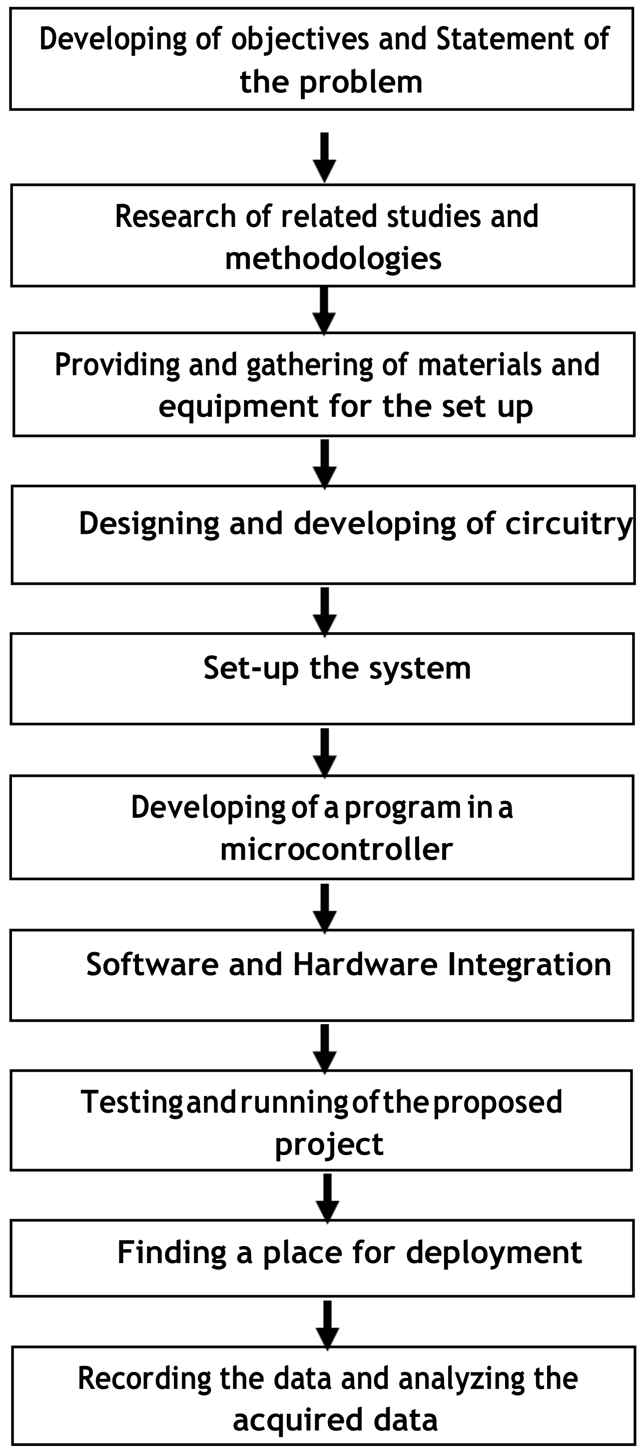


Figure 3.3 (b) Receiver Section

3.1.5 Research Flow Chart



3.2 Project Development

3.2.1 Gathering of the Materials and Equipment

The materials and equipment needed for the development of the project are going to be purchased from different sources.

The MCP2515 CAN BUS Shield will be purchased from Elecdesign Work located at Pasig City.

The OBD2 to DB9 cable (CAN Bus to CAN Bus Shield) serial port adapter cable will be purchased online from www.sparkfun.com

The collimating lens will be purchased online from www.lazada.com.ph

The Arduino Uno microcontroller, Arduino Pro Mini and the SD card module for the black box storage will be purchased from MakerLab-Electronics located in Quiapo, Manila.

3.2.2 Components List

3.2.2.1 MCP2515 CAN BUS Shield

The CAN Bus shield allows to poll the ECU for information including coolant temperature, throttle position, vehicle speed and engine rpms.

This CAN Bus shield uses the microchip MCP2515 CAN controller with the MCP2551 CAN transceiver. This shield also includes a USD card holder, serial

LCD connector and connector for an EMP506 GPS module. This feature makes the shield ideal for data logging application.

Figure 3.4 CAN Bus Shield

3.2.2.2 Photodiode

A photodiode is a semiconductor device that converts light energy to electrical current. This device generates current from photons from the light source. This device can be used as a photodetector which detects light or other electromagnetic radiation near the visible light range.

Figure 3.5 Photodiode

3.2.2.3 Arduino UNO

The Arduino UNO is an open-source programmable microcontroller board which consists of a total of 20 I/O pins (14 digital, 6 analog). Programming of the microcontroller is done through the Arduino IDE (Integrated Development Environment) via USB cable.

Figure 3.6 Arduino UNO Microcontroller

3.2.2.4 Arduino Pro Mini

The Arduino Pro Mini is a minimal version of the Arduino UNO Microcontroller. I/O pins are the same number as the UNO version. However, the Pro Mini runs at 8 MHz, half the speed of the Arduino UNO.

Figure 3.7 Arduino Pro Mini

3.4 Gantt Chart

Topic/Task	December	January	February	March 2018	April 2018	May 2018	June 2018	July 2018	August	September	October	November	December	January	February	March 2019
Conceptualization of Topic for Project Study																
Research of Problem for Topic Defense																
Drafting and Finalization of Presentation for Topic Defense																
Topic Defense																
Proposal Writing for The Problem and its Setting																
Proposal Writing for Related Literature and Studies																
Proposal Writing for Methodology																
Project Research and Consultation for Title Proposal																
Initial Hardware and Software																
Finalization of Chapter 1,2,3 of the Project Documentation																
Title Defense																

Consultation for the Hardware Design															
Canvass and Purchase of Components and Materials															
Final Software Design and Programming															
Project Assembly															
Progress Defense															
Pre-Final Defense															
Testing and Evaluation of the Project															
Documentation of the Project for Final Defense															
Final Defense															
Finalization of the Project Document and Bookbinding															

CHAPTER 4

RESULTS AND DISCUSSION

This chapter presents the project technical description, project structure, interpretation and analysis of data and results relative to the tests conducted.

4.1 Project Technical Description

The system is composed of five major parts: transceiver, CAN Bus, black box, optical filter and vehicle VLC based positioning system or localization. The VLC transceiver system is the device used for the transmission and reception of audio data for the communication of the drivers this transceiver system is composed of different amplifiers and LED driver. The Controlled Area Network Bus Shield monitors, read, and extract the data of the vehicles ECUs to keep track of the vehicles condition. The black box system is for the data recording and storage of audio conversation of the drivers. The optical filter composed of a microlouver film and collimating lens was developed to reduce the ambient light noise in the environment and Furthermore, the VLC based positioning system or the localization system was used to localize the communicating vehicles where the distance and also the position are determined using received signal strength technique.

Arduino Uno is responsible for operating the localization system and used for the programming of the CAN Bus shield that will be directly connected to the vehicle using DB9 to OBD2 connector. The transceiver system will be powered by a 12V Lead acid rechargeable battery for the portability of the system.

4.2 Project Structure

4.2.1 Actual Transceiver System

Figure 4.1 Transceiver Circuit, Black Box and CAN Bus System Setup

Figure 4.1 shows the transceiver, black box and CAN Bus system setup inside the chassis. The whole system will be mount in the vehicle for the transmission and reception of data as well as for the reading and recording of audio conversations and vehicles condition.

4.2.2 Localization Setup

Figure 4.2a LCD display for Localization

Figure 4.2b Visible Light Communication Device

Figures 4.2a and **4.2b** show the chassis of the whole communication system and another system with supply switch, rotary switch and Tact switch for controlling the ON and OFF state of the transceiver, black box and CAN Bus system. Also, an LCD display for the output of the localization system.

Figure 4.3 Localization Testing Setup

Figure 4.3 shows the stationary testing setup for the localization system. The system will recognize the LED transmitter's location based on the received signal strength of the photodiode. The localization system aims to localize and display where the transmitted message comes from.

4.2.3 Actual Testing Setup

Figure 4.4a Front Transmitter setup

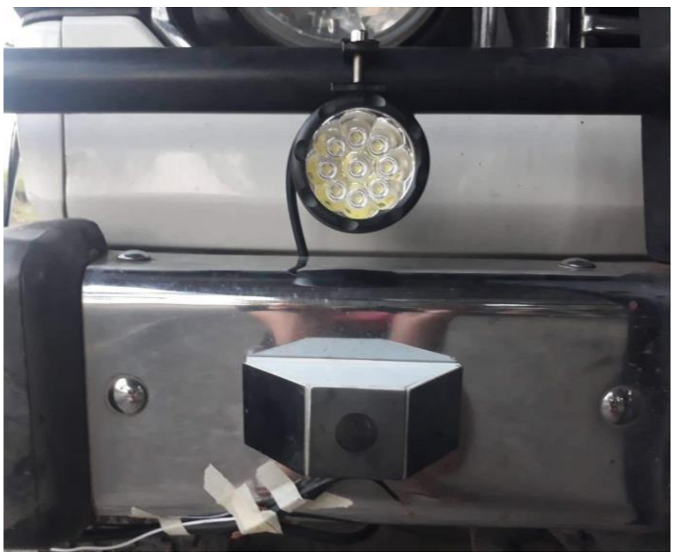


Figure 4.4b Front Transmitter setup

Figure 4.5a Rear Transmitter Setup

Figure 4.5b Rear Transmitter Setup

Figures 4.4a, 4,4b, 4.5a and **4.5b** show the setup of the LED transmitter and Photodiode Receiver mounted at the rear and front side of the vehicle. The both vehicles runs in 10 kph to 30 kph and communicate using the VLC communicating system.

4.3 Data and Results

4.3.1 Test for Functionality

4.3.1.1 Transceiver System

A 12 V 90 W power LED light was integrated to the transceiver circuit. Testing was conducted to see the intensity of the LED light used. The beam angle was calculated using Pythagorean Theorem. The received voltage from the solar cell was also measured during testing.

Table 4.1 Light Intensity and Beam Angle Reading

Distance (m)	Light Intensity (lx)	Vout		Beam Angle (°)
		Min.	Max.	
0.5	2329	3.2	3.4	15.94
1	744	2	2.1	14.25
1.5	325	1.4	1.45	16.69
2	197	1.05	1.1	17.06
2.5	156	0.96	1	15.71
3	139	0.74	0.8	16.50
3.5	73	0.58	0.63	16.90
4	60	0.52	0.56	17.06
4.5	54	0.4	0.44	17.19

Table 4.1 shows the results from the conducted testing for the light intensity as well as the beam angle and output voltage of the used LED light at different distances. It can be seen that as the distance increases the light intensity as well as the voltage output from the receiver section decreases. The beam angle however was not stable due to different light sources from the environment where the testing was conducted.

Table 4.2 Isolated Data Test

DISTANCE (m)	LIGHT INTENSITY (lx)		Vout		BEAM ANGLE (°)
	MIN	MAX	MIN	MAX	
0.5	1960	1998	3.35	3.4	15.94
1	467	477	2.4	2.41	14.81
1.5	193	198	1.46	1.48	15.94
2	105	108	0.99	1	14.82
2.5	70	70	0.7	0.71	15.04
3	48	49	0.53	0.55	14.06
3.5	34	35	0.39	0.4	14.33
4	25	26	0.3	0.31	14.25
4.5	20	20	0.24	0.25	14.94
5	16	16	0.19	0.2	14.14
5.5	13	13	0.15	0.15	13.89
6	11	11	0.13	0.13	13.31
6.5	9	10	0.12	0.13	13.16
7	8	8	0.12	0.12	12.88
7.5	7	7	0.11	0.11	12.48
8	6	6	0.1	0.11	12.55
8.5	6	6	0.09	0.09	12.35
9	5	5	0.08	0.08	12.18
9.5	4	4	0.06	0.06	12.02
10	4	4	0.05	0.05	11.99

Looking at **table 4.2,** this table shows the testing of the transceiver system in an isolated environment with no external light source, it can be noticed that the beam angle is almost constant then starts to decrease at 5 meters of distance. It can be concluded that the beam of the light starts to faint when it goes beyond 5 meters. The light intensity and voltage from the LED transmitter varies as the voice was transmitted.

4.3.2.1.2 Optical Filter System

Table 4.3 Testing without Filter

Distance (m)	Light Intensity (lx)	Vout		Beam Angle (°)
		Min.	Max.	
0.5	2329	3.2	3.4	15.94
1	744	2	2.1	14.25
1.5	325	1.4	1.45	16.69
2	197	1.05	1.1	17.06
2.5	156	0.96	1	15.71
3	139	0.74	0.8	16.50
3.5	73	0.58	0.63	16.90
4	60	0.52	0.56	17.06
4.5	54	0.4	0.44	17.19

Table 4.4 Testing with Filter

Distance (m)	Light Intensity (lx)	Vout		Beam Angle (°)
		Min.	Max.	
0.5	380	1.6	1.8	8.01
1	103	0.65	0.75	13.69
1.5	48	0.45	0.5	15.19
2	30	0.3	0.35	13.12
2.5	20	0.16	0.18	12.56
3	15	0.2	0.12	13.30
3.5	11	0.1	0.1	12.07
4	9	0.09	0.09	11.14
4.5	7	0.03	0.03	11.57

Tables 4.3 and **4.4** show the result for the system without filter and with filter, respectively. It can be noticed that there is a huge difference between the two tests. Light intensity was drastically decreased and therefore so does the voltage output at the receiver

side due to the dark coated microlouver film used for the filtering of ambient light. Moreover, the film used also reduced the noise from external light sources.

4.3.1.3 Control Area Network Bus System

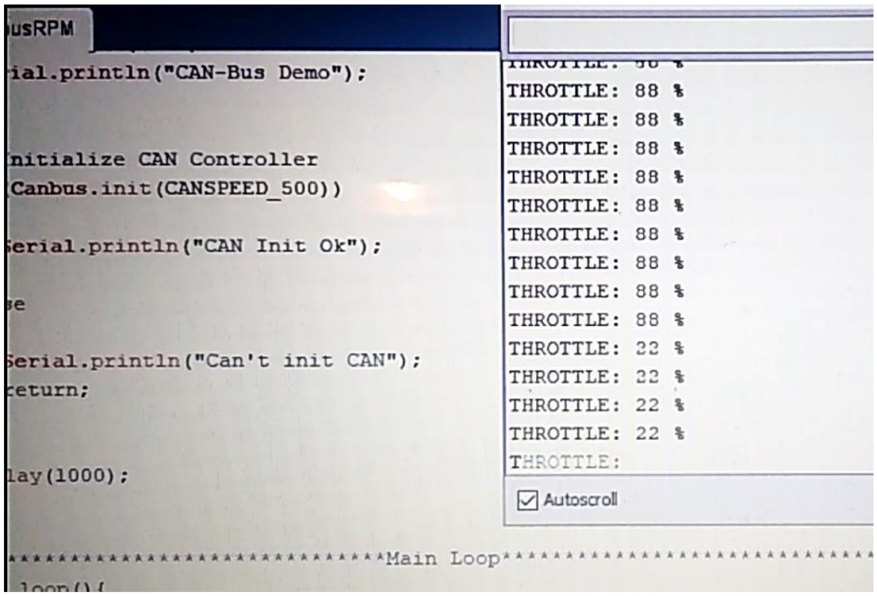


Figure 4.6 CAN Bus Throttle Reading

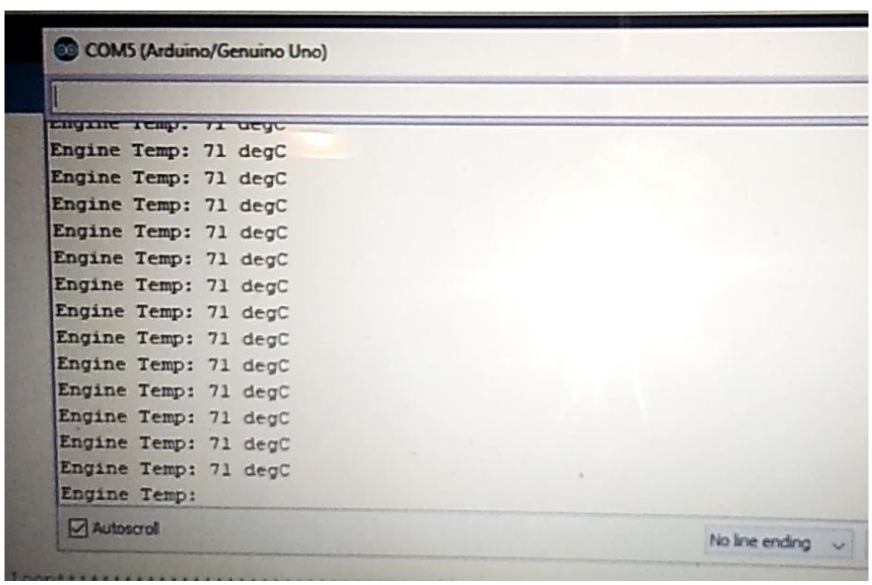


Figure 4.7 CAN Bus Engine Temperature Reading

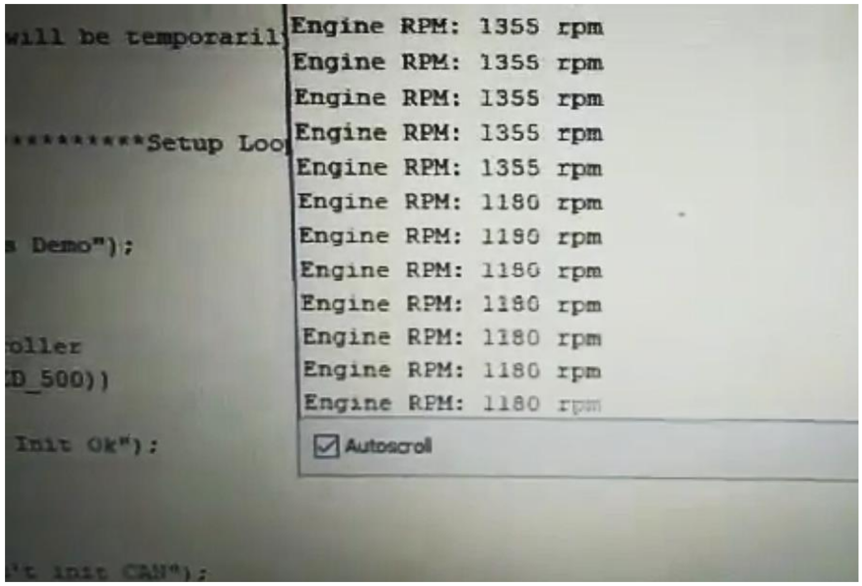


Figure 4.8 CAN Bus RMP Reading

Figures 4.6,4.7,4.8 show the data gathered and reading of the CAN Bus shield for the throttle, engine temperature and engine RPM of the vehicle. The CAN Bus has successfully read and centralize the condition of the vehicle that can be used to inform the driver of the condition of their vehicles.

4.3.1.4 Black Box Storage System

```
BlackBox
    recmode = 1;
    audiofile++;
    digitalWrite(6, HIGH);
    switch (audiofile) {
      case 1: audio.startRecording("1.wav", 16000, A0); break;
      case 2: audio.startRecording("2.wav", 16000, A0); break;
      case 3: audio.startRecording("3.wav", 16000, A0); break;
      case 4: audio.startRecording("4.wav", 16000, A0); break;
      case 5: audio.startRecording("5.wav", 16000, A0); break;
      case 6: audio.startRecording("6.wav", 16000, A0); break;
      case 7: audio.startRecording("7.wav", 16000, A0); break;
      case 8: audio.startRecording("8.wav", 16000, A0); break;
      case 9: audio.startRecording("9.wav", 16000, A0); break;
      case 10: audio.startRecording("10.wav", 16000, A0); break;
    }
```

Figure 4.9a Codes for Data Reading and Logging

```
}
else {
  recmode = 0;
  digitalWrite(6, LOW);
  switch (audiofile) {
    case 1: audio.stopRecording("1.wav"); break;
    case 2: audio.stopRecording("2.wav"); break;
    case 3: audio.stopRecording("3.wav"); break;
    case 4: audio.stopRecording("4.wav"); break;
    case 5: audio.stopRecording("5.wav"); break;
    case 6: audio.stopRecording("6.wav"); break;
    case 7: audio.stopRecording("7.wav"); break;
    case 8: audio.stopRecording("8.wav"); break;
    case 9: audio.stopRecording("9.wav"); break;
    case 10: audio.stopRecording("10.wav"); break;
```

Figure 4.9b Codes for Data Reading and Logging

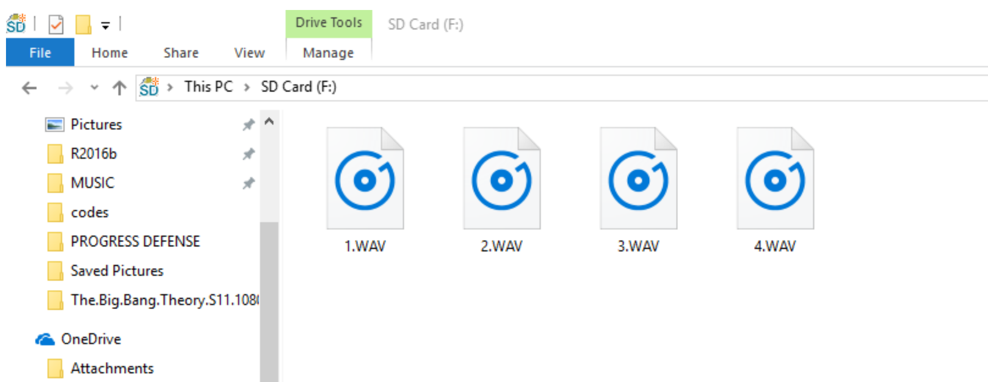


Figure 4.9c Output from the Data Reading and Logging Simulation

Figures 4.9a and **4.9b** and **4.9c** show the program and output audio file for the data reading and logging of the black box. The audio conversation transmitted and received by the transceiver system will be recorded and stored to the SD card module used for the storage of information.

Table 4.5 Black Box Audio Recording

TIME(SEC)	SIZE(KB)	TIME(SEC)	SIZE(KB)
5	165	2	66
8	264	5	165
10	330	16	528
13	429	24	792
15	495	31	1023
16	528	36	1188
18	594	45	1485
21	693	46	1518
22	726	51	1683
23	759	60	1980
24	792	61	2013
33	1089	72	2376
45	1485	75	2475
60	1980	98	3234
65	2145	122	4026
70	2310	134	4422
73	2409	152	5016
83	2739	163	5379
120	3960	164	5412
330	10890	180	5940
350	11550	322	10626
640	21120	512	16896
750	24750	532	17556
800	26400	640	21120
805	26565	645	21285
950	31350	1217	40161
1030	33990	1500	49500
1500	49500	1520	50160
1803	59499	1860	61380

Table 4.5 shows the data in time and size of the audio recording of the VLC system. The data on the table above shows the longest time the black box storage was used which is 1860 seconds or 31 minutes and the largest file size is 60 MB. Based on the data the black box storage can store 2 MB per minute. The largest file

allocation of the system was 500 MB and the longest time that can be used was 4 hours. The black box system storage capability also depends on the SD card used.

4.3.2 Test for Audio Fidelity

Figure 4.10a Deployment Setup

Figure 4.10b Deployment Setup

Figure 4.10a and **4.10b** shows the actual setup of the device mounted in the vehicle and the actual deployment in data gathering of the audio fidelity vs distance while two vehicles are in motion.

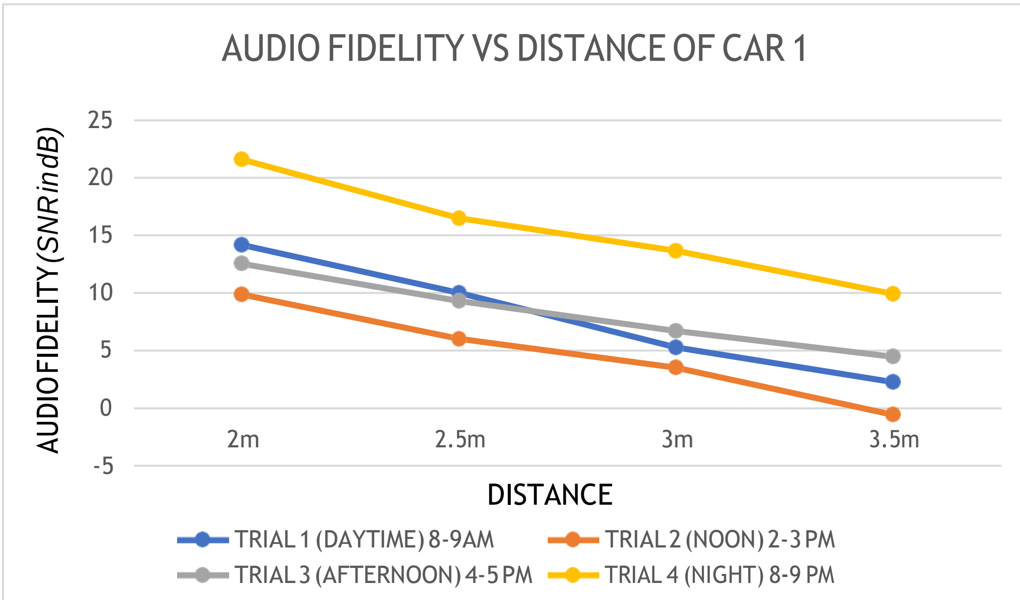


Figure 4.11a Audio Fidelity Vs Distance at Different Time of Car 1

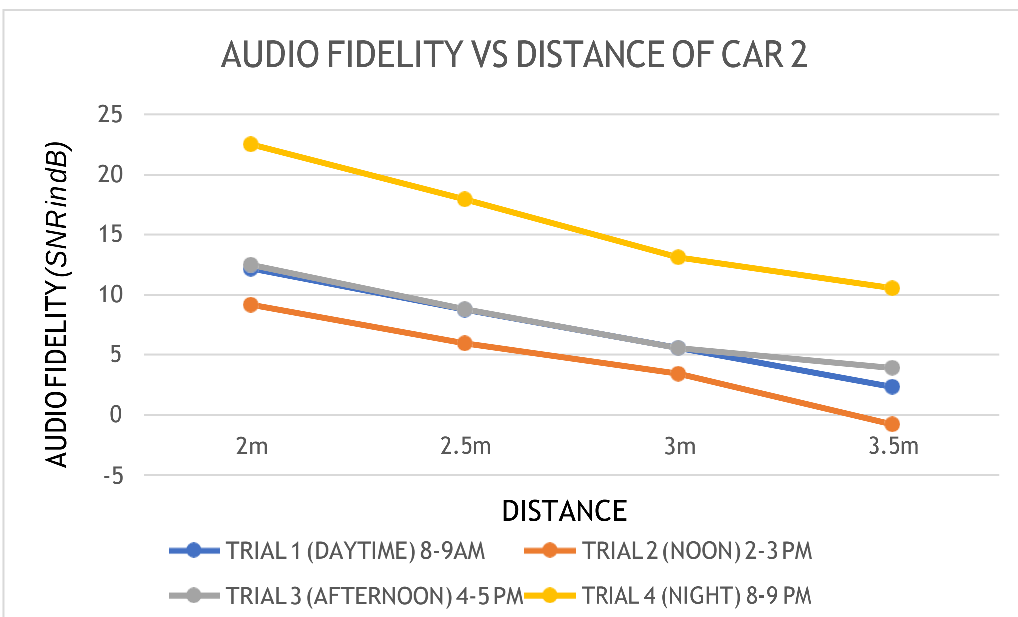


Figure 4.11b Audio Fidelity Vs Distance at Different Time of Car 2

Figure 4.11a and **4.11b** shows the line graph of the Audio fidelity at different time in both car 1 and car 2. The Audio Fidelity of the device was determined by getting the Signal-to-Noise ratio of the device, SNR can be calculated by using the noise voltage and signal voltage. The formula for getting the Signal-to Noise Ratio was $10log_{10}(SNR_p)$ and for getting the SNR_p is $SNR_p = \frac{Vrms(Signal)}{Vrms(Noise)}$. The noise and signal voltage were measured using voltmeter, the noise voltage was measured when the device is not sending data while the signal voltage was measured when the device was sending a data. The data were gathered in different trials at different time to identify at what time the VLC system was more effective, and as the result of the gathered data, trial 2 shows the lowest SNR and trial 4 shows the highest SNR, therefore the system was more effective at night and less effective at noon because of the high level of ambient light noise present.

4.3.3 Test for Proximity Accuracy

Table 4.6 Distance Vs Voltage Data

Voltage	Arduino Serial Equivalent	Distance
3.35	685.41	0.5
2.4	491.04	1
1.46	298.716	1.5
0.99	202.554	2
0.7	143.22	2.5
0.53	108.438	3
0.39	79.794	3.5
0.3	61.38	4
0.24	49.104	4.5
0.19	38.874	5
0.15	30.69	5.5
0.13	26.598	6
0.12	24.552	6.5
0.12	24.552	7
0.11	22.506	7.5
0.1	20.46	8
0.09	18.414	8.5
0.08	16.368	9
0.06	12.276	9.5
0.05	10.23	10

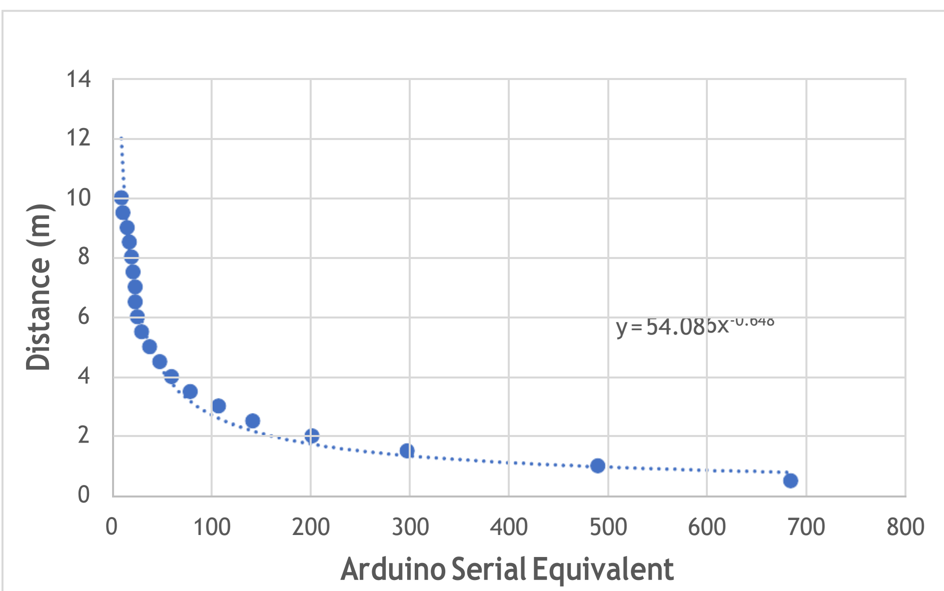


Figure 4.12 Distance VS Voltage Graph

Table 4.6 shows the data of the distance vs voltage and **Figure 4.12** shows the graph of the distance vs voltage. The program for localization is calibrated for indoor isolated use. The data above shows the relationship between the voltage output and distance. The voltage output is converted to its Arduino serial equivalent since the program uses AnalogRead which only gives serial reading of the sensors not the actual voltage. The proponents then used curve fitting and got the power function y = 54.086x^-0.648. This equation is now used because it gives a more accurate result than linear regression

4.3.3.1 Test for Positioning Accuracy

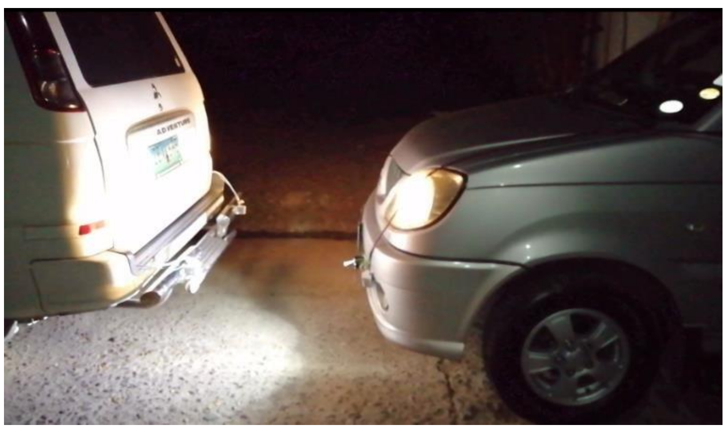


Figure 4.13a Vehicle Setup

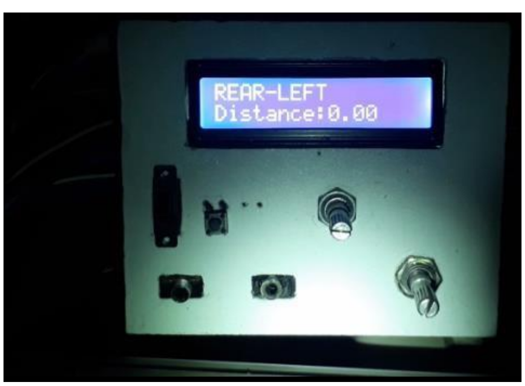


Figure 4.13b Distance and Positioning system output

Figure 4.13a shows the vehicle setup in gathering the data for the position of the sender to test the accuracy of the positioning system, and **4.13b** shows the output of the positioning system displayed in the LCD.

Table 4.7 Positioning Accuracy

POSITION ACCURACY				
TRIAL 1 (MORNING) 8-9 AM				
CAR 1	CAR 2	CAR 2	CAR 1	DURATION
TRANSMITTER USED	RECEIVER USED	TRANSMITTER USED	RECEIVER USED	
FRONT-LEFT	REAR-LEFT	REAR-LEFT	FRONT-LEFT	13 secs
FRONT-LEFT	REAR-LEFT	REAR-RIGHT	FRONT-RIGHT	10 secs
REAR-RIGHT	FRONT-RIGHT	FRONT-LEFT	REAR-LEFT	15 secs
TRIAL 2 (AFTERNOON) 2-3 PM				
CAR 1	CAR 2	CAR 2	CAR 1	DURATION
TRANSMITTER USED	RECEIVER USED	TRANSMITTER USED	RECEIVER USED	
REAR-LEFT	FRONT-LEFT	FRONT-LEFT	REAR-RIGHT	11 secs
REAR-RIGHT	FRONT-RIGHT	FRONT-RIGHT	REAR-RIGHT	14 secs
REAR-LEFT	FRONT-RIGHT	FRONT-LEFT	REAR-LEFT	9 secs
TRIAL 3 (AFTERNOON) 5-6 PM				
CAR 1	CAR 2	CAR 2	CAR 1	DURATION
TRANSMITTER USED	RECEIVER USED	TRANSMITTER USED	RECEIVER USED	
REAR-RIGHT	FRONT-RIGHT	FRONT-LEFT	REAR-LEFT	10 secs
FRONT-LEFT	REAR-LEFT	REAR-LEFT	FRONT-LEFT	14 secs
FRONT-RIGHT	REAR-RIGHT	REAR-LEFT	FRONT-LEFT	8 secs
TRIAL 4 (NIGHT) 8-9 PM				
CAR 1	CAR 2	CAR 2	CAR 1	DURATION
TRANSMITTER USED	RECEIVER USED	TRANSMITTER USED	RECEIVER USED	
REAR-LEFT	FRONT-LEFT	FRONT-RIGHT	REAR-RIGHT	12 secs
FRONT-RIGHT	REAR-RIGHT	REAR-LEFT	FRONT-LEFT	16 secs
FRONT-LEFT	REAR-LEFT	REAR-RIGHT	FRONT-RIGHT	15 secs
TRIAL 5 (NIGHT) 8-9 PM				
CAR 1	CAR 2	CAR 2	CAR 1	DURATION
TRANSMITTER USED	RECEIVER USED	TRANSMITTER USED	RECEIVER USED	
FRONT-RIGHT	REAR-RIGHT	REAR-RIGHT	FRONT-RIGHT	22 secs
FRONT-LEFT	REAR-LEFT	REAR-LEFT	FRONT-LEFT	12 secs
FRONT-LEFT	REAR-LEFT	REAR-RIGHT	FRONT-RIGHT	7 secs

Table 4.7 shows the data gathered for the positioning accuracy from 5 trials at different time interval. It could be seen that when the drivers communicate the VLC based positioning system using received signal strength technique determines where the signal is

coming from. In this data the positioning system accuracy is high at different trials except for trial 2 in the afternoon at 2-3 pm for there is an error where the receiver vehicle displayed rear-right instead of rear-left, because the sender vehicle use front-left transmitter the receiver vehicle should display rear-left.

4.3.3.2 Test for Distance Accuracy

Figure 4.14a Vehicle Setup

Figure 4.14b Distance and Positioning system Output

Figure 14.a shows the vehicle setup for gathering the distance received of the communicating vehicle to test the distance accuracy of the system and **14.b** shows the output distance of the system.

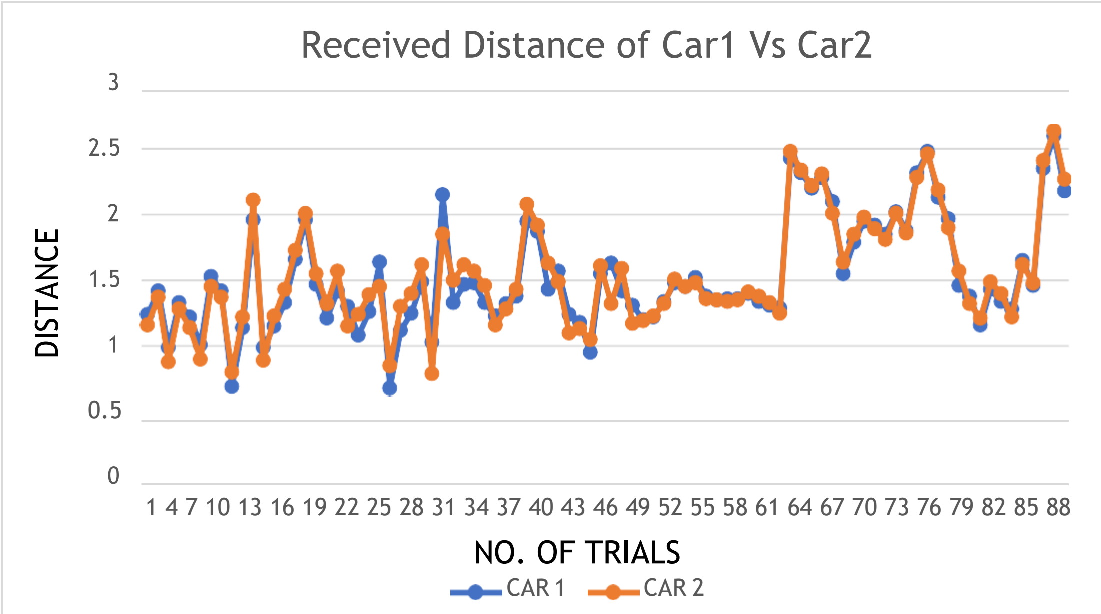


Figure 4.15 Received Distance from Car 1 and Car 2

Figure 4.15 shows the graph of the summarize data of distances received of the two communicating vehicles in five different trials obtained respectively form trial 1 to trial 5 at different time intervals. It can be seen that the two lines are identical, therefore there is no significant difference in the received distances of the two communicating vehicles. Also, it can be seen that the distance increases at the end of the graph meaning that the localization system can be used at further distances when at night, where low ambient light noise is present.

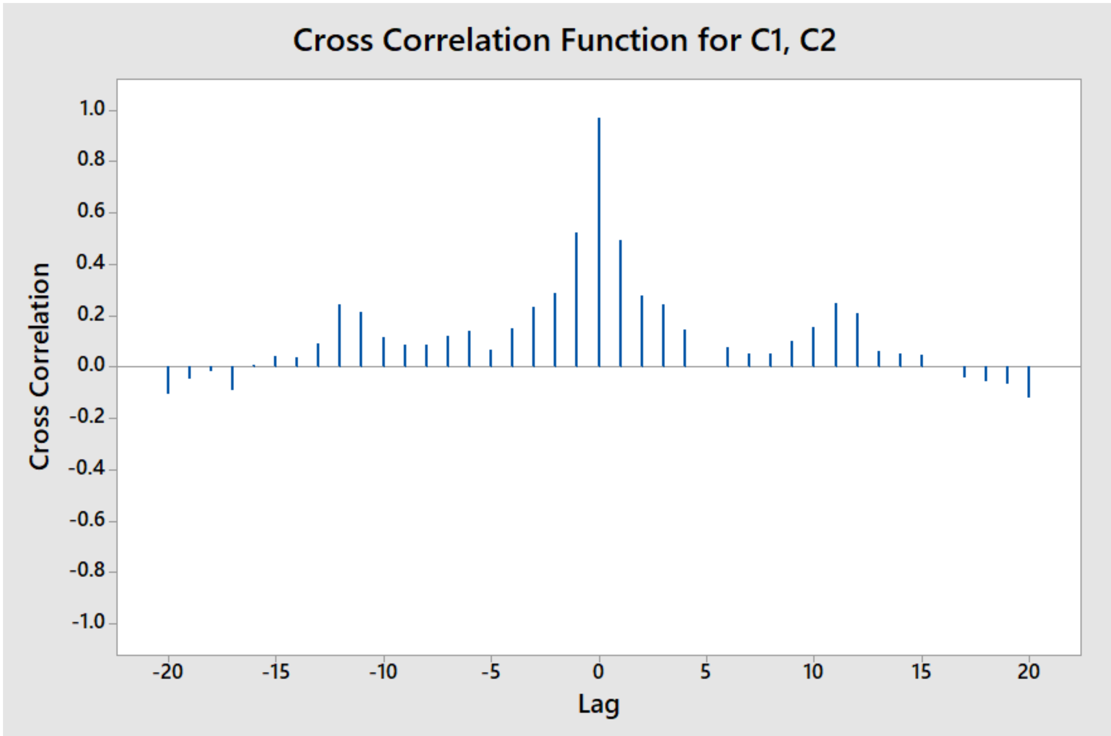


Figure 4.15(b) Cross Correlogram of Received Distances from Car 1 vs Car 2

On the **Figure 4.15(d)** shown above, the correlation at lag 0 is 0.96. Since 0.96 is greater than 0, the correlation is significant.

CHAPTER 5

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This chapter includes summary of findings from the series of test conducted, formulated conclusion and recommendations for the future development of the project.

5.1 Summary of Findings

This study of a new wireless communication system through visible light as the transmission medium for the communication of vehicle to vehicle was made possible. In the development of this system the proponents conducted series of testing for a suitable receiver and transmitter and resulted to a 12 V 90 W powered LED that can be used for longer range of transmission and photodiode for the receiver section for its sensitivity in changes in light intensity. Also, the proponents design and test different transceiver circuit that will transmit and receive audio signal clearly. During the testing of the transceiver system indoor and outdoor with direct sunlight the transmitted voice was received real time without lagging, and only when the light or the photodiode was blocked will the transmission of voice be stopped. This communication system is susceptible to light noise but with the developed optical filter in the receiver section of this system, the ambient light noise was reduced. Several factors must be considered in using this system, the supply source of the system must be 12 V any supply voltage less than that will reduce the transmission range of the LED light. The LED light must be in the sight of the photodiode in order for it to receive the transmitted audio signal.

5.2 Conclusions

This study has developed a new wireless communication system in an outdoor environment that can transmit and receive audio information between vehicles using visible light communication. Also, this study has developed a VLC based positioning system using the RSS or Received Signal Strength technique to determine the distance and position of the sender vehicle and add a black box system for the storage of the audio conversation. The first objective was to design a transceiver circuit that will send and receive audio information, the proponents were able to develop and integrate existing VLC circuit to create a suitable VLC transceiver system that will be used for vehicles in an outdoor environment, the proponents test and design different amplifiers, LED drivers, and transimpedance amplifier that will make a good quality audio signal for the communication system. The second objective was to integrate a black box that can record audio conversation in case of car accidents and utilize the Control Area Network Bus (CAN Bus) capabilities in a vehicle's electronic control. The proponents acquired the needed materials for this objective which are the CAN Bus shield, Arduino Uno and DB9 to OBDII cable for the programming of the CAN Bus and in order for CAN Bus shield read and extract data from the vehicle using the cable to connect the device to the vehicles ECU. Also, the proponents acquired Arduino pro mini for the programming of data reading and lagging of audio conversation of the system and using an Arduino SD card module to store the audio files to an external memory. The third objective was to design a filter for the photodetector that can reduce the data transmission noise caused by ambient light. The proponents have researched and tried different ambient light blocking materials and different design for the filtering system that will have a good blocking effect for ambient light noises. The proponents then come up with the design to be mounted in the receiver section using 20 mm collimating lens for the focusing of the light that the LED transmitter emits and a microlouver film to block unwanted light sources in 40 degrees. The fourth objective was to design a visible light-based outdoor positioning system using received signal strength technique. The proponents were able to create a program using Arduino Uno microcontroller to determine the distance and position of the transmitting vehicle from front left, front right, rear left and rear right using the received signal strength algorithm.

In this study, all the objectives were met. During the testing of the VLC system it can be seen that the system is less efficient at daytime because of a high level of ambient light noise and since VLC is susceptible to light noise. The communication system and the positioning system was more effective to use at night time. The audio quality of the device gets noisy when distance increases and so as the positioning system gets less accurate. Since the system depends on the light intensity, the further the communicating vehicles are, the weaker the light intensity of the light source, therefore the system can be used at a limited distance.

Over all the VLC system is a new way for drivers to communicate with one another. The system can aid for the prevention of car accidents and different vehicle issues such as flat tires, open trunk and for some cases where drivers can ask for help. This system was also made portable, low cost and safe to use but if ever this study will be recognized it can be developed and mounted permanently to a vehicle.

5.3 Recommendations

To further improve the study the proponents would like to recommend another way of localizing vehicle aside from using the received signal strength such as time of arrival, time difference of arrival and can also be angle of arrival for the received audio signal of the photodiode from the light. The proponents also recommend the use of other optical filtering device such as a bandpass optical filter that will block unwanted light at a certain wavelength.

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APPENDIX A

Survey Form

TECHNOLOGICAL UNIIVERSITY OF THE PHILIPPINES

Ayala Blvd., Ermita, Manila

COLLEGE OF ENGINEERING

ELECTRONICS ENGINEERING DEPARTMENT

electronics@tup.edu.ph

VEVOCOM LIGHT SURVEY FORM

Name:

Date and Time:

Rate the items from 1-5 (1 – Lowest, 5 – highest)

	1	2	3	4	5
Audio Fidelity *(the quality of the voice received)*					
Localization Accuracy *(the LCD displays the correct distance and position of the sender vehicle ex. Rear, Front, Rear Left, Rear Right, Front Left, Front Right)*					
User Friendly *(is the device easy to use?)*					
Reliability *(are the messages received and sent the same and can the device be trusted to use as communication system with other vehicles?)*					

1. Is the device essential and helpful to your daily driving?

   ____

2. If yes, in what way is the device helpful to you?

   ____

   ____

APPENDIX B

Bill of Materials

BILL OF MATERIALS

Materials	Quantity	Unit Price (₱)	Price (₱)
Transmitter			
LM7805	1	20	20
LM7809	1	20	20
IRF9530N	1	50	50
NJM2904D	1	25	25
LM386	1	20	20
BC548	1	4	4
BC547	1	4	4
1000µF / 16V Electrolytic capacitor	1	6	6
470µF / 16V Electrolytic capacitor	1	3	3
220µF / 25V Electrolytic capacitor	1	2	2
10µF / 50V Electrolytic capacitor	2	1	2
0.1µF / 16V Electrolytic capacitor	4	1	4
47nF / 50V Ceramic Capacitor	1	1	1
100KΩ / 1/2 Watts	1	0.5	0.5
10KΩ / 1/2 Watts	5	0.5	2.5
1KΩ / 1/2 Watts	1	0.5	0.5
10Ω / 1/2 Watts	1	0.5	0.5
82kΩ / 1/2 Watts	1	0.5	0.5
Terminal Socket	3	10	30
Receiver			
LM7809	1	20	20
LM386	2	30	60
1000µF / 16V Electrolytic capacitor	1	6	6
10µF / 16V Electrolytic capacitor	6	1	6
0.1µF / 50V Ceramic capacitor	4	2	8
0.1µF / 50V Monolithic capacitor	1	1	1
0.1µF / 100V Mylar capacitor	2	2	4
10Ω / 1/2 Watts	2	0.5	1
10KΩ / 1/2 Watts	1	0.5	0.5
10KΩ Potentiometer	3	12	36
Terminal Socket	3	10	30
Photo diode	12	45	540
Black Box			
Arduino Pro Mini	1	250	250
SD Card Module	1	150	150
SD Card (2GB)	1	100	100
Light Emmiting Diode (LED)	1	3	3
Tact Switch	1	7	7

Chassis			
Sintra PVC Foam Board 20 x20	1	1000	1000
Female Jack	2	10	20
SPST Switch	2	10	20
Push Button	2	10	20
12V/20AH Battery	2	800	1600
Blue Water LED 90W	4	800	3200
Wires			
Stranded (Meter)	1	50	50
Solid (Meter)	1	50	50
Shielded (Yards)	5	600	3000
Microcontroller			
CAN BUS Shield V2.0	1	1350	1350
Arduino Uno	1	1455	1455
OBD2-Db9	1	500	500
			13683

APPENDIX C

Source Codes

Source Codes

Black Box

```
#include <SD.h>

#include <SPI.h>

#include <TMRpcm.h>

#define SD_ChipSelectPin 10

TMRpcm audio;

int audiofile = 0;

unsigned long i = 0;

bool recmode = 0;



void setup() {
```

```
}

void loop() {
}

void button() {
  while (i < 300000) {
    i++;
  }
  i = 0;
  if (recmode == 0) {
    recmode = 1;
    audiofile++;
    digitalWrite(6, HIGH);
    switch (audiofile) {
      case 1: audio.startRecording("1.wav", 16000, A0); break;
      case 2: audio.startRecording("2.wav", 16000, A0); break;
```

```
case 3: audio.startRecording("3.wav", 16000, A0); break;

case 4: audio.startRecording("4.wav", 16000, A0); break;

case 5: audio.startRecording("5.wav", 16000, A0); break;

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case 85: audio.startRecording("85.wav", 16000, A0); break;

case 86: audio.startRecording("86.wav", 16000, A0); break;

case 87: audio.startRecording("87.wav", 16000, A0); break;

case 88: audio.startRecording("88.wav", 16000, A0); break;

case 89: audio.startRecording("89.wav", 16000, A0); break;

case 90: audio.startRecording("90.wav", 16000, A0); break;

case 91: audio.startRecording("91.wav", 16000, A0); break;

case 92: audio.startRecording("92.wav", 16000, A0); break;
```

```
    case 93: audio.startRecording("93.wav", 16000, A0); break;

    case 94: audio.startRecording("94.wav", 16000, A0); break;

    case 95: audio.startRecording("95.wav", 16000, A0); break;

    case 96: audio.startRecording("96.wav", 16000, A0); break;

    case 97: audio.startRecording("97.wav", 16000, A0); break;

    case 98: audio.startRecording("98.wav", 16000, A0); break;

    case 99: audio.startRecording("99.wav", 16000, A0); break;

    case 100: audio.startRecording("100.wav", 16000, A0); break;



  }

}

else {

  recmode = 0;

  digitalWrite(6, LOW);

  switch (audiofile) {

  case 1: audio.stopRecording("1.wav", 16000, A0); break;

    case 2: audio.stopRecording("2.wav", 16000, A0); break;
```

```
case 3: audio.stopRecording("3.wav", 16000, A0); break;

case 4: audio.stopRecording("4.wav", 16000, A0); break;

case 5: audio.stopRecording("5.wav", 16000, A0); break;

case 6: audio.stopRecording("6.wav", 16000, A0); break;

case 7: audio.stopRecording("7.wav", 16000, A0); break;

case 8: audio.stopRecording("8.wav", 16000, A0); break;

case 9: audio.stopRecording("9.wav", 16000, A0); break;

case 10: audio.stopRecording("10.wav", 16000, A0); break;

case 11: audio.stopRecording("11.wav", 16000, A0); break;

case 12: audio.stopRecording("12.wav", 16000, A0); break;

case 13: audio.stopRecording("13.wav", 16000, A0); break;

case 14: audio.stopRecording("14.wav", 16000, A0); break;

case 15: audio.stopRecording("15.wav", 16000, A0); break;

case 16: audio.stopRecording("16.wav", 16000, A0); break;

case 17: audio.stopRecording("17.wav", 16000, A0); break;

case 18: audio.stopRecording("18.wav", 16000, A0); break;

case 19: audio.stopRecording("19.wav", 16000, A0); break;

case 20: audio.stopRecording("20.wav", 16000, A0); break;
```

```
case 21: audio.stopRecording("21.wav", 16000, A0); break;

case 22: audio.stopRecording("22.wav", 16000, A0); break;

case 23: audio.stopRecording("23.wav", 16000, A0); break;

case 24: audio.stopRecording("24.wav", 16000, A0); break;

case 25: audio.stopRecording("25.wav", 16000, A0); break;

case 26: audio.stopRecording("26.wav", 16000, A0); break;

case 27: audio.stopRecording("27.wav", 16000, A0); break;

case 28: audio.stopRecording("28.wav", 16000, A0); break;

case 29: audio.stopRecording("29.wav", 16000, A0); break;

case 30: audio.stopRecording("30.wav", 16000, A0); break;

case 31: audio.stopRecording("31.wav", 16000, A0); break;

case 32: audio.stopRecording("32.wav", 16000, A0); break;

case 33: audio.stopRecording("33.wav", 16000, A0); break;

case 34: audio.stopRecording("34.wav", 16000, A0); break;

case 35: audio.stopRecording("35.wav", 16000, A0); break;

case 36: audio.stopRecording("36.wav", 16000, A0); break;

case 37: audio.stopRecording("37.wav", 16000, A0); break;

case 38: audio.stopRecording("38.wav", 16000, A0); break;
```

```
case 39: audio.stopRecording("39.wav", 16000, A0); break;

case 40: audio.stopRecording("40.wav", 16000, A0); break;

case 41: audio.stopRecording("41.wav", 16000, A0); break;

case 42: audio.stopRecording("42.wav", 16000, A0); break;

case 43: audio.stopRecording("43.wav", 16000, A0); break;

case 44: audio.stopRecording("44.wav", 16000, A0); break;

case 45: audio.stopRecording("45.wav", 16000, A0); break;

case 46: audio.stopRecording("46.wav", 16000, A0); break;

case 47: audio.stopRecording("47.wav", 16000, A0); break;

case 48: audio.stopRecording("48.wav", 16000, A0); break;

case 49: audio.stopRecording("49.wav", 16000, A0); break;

case 50: audio.stopRecording("50.wav", 16000, A0); break;

case 51: audio.stopRecording("51.wav", 16000, A0); break;

case 52: audio.stopRecording("52.wav", 16000, A0); break;

case 53: audio.stopRecording("53.wav", 16000, A0); break;

case 54: audio.stopRecording("54.wav", 16000, A0); break;

case 55: audio.stopRecording("55.wav", 16000, A0); break;

case 56: audio.stopRecording("56.wav", 16000, A0); break;
```

```
case 57: audio.stopRecording("57.wav", 16000, A0); break;

case 58: audio.stopRecording("58.wav", 16000, A0); break;

case 59: audio.stopRecording("59.wav", 16000, A0); break;

case 60: audio.stopRecording("60.wav", 16000, A0); break;

case 61: audio.stopRecording("61.wav", 16000, A0); break;

case 62: audio.stopRecording("62.wav", 16000, A0); break;

case 63: audio.stopRecording("63.wav", 16000, A0); break;

case 64: audio.stopRecording("64.wav", 16000, A0); break;

case 65: audio.stopRecording("65.wav", 16000, A0); break;

case 66: audio.stopRecording("66.wav", 16000, A0); break;

case 67: audio.stopRecording("67.wav", 16000, A0); break;

case 68: audio.stopRecording("68.wav", 16000, A0); break;

case 69: audio.stopRecording("69.wav", 16000, A0); break;

case 70: audio.stopRecording("70.wav", 16000, A0); break;

case 71: audio.stopRecording("71.wav", 16000, A0); break;

case 72: audio.stopRecording("72.wav", 16000, A0); break;

case 73: audio.stopRecording("73.wav", 16000, A0); break;

case 74: audio.stopRecording("74.wav", 16000, A0); break;
```

```
case 75: audio.stopRecording("75.wav", 16000, A0); break;

case 76: audio.stopRecording("76.wav", 16000, A0); break;

case 77: audio.stopRecording("77.wav", 16000, A0); break;

case 78: audio.stopRecording("78.wav", 16000, A0); break;

case 79: audio.stopRecording("79.wav", 16000, A0); break;

case 80: audio.stopRecording("80.wav", 16000, A0); break;

case 81: audio.stopRecording("81.wav", 16000, A0); break;

case 82: audio.stopRecording("82.wav", 16000, A0); break;

case 83: audio.stopRecording("83.wav", 16000, A0); break;

case 84: audio.stopRecording("84.wav", 16000, A0); break;

case 85: audio.stopRecording("85.wav", 16000, A0); break;

case 86: audio.stopRecording("86.wav", 16000, A0); break;

case 87: audio.stopRecording("87.wav", 16000, A0); break;

case 88: audio.stopRecording("88.wav", 16000, A0); break;

case 89: audio.stopRecording("89.wav", 16000, A0); break;

case 90: audio.stopRecording("90.wav", 16000, A0); break;

case 91: audio.stopRecording("91.wav", 16000, A0); break;

case 92: audio.stopRecording("92.wav", 16000, A0); break;
```

```
      case 93: audio.stopRecording("93.wav", 16000, A0); break;

      case 94: audio.stopRecording("94.wav", 16000, A0); break;

      case 95: audio.stopRecording("95.wav", 16000, A0); break;

      case 96: audio.stopRecording("96.wav", 16000, A0); break;

      case 97: audio.stopRecording("97.wav", 16000, A0); break;

      case 98: audio.stopRecording("98.wav", 16000, A0); break;

      case 99: audio.stopRecording("99.wav", 16000, A0); break;

      case 100: audio.stopRecording("100.wav", 16000, A0); break;

    }

  }
}
```

Localization

```
#include <Wire.h>

#include <LiquidCrystal_I2C.h>



LiquidCrystal_I2C lcd(0x27,20,4);
```

```
void setup() {

 Serial.begin(9600);

 lcd.init();

 lcd.init();



}



void loop() {

  // put your main code here, to run repeatedly:

float A= analogRead(A0);

float B=analogRead(A1);

float C=analogRead(A2);

float D=analogRead(A3);

 // Serial.println(A);

   // Serial.println(B);

     // Serial.println(C);

       // Serial.println(D);
```

```
if ((A+B)>(C+D)){ //Front receivers
  if (A>B){ //Left
  lcd.clear();
  lcd.backlight();
  lcd.setCursor(0,0);
  lcd.print("FRONT-LEFT");



  lcd.setCursor(0,1);
  lcd.print("Distance:");
  lcd.setCursor(9,1);
  lcd.print(x);
  Serial.println(A);
  }
  else if (B>A){// Right
  lcd.clear();
  lcd.backlight();
```

```
  lcd.setCursor(0,0);

  lcd.print("FRONT-RIGHT");

  Q=(B*3.3)/675;

  x=4.7689*pow(e,(-2.708*Q));

  lcd.setCursor(0,1);

  lcd.print("Distance:");

  lcd.setCursor(9,1);

  lcd.print(x);

  Serial.println(x);

  }

}

else if((C+D)>(A+B)){ //BACK

if (C>D){ //LEFT

  lcd.clear();

  lcd.backlight();

  lcd.setCursor(0,0);

  lcd.print("REAR-LEFT");

  Q=(C*3.3)/675;
```

```
  x=4.7689*pow(e,(-2.708*Q));

  lcd.setCursor(0,1);

  lcd.print("Distance:");

  lcd.setCursor(9,1);

  lcd.print(x);

  Serial.println(A);}

else if (D>C){// Right

  lcd.clear();

  lcd.backlight();

  lcd.setCursor(0,0);

  lcd.print("REAR-RIGHT");



  lcd.setCursor(0,1);

  lcd.print("Distance:");

  lcd.setCursor(9,1);

  lcd.print(x);

  Serial.println(A);
```

```
}
}
else{
  lcd.clear();
  lcd.backlight();
  lcd.setCursor(0,0);
  lcd.print("No signal");
  lcd.setCursor(0,1);
  lcd.print("Received");

}
delay(2000);
}
```

CAN BUS

```
//Include necessary libraries for compilation

#include <Canbus.h>

char buffer[64]; //Data will be temporarily stored to this buffer before being written to the file



//******************************Setup Loop*******************************//

void setup() {

  Serial.begin(9600);

  Serial.println("CAN-Bus Demo");



  //Initialize CAN Controller

  if(Canbus.init(CANSPEED_500))

  {

    Serial.println("CAN Init Ok");

  }

  else
```

```
  {
    Serial.println("Can't init CAN");
    return;
  }

  delay(1000);
}

//******************************Main Loop********************************//
void loop(){



     (Canbus.ecu_req(VEHICLE_SPEED,buffer)) ;      /* Request for vehicle KM */


    Serial.print ("VEHICLE SPEED:");
    Serial.println(buffer);


}
```

APPENDIX D

Additional Tables

Table 1. Test for Audio Fidelity of Car 1 and Car 2

TRIAL 1 (MORNING) 8-9AM						
Audio Fidelity Vs Distance Vs Mobility			Vpeak		Vrms	
Audio Fidelity (SNR in Db)	Distance	Speed (Kph)	Noise	Signal	Noise	Signal
14.170	2	16	0.36	1.84	0.254	1.301
10.012	2.5	20	0.48	1.52	0.339	1.074
5.290	3	15	0.62	1.14	0.438	0.806
2.260	3.5	18	0.74	0.96	0.523	0.678
TRIAL 2 (NOON) 2-3 PM						
Audio Fidelity (SNR in Db)	Distance	Speed (Kph)	Noise	Signal	Noise	Signal
9.870	2	15	0.52	1.62	0.367	1.145
6.020	2.5	18	0.68	1.36	0.480	0.961
3.521	3	20	0.76	1.14	0.537	0.806
-0.572	3.5	18	0.94	0.88	0.664	0.622
TRIAL 3 (AFTERNOON) 4-5 PM						
Audio Fidelity (SNR in Db)	Distance	Speed (Kph)	Noise	Signal	Noise	Signal
12.543	2	16	0.42	1.78	0.296	1.258
9.333	2.5	18	0.56	1.64	0.395	1.159
6.704	3	18	0.61	1.32	0.431	0.933
4.483	3.5	20	0.74	1.24	0.523	0.876
TRIAL 4 (NIGHT) 8-9 PM						
Audio Fidelity (SNR in Db)	Distance	Speed (Kph)	Noise	Signal	Noise	Signal
21.583	2	20	0.16	1.92	0.113	1.357
16.493	2.5	22	0.28	1.87	0.197	1.322
13.684	3	18	0.36	1.74	0.254	1.230
9.923	3.5	20	0.52	1.63	0.367	1.152

TRIAL 1 (DAYTIME) 8-9AM						
Audio Fidelity Vs Distance Vs Mobility			Vpeak		Vrms	
Audio Fidelity (SNR in Db)	Distance	Speed (Kph)	Noise	Signal	Noise	Signal
12.181	2	16	0.46	1.87	0.325	1.322
8.744	2.5	20	0.57	1.56	0.403	1.103
5.532	3	15	0.64	1.21	0.452	0.855
2.315	3.5	18	0.72	0.94	0.509	0.664
TRIAL 2 (NOON) 2-3 PM						
Audio Fidelity (SNR in Db)	Distance	Speed (Kph)	Noise	Signal	Noise	Signal
9.165	2	15	0.55	1.58	0.388	1.117
5.959	2.5	18	0.71	1.41	0.502	0.997
3.416	3	20	0.83	1.23	0.586	0.869
-0.799	3.5	18	0.91	0.83	0.643	0.586

TRIAL 3 (AFTERNOON) 4-5 PM						
Audio Fidelity (SNR in Db)	Distance	Speed (Kph)	Noise	Signal	Noise	Signal
12.484	2	16	0.43	1.81	0.304	1.279
8.773	2.5	18	0.59	1.62	0.417	1.145
5.554	3	18	0.67	1.27	0.473	0.898
3.894	3.5	20	0.76	1.19	0.537	0.841
TRIAL 4 (NIGHT) 8-9 PM						
Audio Fidelity (SNR in Db)	Distance	Speed (Kph)	Noise	Signal	Noise	Signal
22.514	2	20	0.14	1.87	0.098	1.322
17.919	2.5	22	0.23	1.81	0.162	1.279
13.114	3	18	0.38	1.72	0.268	1.216
10.545	3.5	20	0.49	1.65	0.346	1.166

Table 4.1 shows the Audio Fidelity Vs Distance Vs Mobility of Car 1 and Car 2 for the two communicating vehicles. The Audio Fidelity was in signal-to-noise ratio in decibel that is obtained using the measured voltage from the transimpedance amplifier of the receiver. The table shows 4 trials in different time interval. Also, it can be seen that as the distance increases the audio fidelity decreases therefore the system can only be used at certain distance.

Table 2 Distance Accuracy

TRIAL 1 MOVING (MORNING 8-9 AM)					
1st Duration (13s)		2nd Duration (10s)		3rd Duration (15s)	
CAR 1 DISTANCE	CAR 2 DISTANCE	CAR 1 DISTANCE	CAR 2 DISTANCE	CAR 1 DISTANCE	CAR 2 DISTANCE
1.23	1.15	1.52	1.44	0.98	0.88
1.41	1.36	1.41	1.36	1.14	1.22
0.98	0.87	0.68	0.79	1.32	1.42
1.32	1.27	1.13	1.21	1.65	1.72
1.21	1.13	1.95	2.1	1.95	2
1	0.89			1.46	1.54
				1.2	1.31
TRIAL 2 MOVING (AFTERNOON 2-3 PM)					
1st Duration (11 s)		2nd Duration (14 s)		3rd Duration (9 s)	
CAR 1 DISTANCE	CAR 2 DISTANCE	CAR 1 DISTANCE	CAR 2 DISTANCE	CAR 1 DISTANCE	CAR 2 DISTANCE
1.41	1.56	0.67	0.84	2.14	1.84
1.29	1.14	1.11	1.29	1.32	1.49
1.07	1.23	1.24	1.39	1.46	1.61
1.25	1.38	1.48	1.61		
1.63	1.44	1.02	0.78		
TRIAL 3 MOVING (AFTERNOON 5-6 PM)					
1st Duration (10s)		2nd Duration (14s)		3rd Duration (8s)	
CAR 1 DISTANCE	CAR 2 DISTANCE	CAR 1 DISTANCE	CAR 2 DISTANCE	CAR 1 DISTANCE	CAR 2 DISTANCE
1.47	1.56	1.94	2.07	1.54	1.6
1.32	1.45	1.86	1.91	1.62	1.31
1.22	1.15	1.42	1.62	1.41	1.58
1.31	1.27	1.56	1.48	1.3	1.16
1.37	1.42	1.23	1.09		
		1.17	1.12		
		0.94	1.04		
TRIAL 4 MOVING (NIGHT 7-8 PM)					
1st Duration (12s)		2nd Duration (16s)		3rd Duration (15s)	
CAR 1 DISTANCE	CAR 2 DISTANCE	CAR 1 DISTANCE	CAR 2 DISTANCE	CAR 1 DISTANCE	CAR 2 DISTANCE
1.19	1.18	1.37	1.35	2.42	2.47
1.21	1.22	1.34	1.34	2.31	2.33
1.33	1.31	1.35	1.33	2.19	2.21
1.47	1.5	1.35	1.34	2.27	2.3
1.44	1.44	1.39	1.4	2.09	2
1.51	1.47	1.33	1.37	1.54	1.63
		1.3	1.32	1.78	1.84
		1.28	1.24		

TRIAL 5 MOVING (NIGHT 8-9 PM)					
1st Duration (22s)		2nd Duration (12s)		3rd Duration (7s)	
CAR 1 DISTANCE	CAR 2 DISTANCE	CAR 1 DISTANCE	CAR 2 DISTANCE	CAR 1 DISTANCE	CAR 2 DISTANCE
1.94	1.97	1.15	1.2	2.34	2.4
1.91	1.88	1.42	1.48	2.59	2.63
1.84	1.8	1.33	1.39	2.17	2.26
2.01	2	1.27	1.21		
1.87	1.85	1.64	1.61		
2.31	2.27	1.45	1.47		
2.47	2.45				
2.12	2.18				
1.96	1.89				
1.45	1.56				
1.37	1.31				

Table 4.2 show the data gathered to determine the distance accuracy of the VLC localization system. It can be seen that the two communicating vehicles displayed different distance as they communicate. The difference in the distance of the two vehicles are not that significant therefore the difference might be because the vehicle is moving.

APPENDIX E

Project Body Parts and Manual

Development of an Inter-Vehicle Voice Communication System via Controller Area Network (CAN Bus) through Visible Light with Black Box as Data Storage

Project Body Parts

1. SR (Receiver Switch) – Turns on and off the receiver
2. ST (Transmitter Switch) – Turns on and off the transmitter
3. LED 1 – Turns on and off the LED on the Front side of the vehicle
4. LED 2 – Turns on and off the LED on the Rear side of the vehicle
5. Speaker – This is where the speaker is connected
6. Mic – This is where the microphone is connected
7. Receiver – This is where the photodetectors are connected
8. Transmitter – This is where the LEDs are connected
9. Gain 1 – This controls the reception of the received audio
10. Gain 2 -This controls the volume of the received audio
11. LCD – This is where the distance and position are displayed

Photodiode (Receiver)

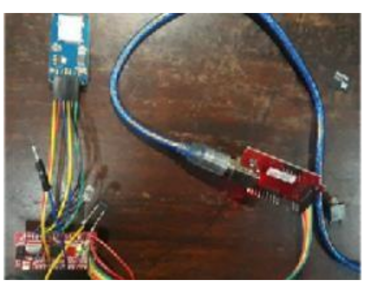
LED (Transmitter)

Transceiver Circuit

CAN Bus Shield

Speaker

LCD



Arduino Pro Mini (Black Box)

Project Manual

1.0 AUTHORIZED USE PERMISSIOM

Any unauthorized reproduction of the documents and usage of the system without the consent of the proponents is unlawful

2.0 GETTING STARTED

2.1 Installation of the Device

1. Survey the Vehicle where the device will be installed. It must be placed near the driver's seat and where the drivers will not be distracted and may not interfere to their driving.

2. Check the stability of the device. It must be placed where the device may avoid tilting and sliding while the vehicle is moving.

2.2 Hardware Installed

- Arduino Uno Microcontroller
- Arduino Pro Mini (Black Box)
- CAN Bus Shield
- Speaker

- LED

- Light Sensor

3.0 HOW TO USE THE VISIBLE LIGHT COMMUNICATION SYSTEM WITH LOCALIZATION

3.1 User's Manual

3.1.1. Plug in the device to the car's power adopter.

3.1.2. Connect the Microphone and speaker to the device.

3.1.3. Turn on the transmitter and receiver.

3.1.4. Choose the desired LED you want to use to transmit your voice.

- LED 1 (Front Right)
- LED 2 (Front Left)
- LED 3 (Rear Right)
- LED 4 (Rear Left)

3.1.5. Use the microphone and relay your message.

3.1.6. The LCD will notify if there is signal received and will display the distance and position of the sender.

3.1.7. You will receive the voice and will be heard in the speaker.

3.2 Data Acquisition and Viewing

3.2.1 Data Acquisition

1. Insert/Plug the microSD card to the SD Card module of the Black box system. A new Wav file is generated.

2. If one the microSD card is removed for data viewing, just insert/plug the microSD card back to the SD card module before using the device in order to record the audio conversation. The succeeding data to be recorded will be added to the microSD card as another wav file.

3.2.2 Data Viewing

1. Remove/Unplug the microSD card from the SD card module.

2. Insert/Plug the microSD card to your computer/laptop.

3. Open the wav file.

APPENDIX F

Statistical Analysis

Statistical Analysis

This shows the statistical analysis using regression analysis and t-test, these were used to compare the data gathered between two treatments in this study. The proponents used excel data analysis to analyze the two different variables.

I. Audio Fidelity

Regression Analysis Line Plot of Distance Vs Audio Fidelity

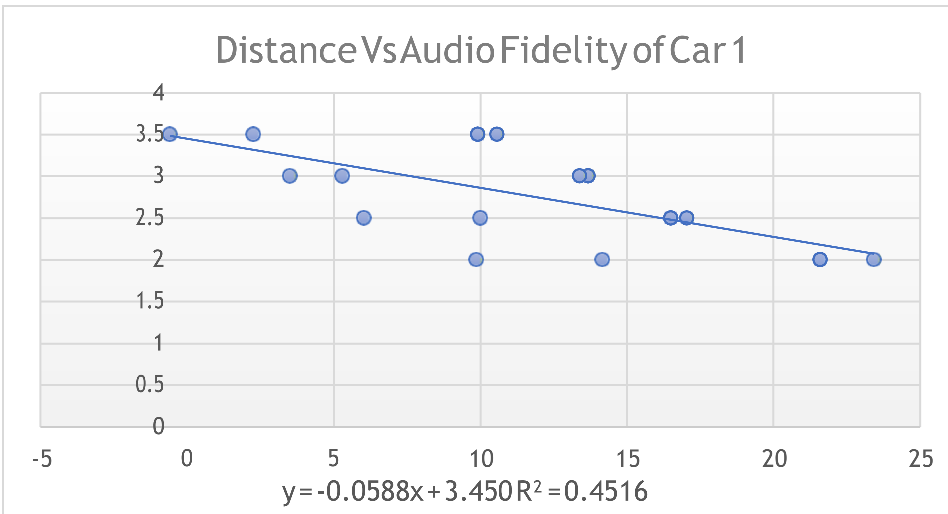


Figure 1 Distance Vs Audio Fidelity of Car 1

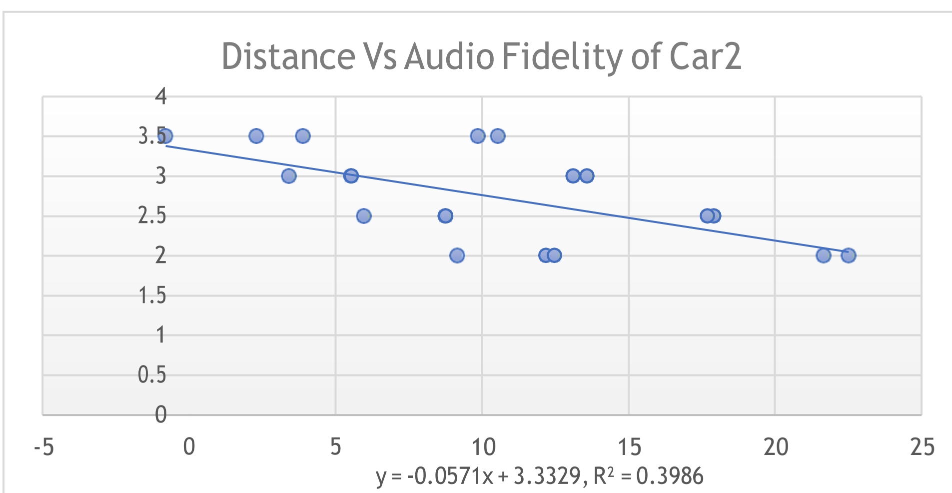


Figure 2 Distance Vs Audio Fidelity of Car 2

Figure 1 and **2** shows the Distance Vs Audio Fidelity Regression Line plot of Car 1 and Car 2. The graph shows a linear relationship in inverse. Car 1 has y = -0.0588x + 3.4505 and car 2 has y = -0.0571x + 3.3329 regression equation where both of the graph has negative slope. It can be seen that as the distance increases the audio fidelity decreases therefore, the system can only be used at short distances.

Summary of the Regression Analysis of Car 1

Multiple r = 0.67201109 (range 0.41-0.7)

moderate correlation, substantial relationship

R square = 0.45159891 (45.16%)

45.16% of the independent variable (audio fidelity) fits the regression line

Significance f = 0.00117

the result is reliable since significance f is less than 0.05

P-value =1.38132e-05, 0.001173048 (p-value < 0.01)

the difference in the distance and audio fidelity is significant

Summary of the Regression Analysis of Car 2

Multiple r = 0.631326 (range 0.41-0.7)

moderate correlation, substantial relationship

R square = 0.398572 (39.86%)

39.86% of the independent variable (audio fidelity) fits the regression line

Significance f = 0.002833

The result is reliable since significance f is less than 0.05

P-value =6.24e-05, 0.002833 (p-value < 0.01)

the difference in the distance and audio fidelity is significant

II. Distance Accuracy

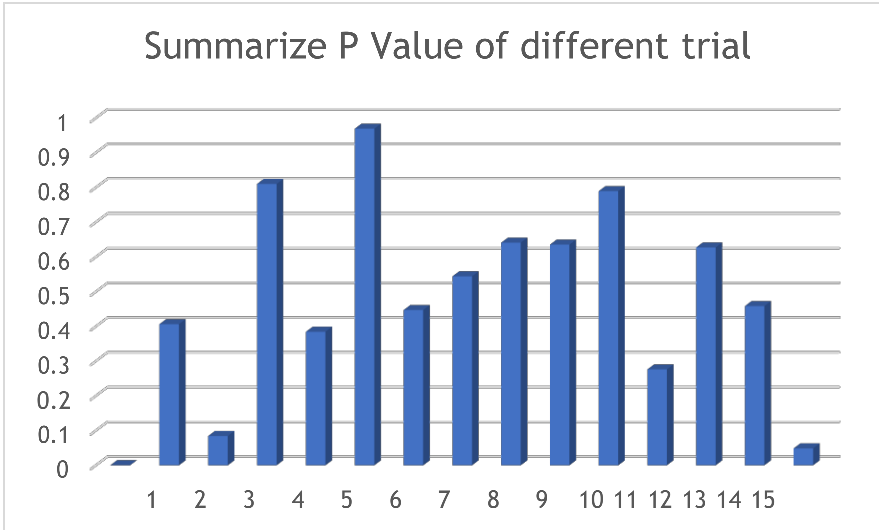


Figure 4.3 Summarize P Value of different trial

Figure 3 shows the bar graph of summarize P-Value of different trials using the t-test: Paired Sample for Mean. The data at the above table shows the different trials in different time interval when two vehicles communicate in different durations.

Null hypothesis (H0): There is significant difference on the distance measured by the two communicating vehicle

Alternative hypothesis (Ha): There is no significant difference on the distance measured by the two communicating vehicle

Based on the graph most of the P-Value lies above the alpha which is 0.05, therefore the t-test failed to reject the null hypothesis meaning there is no significant difference in the measured distance of the two communicating vehicles.

APPENDIX G

Gantt Chart

GANTT CHART

Topic/Task	December	January	February	March 2018	April 2018	May 2018	June 2018	July 2018	August	September	October	November	December	January	February	March 2019
Conceptualization of Topic for Project Study																
Research of Problem for Topic Defense																
Drafting and Finalization of Presentation for Topic Defense																
Topic Defense																
Proposal Writing for The Problem and its Setting																
Proposal Writing for Related Literature and Studies																
Proposal Writing for Methodology																
Project Research and Consultation for Title Proposal																
Initial Hardware and Software																
Finalization of Chapter 1,2,3 of the Project Documentation																
Title Defense																

Consultation for the Hardware Design																
Canvass and Purchase of Components and Materials																
Final Software Design and Programming																
Project Assembly																
Progress Defense																
Pre-Final Defense																
Testing and Evaluation of the Project																
Documentation of the Project for Final Defense																
Final Defense																
Finalization of the Project Document and Bookbinding																

APPENDIX H

Documentation

DOCUMENTATION

`

I. METHODS OF RESEARCH - 2018

1.1 TITLE DEFENSE

1.1(a) with Engr. Romeo L. Jorda

1.1(b) with Engr. Lean Karlo S. Tolentino

II. SUMMER 2018

2.1 PROJECT CONSTRUCTION

2.1(a) Exposing Presensitized PCB

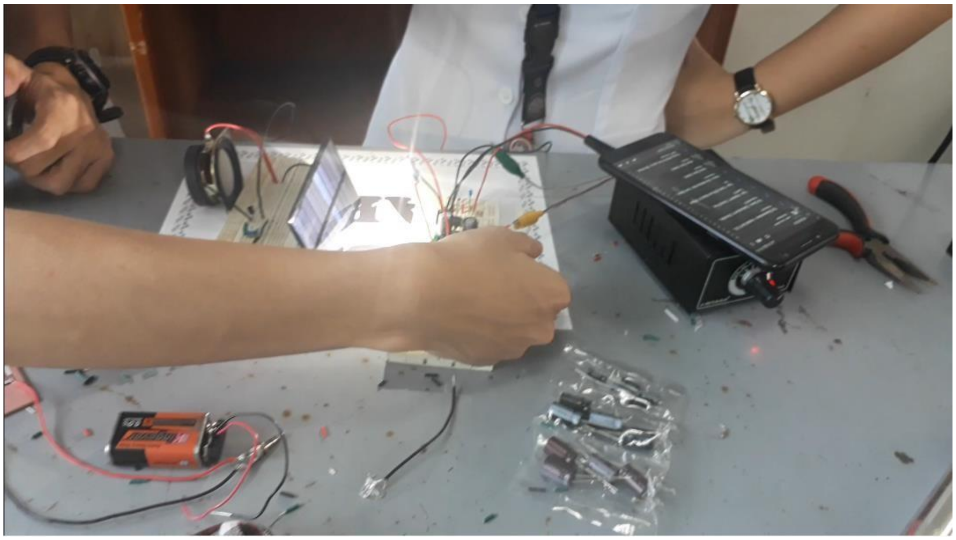
2.1(b) Developing exposed PCB

2.1(c) Testing Initial Transceiver Circuit Design

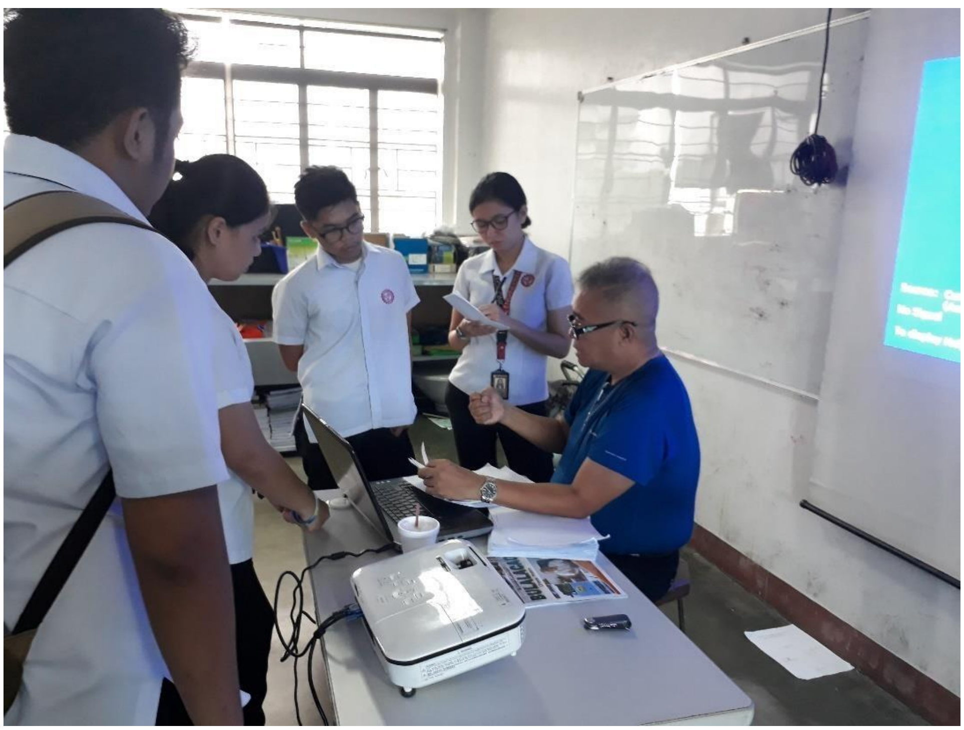
2.1(d) Testing Initial Transceiver Circuit Design

III. 1st Semester – 2018

3.1 PROJECT CONSTRUCTION



3.1 (a) Testing improved Transceiver Circuit Design With Optical Filter



3.1 (b) Consultation with Engr. Romeo L. Jorda

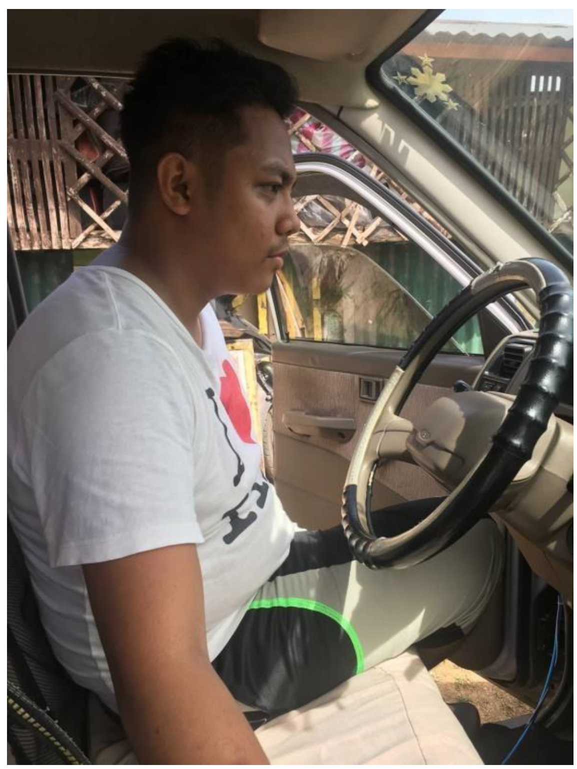
3.1(c) Data Gathering for Proximity

3.1 (d) Data Gathering for Proximity

3.1 (e) Construction and Testing of Final Transceiver Circuit Design

3.1 (f) Testing Final Transceiver Circuit on Oscilloscope

3.1 (g) Data Gathering for Transceiver Circuit from Oscilloscope



3.1 (h) Project Testing on Actual Vehicle

IV. 2nd Semester – 2018 – 2019

4.1 FINAL DEFENSE

4.1 (a) Photo after Final Defense

4.2 APPRECIATE 2019

4.2 (a) at Appreciate, Vevocom Light Booth

4.3 DEPLOYMENT

4.3 (a) McDonald's, RFC Molino

4.3 (b) a photo with the Employees of USBYG Food Corp.

4.3 (c) Driver #1

4.3 (d) Driver #2

4.3 (e) Driver #3

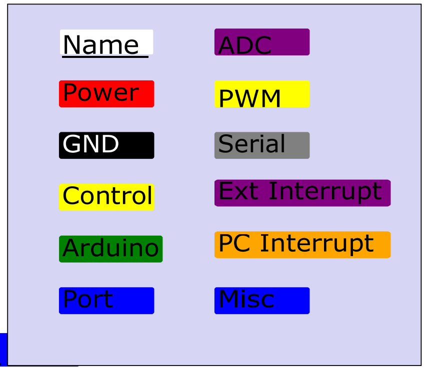
4.3 (f) Driver #4

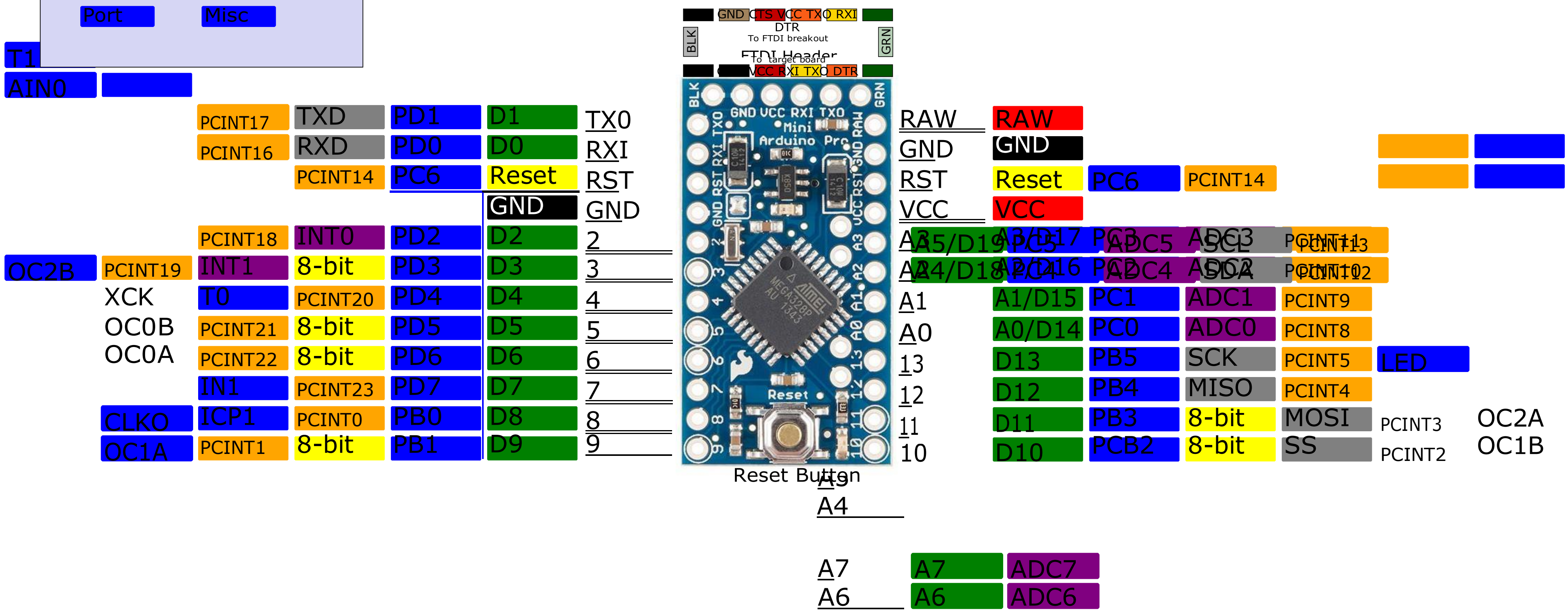
APPENDIX I

Data Sheets

Arduino Pro Mini (DEV-11113)

Programmed as Arduino Pro Mini w/ ATMega328
16MHz/ 5V



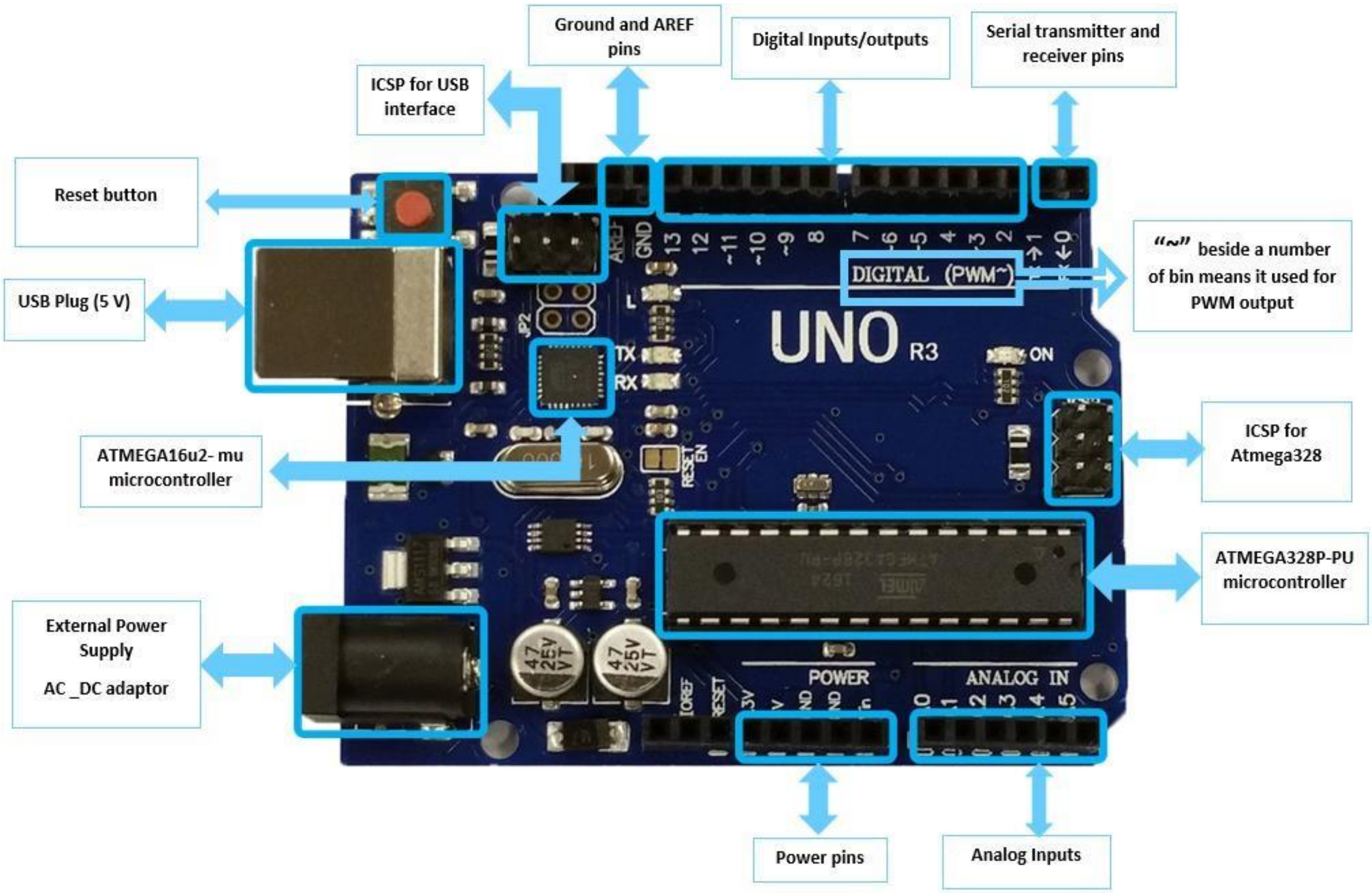


Power
Raw:5V-16V (6V-12V recommended)
VCC:5V
Maximum current: 150mA @5V

ATMega328P
- Absolute maxiumum VCC: 6V
- Maximum current for chip: 200mA
- Maximum current per pin: 40mA
- Recommended current per pin: 20mA
- 8-bit Atmel AVR
- Flash Program Memory: 32kB
- EEPROM: 1kB
- Internal SRAM 2kB
- ADC:10-bit
- PWM:8bit

LEDs
Power: Red
User (D13): Green

Arduino Uno R3



INTRODUCTION

Arduino is used for building different types of electronic circuits easily using of both a physical programmable circuit board usually microcontroller and piece of code running on computer with USB connection between the computer and Arduino.

Programming language used in Arduino is just a simplified version of C++ that can easily replace thousands of wires with words.

ARDUINO UNO-R3 PHYSICAL COMPONENTS

ATMEGA328P-PU microcontroller

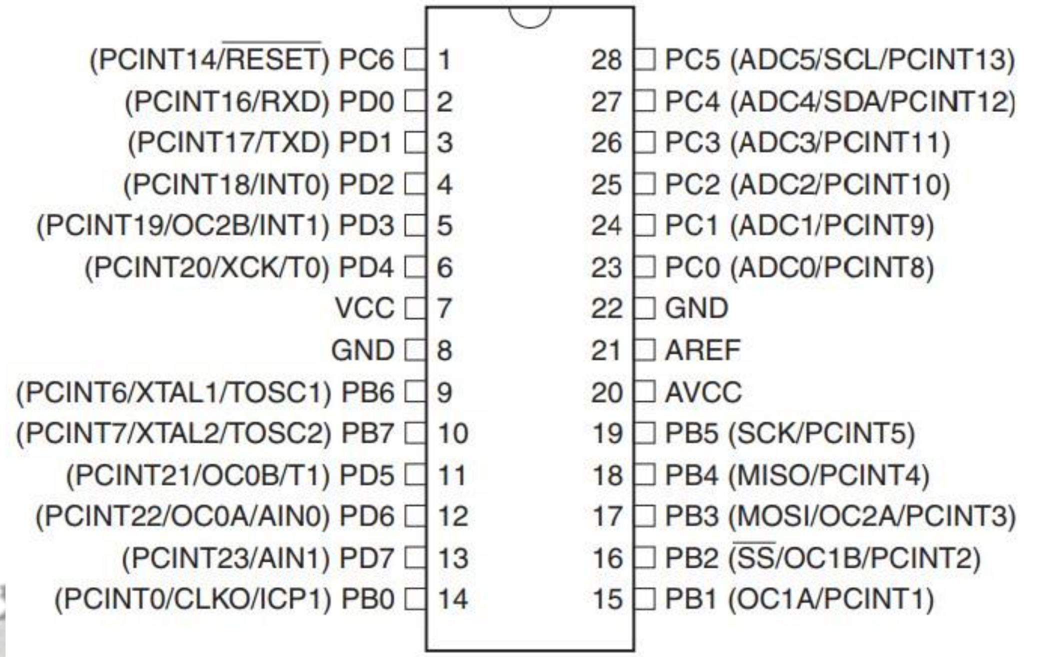
The most important element in Arduino Uno R3 is ATMEGA328P-PU is an 8-bit Microcontroller with flash memory reach to 32k bytes. It's features as follow:

- High Performance, Low Power AVR
- Advanced RISC Architecture
  - 131 Powerful Instructions – Most Single Clock Cycle Execution
  - 32 x 8 General Purpose Working Registers
  - Up to 20 MIPS Throughput at 20 MHz
  - On-chip 2-cycle Multiplier
- High Endurance Non-volatile Memory Segments
  - 4/8/16/32K Bytes of In-System Self-Programmable Flash program memory
  - 256/512/512/1K Bytes EEPROM
  - 512/1K/1K/2K Bytes Internal SRAM
  - Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
  - Data retention: 20 years at 85°C/100 years at 25°C
  - Optional Boot Code Section with Independent Lock Bits
  - In-System Programming by On-chip Boot Program
  - True Read-While-Write Operation
  - Programming Lock for Software Security
- Peripheral Features
  - Two 8-bit Timer/Counters with Separate Prescaler and Compare Mode
  - One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
  - Real Time Counter with Separate Oscillator
  - Six PWM Channels
  - 8-channel 10-bit ADC in TQFP and QFN/MLF package
  - Temperature Measurement
  - 6-channel 10-bit ADC in PDIP Package
  - Temperature Measurement
  - Programmable Serial USART

- Master/Slave SPI Serial Interface
- Byte-oriented 2-wire Serial Interface (Philips I2 C compatible)
- Programmable Watchdog Timer with Separate On-chip Oscillator
- On-chip Analog Comparator
- Interrupt and Wake-up on Pin Change

- Special Microcontroller Features
  - Power-on Reset and Programmable Brown-out Detection
  - Internal Calibrated Oscillator
  - External and Internal Interrupt Sources
  - Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby, and Extended Standby
- I/O and Packages
  - 23 Programmable I/O Lines
  - 28-pin PDIP, 32-lead TQFP, 28-pad QFN/MLF and 32-pad QFN/MLF
- Operating Voltage:
  - 1.8 - 5.5V
- Temperature Range:
  - -40°C to 85°C
- Speed Grade:
  - 0 - 4 MHz@1.8 - 5.5V, 0 - 10 MHz@2.7 - 5.5.V, 0 - 20 MHz @ 4.5 - 5.5V
- Power Consumption at 1 MHz, 1.8V, 25°C
  - Active Mode: 0.2 mA
  - Power-down Mode: 0.1 µA
  - Power-save Mode: 0.75 µA (Including 32 kHz RTC)

- Pin configuration



ATMEGA16u2- mu microcontroller

Is a 8-bit microcontroller used as USB driver in Arduino uno R3 it's features as follow:

- High Performance, Low Power AVR

- Advanced RISC Architecture
  - 125 Powerful Instructions – Most Single Clock Cycle Execution
  - 32 x 8 General Purpose Working Registers
  - Fully Static Operation
  - Up to 16 MIPS Throughput at 16 MHz

- Non-volatile Program and Data Memories
  - 8K/16K/32K Bytes of In-System Self-Programmable Flash
  - 512/512/1024 EEPROM
  - 512/512/1024 Internal SRAM
  - Write/Erase Cycles: 10,000 Flash/ 100,000 EEPROM
  - Data retention: 20 years at 85˚C/ 100 years at 25˚C

    - Optional Boot Code Section with Independent Lock Bits
    - In-System Programming by on-chip Boot Program hardware-activated after reset
    - Programming Lock for Software Security

- USB 2.0 Full-speed Device Module with Interrupt on Transfer Completion

    - Complies fully with Universal Serial Bus Specification REV 2.0
    - 48 MHz PLL for Full-speed Bus Operation: data transfer rates at 12 Mbit/s
    - Fully independent 176 bytes USB DPRAM for endpoint memory allocation
    - Endpoint 0 for Control Transfers: from 8 up to 64-bytes
    - 4 Programmable Endpoints:
        - IN or Out Directions
        - Bulk, Interrupt and Isochronous Transfers
        - Programmable maximum packet size from 8 to 64 bytes
        - Programmable single or double buffer
    - Suspend/Resume Interrupts
    - Microcontroller reset on USB Bus Reset without detach
    - USB Bus Disconnection on Microcontroller Request

- Peripheral Features

    - One 8-bit Timer/Counters with Separate Prescaler and Compare Mode (two 8-bit PWM channels)
    - One 16-bit Timer/Counter with Separate Prescaler, Compare and Capture Mode(three 8-bit PWM channels)
    - USART with SPI master only mode and hardware flow control (RTS/CTS)
    - Master/Slave SPI Serial Interface
    - Programmable Watchdog Timer with Separate On-chip Oscillator
    - On-chip Analog Comparator
    - Interrupt and Wake-up on Pin Change

- On Chip Debug Interface (debug WIRE)

- Special Microcontroller Features

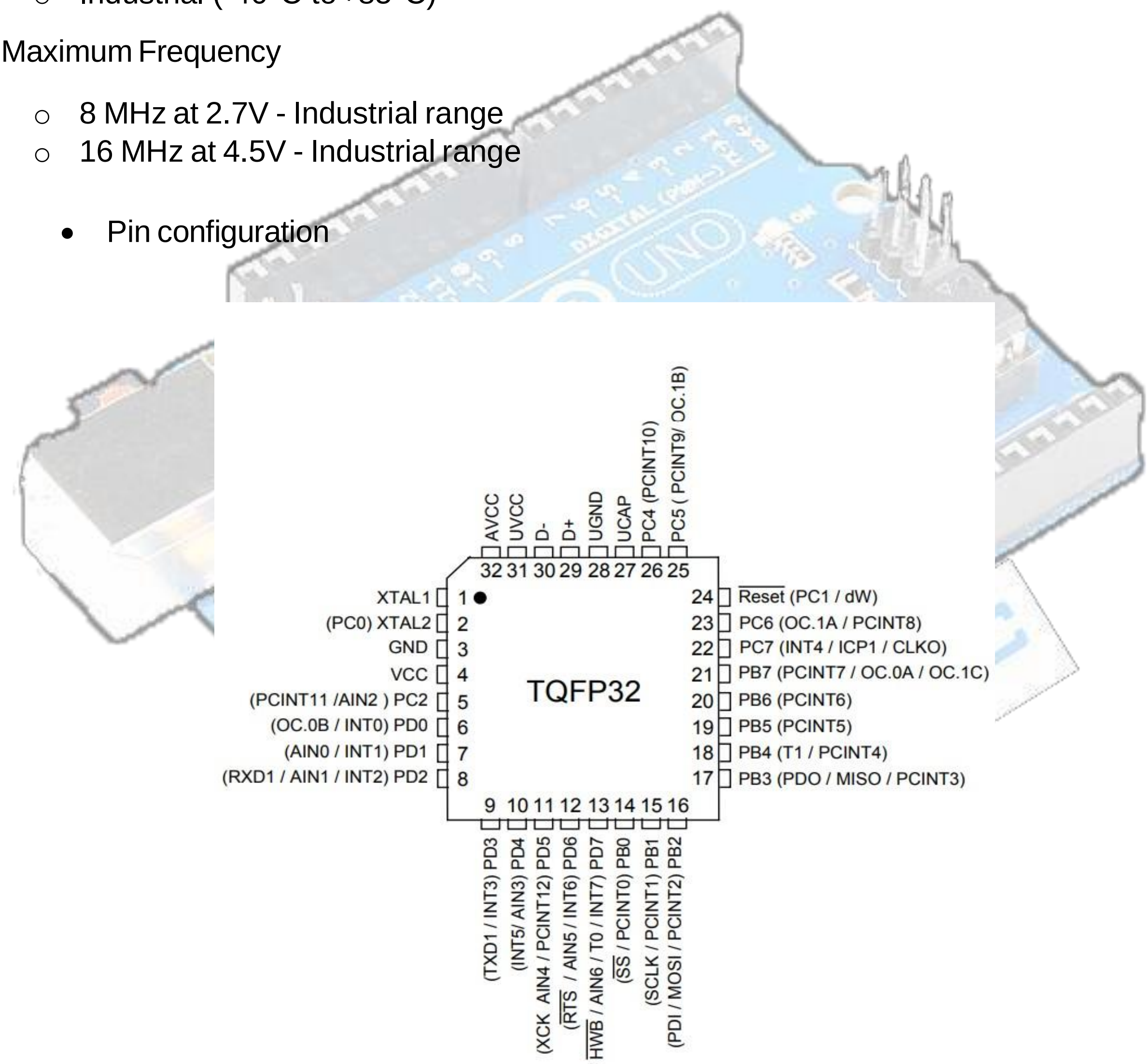
    - Power-On Reset and Programmable Brown-out Detection
    - Internal Calibrated Oscillator
    - External and Internal Interrupt Sources
    - Five Sleep Modes: Idle, Power-save, Power-down, Standby, and Extended Standby

- I/O and Packages

    - 22 Programmable I/O Lines
    - QFN32 (5x5mm) / TQFP32 packages

- Operating Voltages
  - 2.7 - 5.5V
- Operating temperature
  - Industrial (-40°C to +85°C)
- Maximum Frequency
  - 8 MHz at 2.7V - Industrial range
  - 16 MHz at 4.5V - Industrial range

- Pin configuration



OTHER ARDUINO UNO R3 PARTS

Input and Output

Each of the 14 digital pins on the Uno can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 k Ohms. In addition, some pins have specialized functions:

- Serial: 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.
- External Interrupts: 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value.
- PWM: 3, 5, 6, 9, 10, and 11. Provide 8-bit PWM output with the analogWrite() function.
- SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication using the SPI library.
- LED: 13. There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

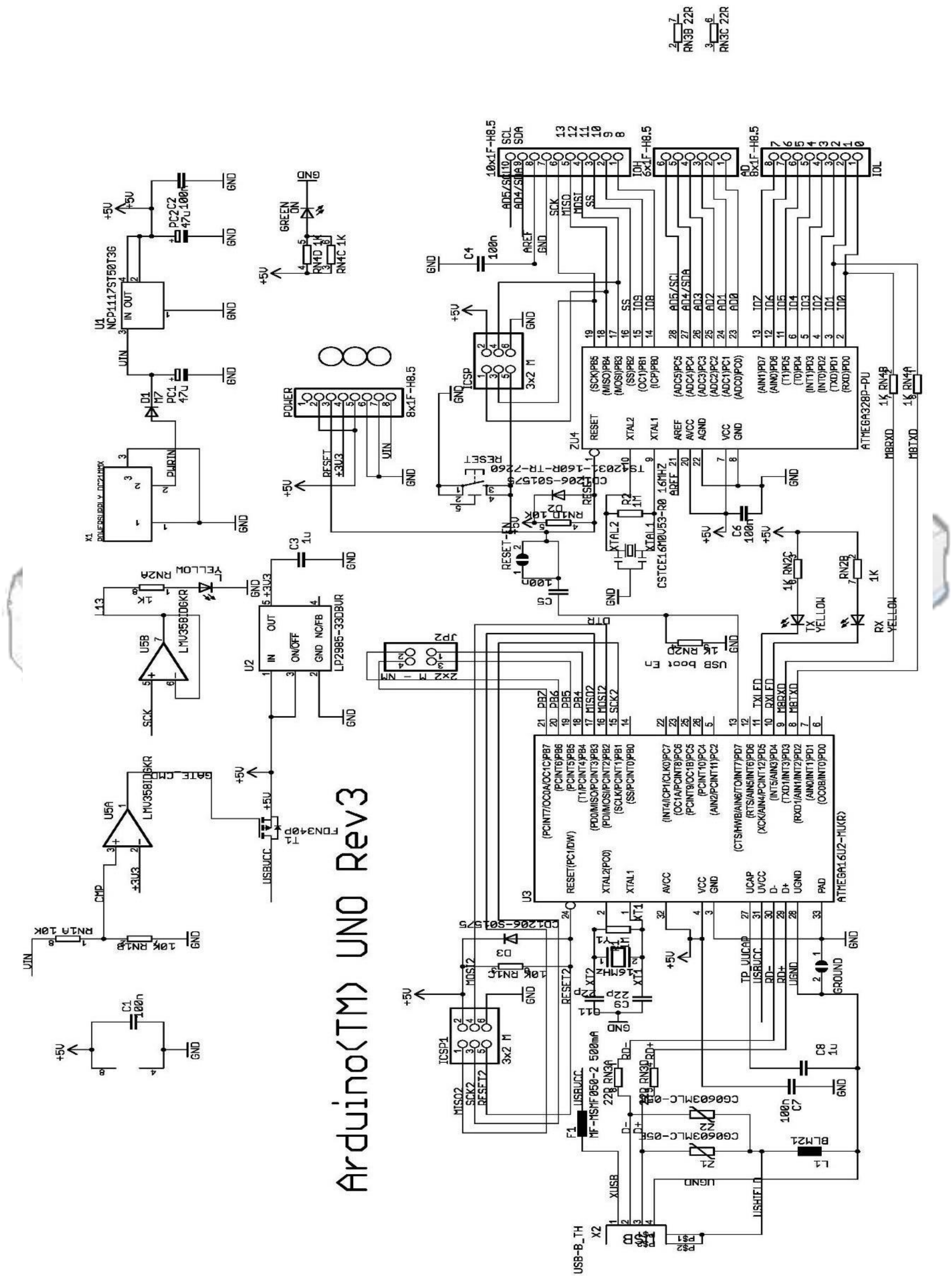
The Uno has 6 analog inputs, labeled A0 through A5, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and the analogReference() function. Additionally, some pins have specialized functionality:

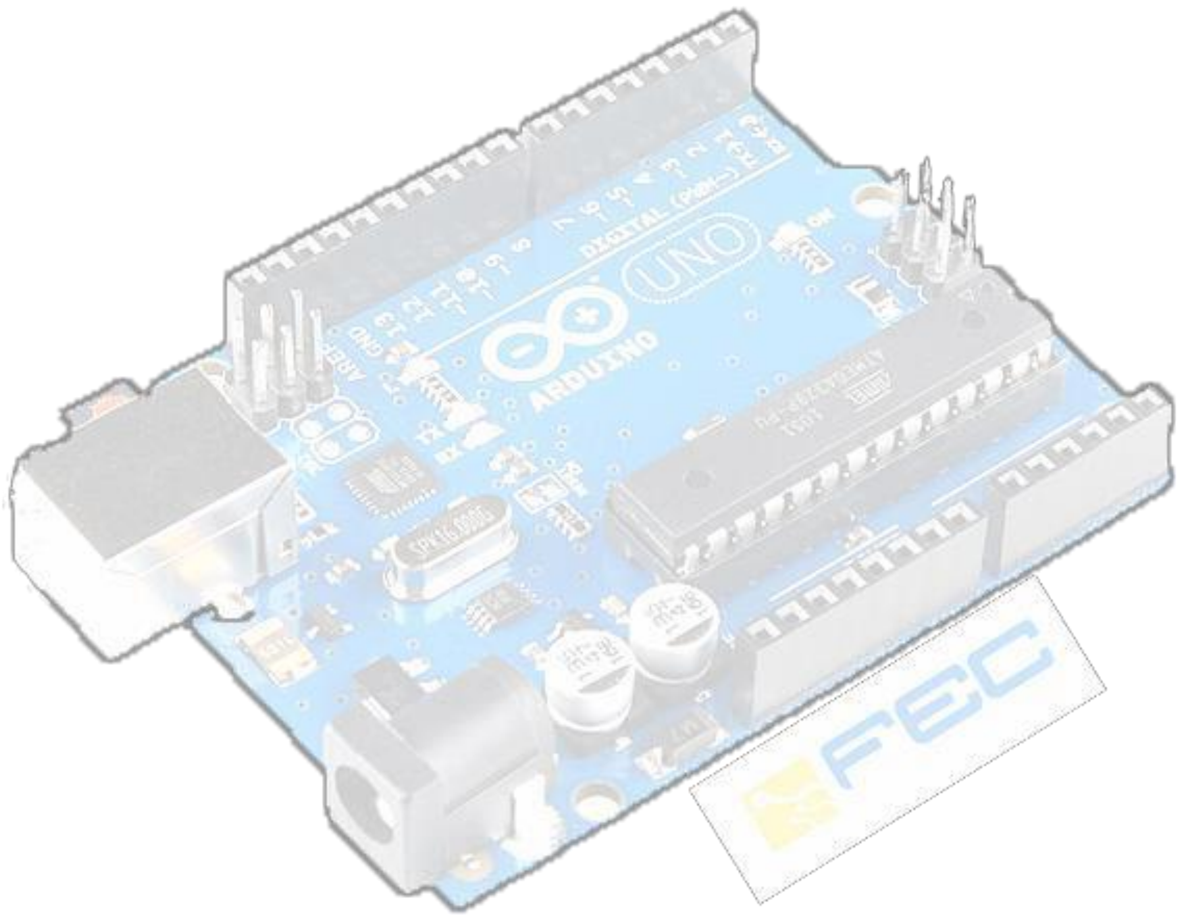
- TWI: A4 or SDA pin and A5 or SCL pin. Support TWI communication using the Wire library.

There are a couple of other pins on the board:

- AREF: Reference voltage for the analog inputs. Used with analogReference().
- Reset: Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

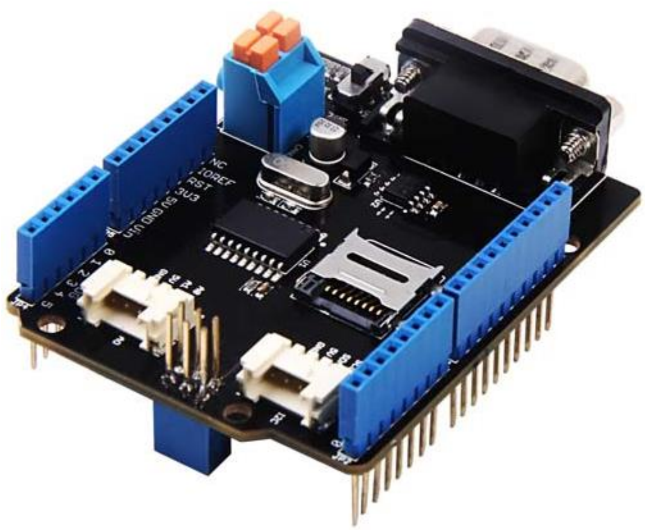
ARDUINO UNO R3 SCHEMATIC DIAGRAM




ARDUINO
UNO

CAN-BUS Shield V2.0

Introduction



CAN-BUS is a common industrial bus because of its long travel distance, medium communication speed and high reliability. It is commonly found on modern machine tools, such as an automotive diagnostic bus.

This CAN-BUS Shield adopts **MCP2515** CAN Bus controller with SPI interface and **MCP2551** CAN transceiver to give your Arduino/Seeeduino CAN-BUS capability. With an **OBD-II** converter cable added on and the OBD-II library imported, you are ready to build an onboard diagnostic device or data logger.

Previously we have made two versions of CAN-BUS Shield, the V1.0 and V1.2. They are all awesome shields that widely liked by our users. In order to make it better, several months ago we conducted a survey about CAN-BUS Shield V1.2 and received many valuable advices (Thanks to all the users who replied to us), so we decided to make an update and here it is - CAN-BUS Shield V2.

Version

This document applies to the following version of products:

Version	Released Date	
CAN BUS Shield V1.0	Oct 14, 2012	
CAN BUS Shield V1.1	Aug 10, 2013	
CAN BUS Shield V1.2	Jan 05, 2015	
CAN BUS Shield V2.0	Aug 01,2017	

Version Tracker

Features	V1.2	V2.0
CAN-BUS Controller	MCP2515	MCP2515
CAN Transceiver	MCP2551	MCP2551
Default OBD Pinout	OBD-II Standard	OBD-II Standard
CAN Standard Pinout	Not compatible	Compatible (jumper)
INT Pin	Not changeable	D2 or D3 (jumper)
CS pin for TF card slot	No TF card slot	D4 or D5 (jumper)

Features	V1.2	V2.0
Serial Grove	D0/D1	A0/A1
I2C Grove	A4/A5	SDA/SCL
Grove Orientation	Vertical	Horizontal
P1 pad	Front of the shied	Back of the shield

What's new in CAN BUS Shield V2.0

Hardware

- OBD-II or CAN standard pinout can be selected by switching jumpers on DB9 interface, the default pinout is OBD-II.
- Add a TF card slot for data storage and the CS pin can be either set to D4 or D5.
- The INT pin can be set to D2 or D3 by switching jumpers on the back of the shield.
- Moved the P1 pad from front to the back of the shield to make it easier to cut and solder.
- Consider that the D0/D1 pin are usually used for downloading code, we changed the serial Grove connector to pin A0/A1.
- The I2C grove connector is also changed to more reasonable standard SDA/SCL pin instead of previous A4/A5.
- The two grove connectors are both changed to horizontal rather than vertical to the shield so that it would be more convenient when connecting to other grove modules.

Software

- Add the function and example to access the data of your car.
- Add the function to read the SD card.
- Add the example to store the data of your car into the SD card.
- Fix some bugs and optimize some program.

D-Sub CANbus PinOut

pin#	Signal names	Signal Description
1	Reserved	Upgrade Path
2	CAN_L	Dominant Low
3	CAN_GND	Ground
4	Reserved	Upgrade Path
5	CAN_SHLD	Shiled, Optional
6	GND	Ground, Optional
7	CAN_H	Dominant High
8	Reserved	Upgrade Path
9	CAN_V+	Power, Optional

What if I want to connect this shield to my car

If you want to read data or control your car, there's an OBD>DB9 cable available for you, this cable make easier to connect to OBD-connector and DB9-connector. This cable will also work with anything that has a OBD-connector. Add a power switch makes such a satisfying click.

USB-CAN Analyzer

If you want a CAN Bus Analyzer to debug your CAN Bus, this USB-CAN Analyzer is recommended.

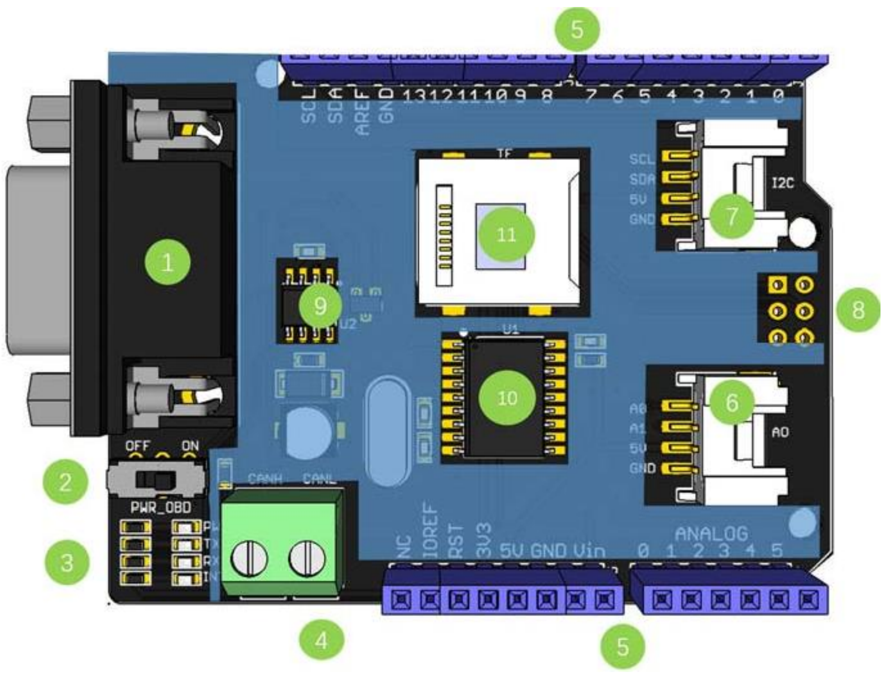
Features

- Implements CAN V2.0B at up to 1 Mb/s
- Industrial standard 9 pin sub-D connector
- OBD-II and CAN standard pinout selectable.
- Changeable chip select pin
- Changeable CS pin for TF card slot
- Changeable INT pin
- Screw terminal that easily to connect CAN_H and CAN_L
- Arduino Uno pin headers
- 2 Grove connectors (I2C and UART)
- SPI Interface up to 10 MHz
- Standard (11 bit) and extended (29 bit) data and remote frames
- Two receive buffers with prioritized message storage

Note

CAN BUS Shield Work well with Arduino UNO (ATmega328), Arduino Mega (ATmega1280/2560) as well as Arduino Leonardo (ATmega32U4).

Hardware Overview

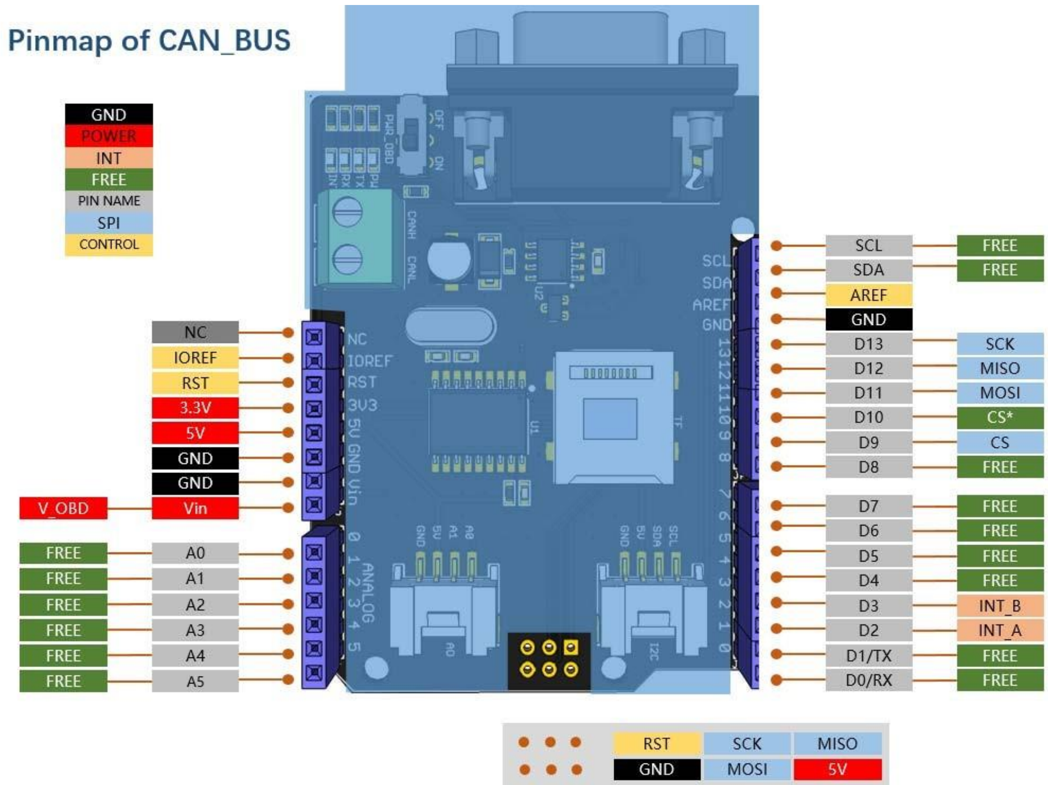


1. **DB9 Interface** - to connect to OBDII Interface via a DBG-OBD Cable.
2. **V_OBD** - It gets power from OBDII Interface (from DB9)
3. **Led Indicator**:
   - **PWR**: power
   - **TX**: blink when the data is sending
   - **RX**: blink when there's data receiving
   - **INT**: data interrupt
4. **Terminal** - CAN_H and CAN_L
5. **Arduino UNO pin out**
6. **Serial Grove connector**
7. **I2C Grove connector**
8. **ICSP pins**
9. **IC** - MCP2551, a high-speed CAN transceiver (datasheet)
10. **IC** - MCP2515, stand-alone CAN controller with SPI interface (datasheet)
11. **SD card slot**

Warning

When you use more than two CAN Bus Shield in one net, you should take the impedance into consideration. You should either cut P1 in the PCB with a knife, or just remove R3 on the PCB.

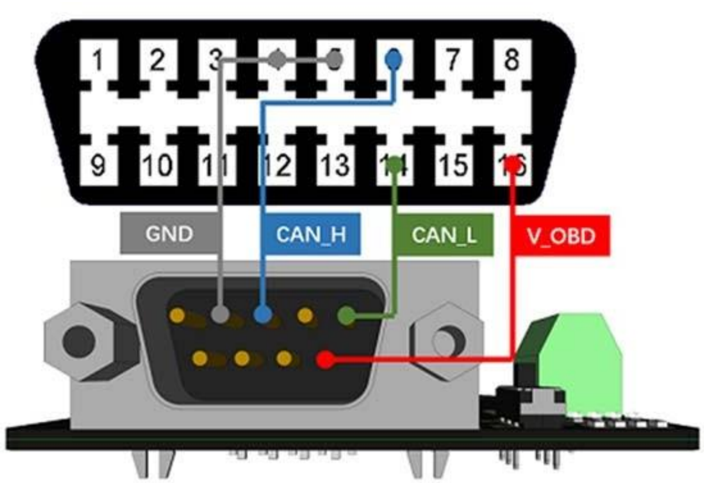
Pin map



Note

- The FREE pin is available for the other usages.

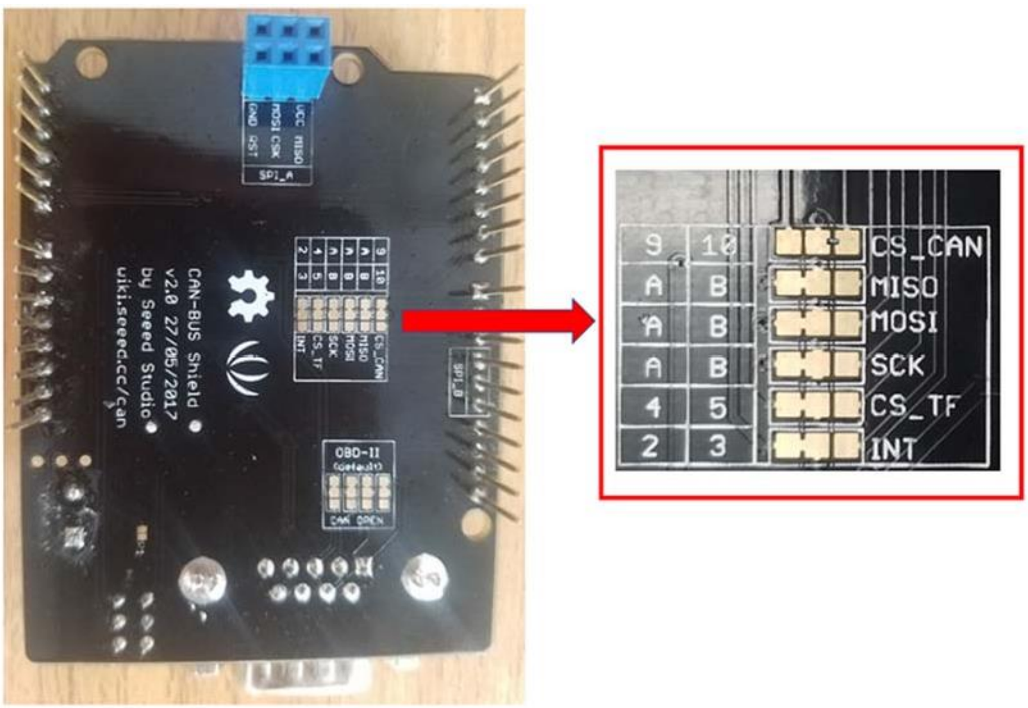
DB9&OBDii Interface



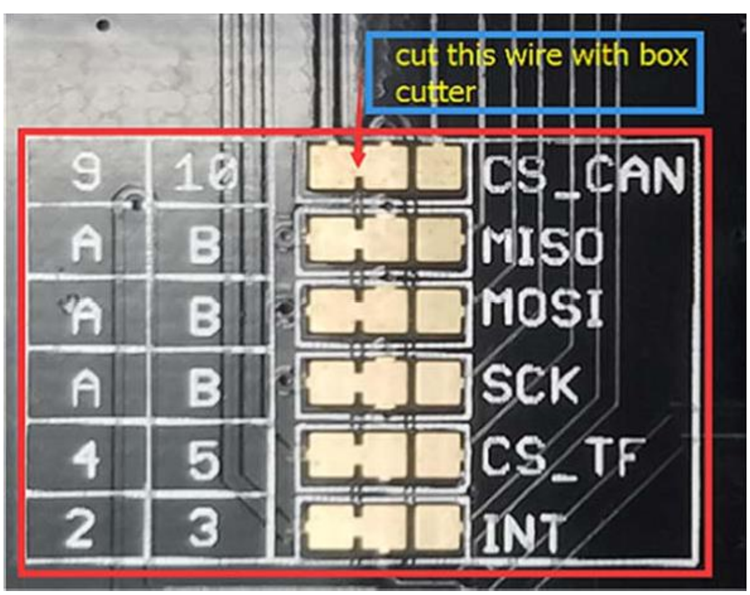
CS_CAN pin

SPI_CS pin of V2.0 is connected to **D9** by default. If you want to change to **D10**, please follow below instructions.

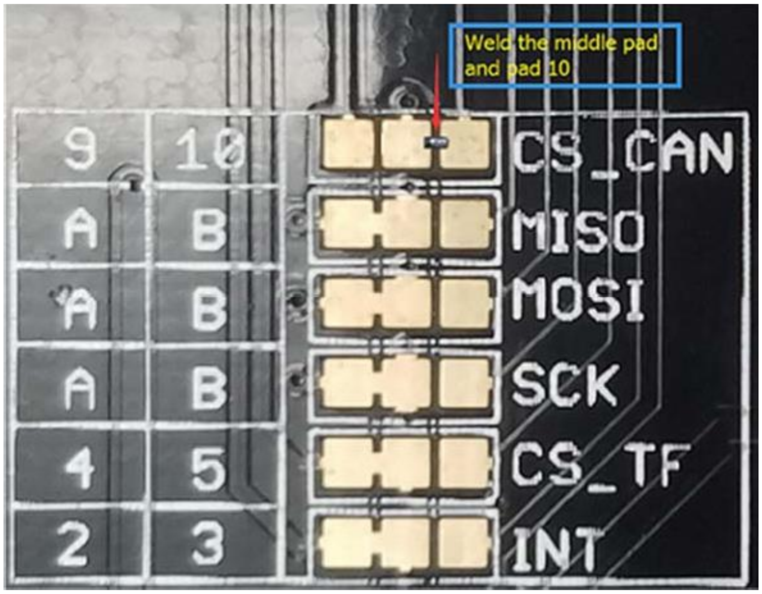
- Step1: Take a look at the backside of the PCBA, you will find a pad named CS_CAN.



- Step2: Cut the wire between pad9 and the middle pad.



- Step3:Weld the middle pad and pad 10.



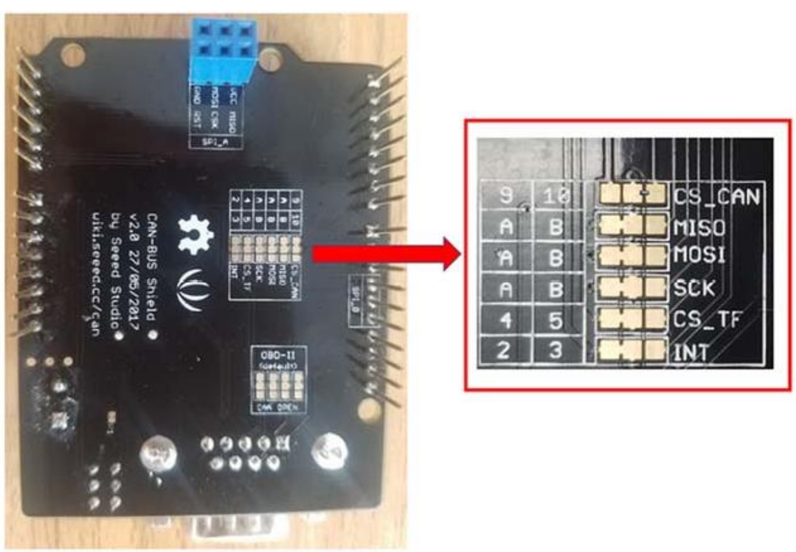
Warning

Be careful with the box cutter, it's easy to hurt yourself or the PCBA.

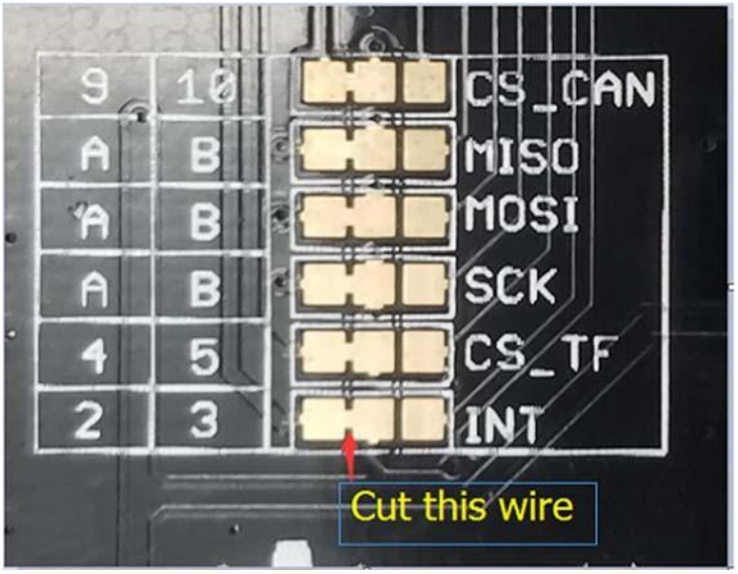
INT pin

INT pin of V2.0 is connected to **D2** by default. If you want to change to **D3**, please follow below instructions.

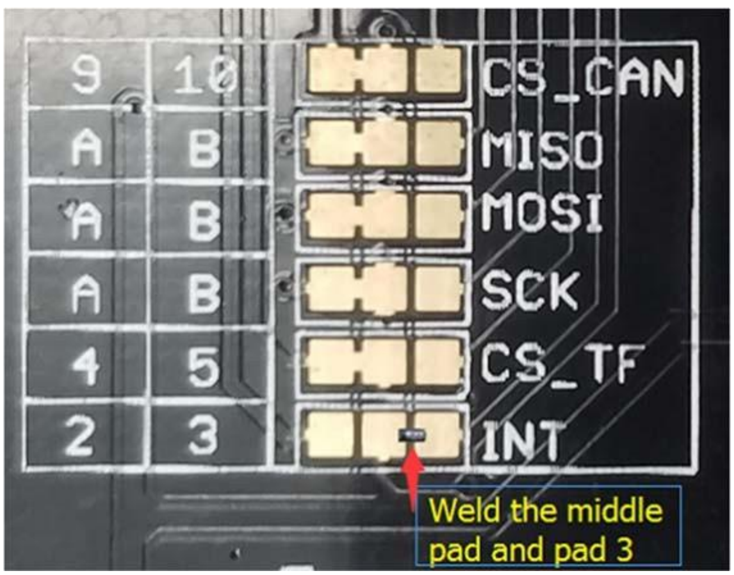
- Step1: Take a look at the backside of the PCBA, you will find a pad named INT.



- Step2: Cut the wire between pad 2 and the middle pad.



- Step3:Weld the middle pad and pad 3.



SPI pins

The SPI pins (SCK, MISO, MOSI) are routed to the ICSP pins by default. But for some boards, the SPI pins are located at D11~D13. if this happens, you need make some change to the PCBA. Take a look at the backside of the PCBA, there're three pads, MOSI, MISO and SCK, they are connected to A by default. You can change them to B if needed.

Note

For Arduino UNO, Arduino Mega, Arduino Leonardo and any others AVR based Arduino boards, it works well by default setting.

Warning

Be careful when you are going to change SPI pins, it's easy to hurt yourself or the PCBA.

Getting Started

Here's a simple example to show you how CAN-BUS Shield works. In this example we need 2 pieces of CAN-BUS Shields as well as Arduino or Seeeduino.

Note

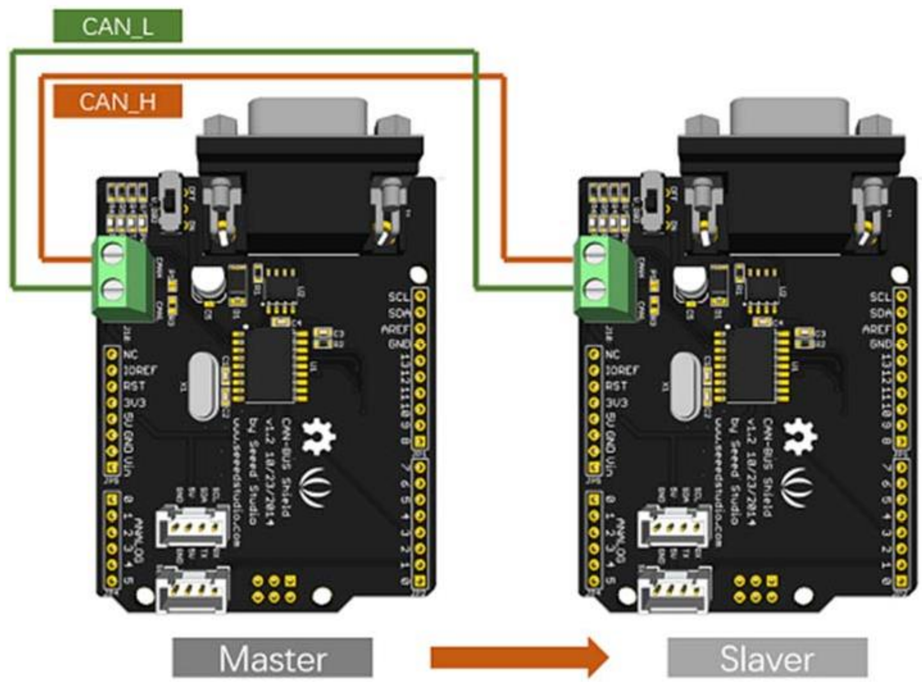
This example is built under Arduino IDE version 1.6.9.

STEP1: What do we need

Name	Function	Qty	
CAN-BUS Shield	CAN Bus communication	2	
Seeeduino V4.2	Controller	2	
Jumper Wire	connection	2	

STEP2: Hardware Connection

Insert each CAN-BUS Shield into Seeeduino V4.2, and connect the 2 CAN-BUS Shield together via 2 jumper wires. Shown as below images.



Note

CAN_H to CAN_H, CAN_L to CAN_L

STEP3: Software

Please follow how to install an arduino library procedures to install CAN BUS shield library.

Click on below button to download the library.
http://wiki.seeed.cc/How_to_install_Arduino_Library/

Download CAN BUS Shield Library

https://github.com/Seeed-Studio/CAN_BUS_Shield

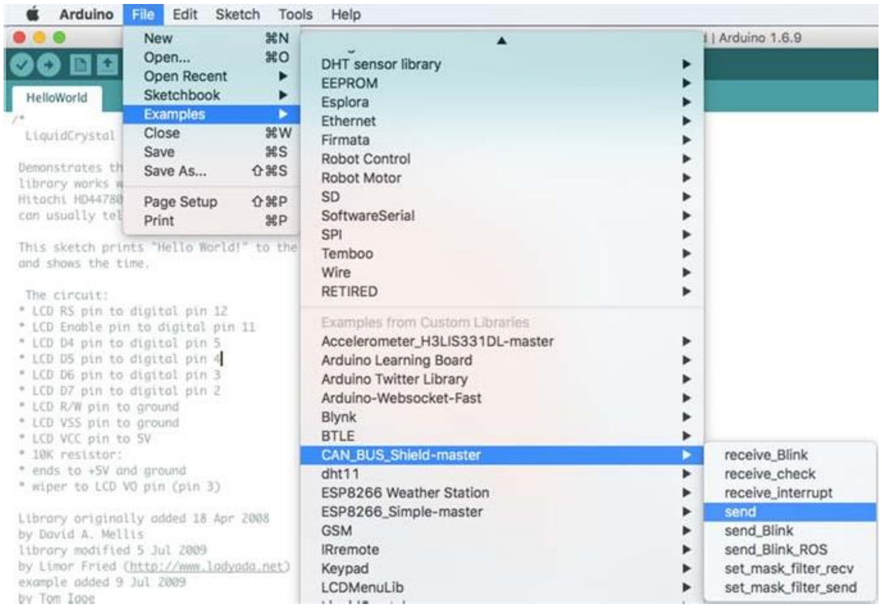
Install the library to your Arduino IDE when it is downloaded.

One of the node (a node means Seeeduino + CAN_BUS Shield) acts as master, the other acts as slaver. The master will send data to slaver constantly.

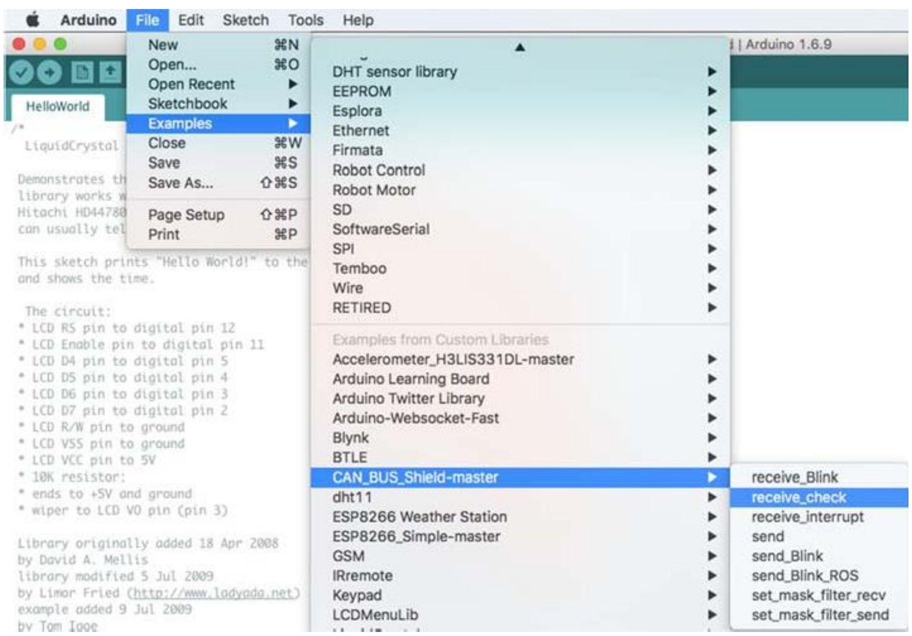
Note

Each node can act as master before the code being uploaded.

Open the **send** example (**File > Examples > CAN_BUS_Shield-master > send**) and upload to the **master**.

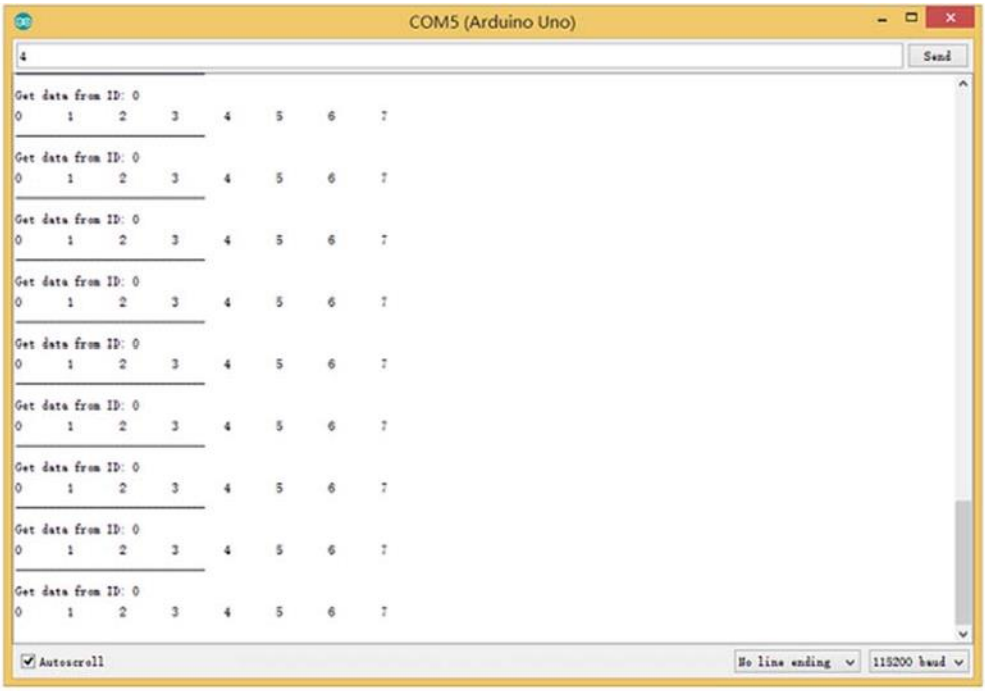


Open the **receive_check** example (**File > Examples > CAN_BUS_Shield-master > receive_check**) and upload to the **slaver**.



STEP4: View Result

Open the Serial Monitor of Arduino IDE(**slaver**), you will get the data sent from the master.



APIs

---

1. Set the Baud rate

This function is used to initialize the baud rate of the CAN Bus system.

The available baud rates are listed as follows:

```
#define CAN_5KBPS     1
#define CAN_10KBPS    2
#define CAN_20KBPS    3
#define CAN_25KBPS    4
#define CAN_31K25BPS  5
#define CAN_33KBPS    6
#define CAN_40KBPS    7
#define CAN_50KBPS    8
#define CAN_80KBPS    9
#define CAN_83K3BPS  10
#define CAN_95KBPS   11
#define CAN_100KBPS  12
```

```
#define CAN_125KBPS 13
#define CAN_200KBPS 14
#define CAN_250KBPS 15
#define CAN_500KBPS 16
#define CAN_666kbps 17
#define CAN_1000KBPS 18
```

2. Set Receive Mask and Filter

There are **2** receive mask registers and **5** filter registers on the controller chip that guarantee you getting data from the target device. They are useful especially in a large network consisting of numerous nodes.

We provide two functions for you to utilize these mask and filter registers. They are:

Mask:

```
init_Mask(unsigned char num, unsigned char ext, unsigned char ulData);
```

Filter:

```
init_Filt(unsigned char num, unsigned char ext, unsigned char ulData);
```

- **num** represents which register to use. You can fill 0 or 1 for mask and 0 to 5 for filter.
- **ext** represents the status of the frame. 0 means it's a mask or filter for a standard frame. 1 means it's for a extended frame.
- **ulData** represents the content of the mask of filter.

3. Check Receive

The MCP2515 can operate in either a polled mode, where the software checks for a received frame, or using additional pins to signal that a frame has been received or transmit completed.

Use the following function to poll for received frames.

```
INT8U MCP_CAN::checkReceive(void);
```

The function will return 1 if a frame arrives, and 0 if nothing arrives.

4. Get CAN ID

When some data arrive, you can use the following function to get the CAN ID of the "send" node.

```
INT32U MCP_CAN::getCanId(void)
```

5. Send Data

```
CAN.sendMsgBuf(INT8U id, INT8U ext, INT8U len, data_buf);
```

It is a function to send data onto the bus. In which:

- **id** represents where the data comes from.
- **ext** represents the status of the frame. '0' means standard frame. '1' means extended frame.
- **len** represents the length of this frame.
- **data_buf** is the content of this message.

For example, In the 'send' example, we have:

```
unsigned char stmp[8] = {0, 1, 2, 3, 4, 5, 6, 7};
CAN.sendMsgBuf(0x00, 0, 8, stmp); //send out the message 'stmp' to the bus and tell other devices this is a standard frame from 0x00.
```

6. Receive Data

The following function is used to receive data on the 'receive' node:

```
CAN.readMsgBuf(unsigned char len, unsigned char buf);
```

In conditions that masks and filters have been set. This function can only get frames that meet the requirements of masks and filters.

- **len** represents the data length.
- **buf** is where you store the data.

Generate a New BaudRate

We had provided many frequently-used baud rates, as below:

```
#define CAN_5KBPS    1
#define CAN_10KBPS   2
#define CAN_20KBPS   3
#define CAN_25KBPS   4
#define CAN_31KBPS   5
#define CAN_33KBPS   6
#define CAN_40KBPS   7
#define CAN_50KBPS   8
#define CAN_80KBPS   9
#define CAN_83KBPS   10
#define CAN_95KBPS   11
#define CAN_100KBPS 12
#define CAN_125KBPS 13
#define CAN_200KBPS 14
#define CAN_250KBPS 15
#define CAN_500KBPS 16
#define CAN_666KBPS 17
#define CAN_1000KBPS 18
```

Yet you may still can't find the rate you want. Here we provide a software to help you to calculate the baud rate you need.

Click here to download the software, it's in Chinese, but never mind, it's easy to use. https://github.com/SeeedDocument/CAN_BUS_Shield/raw/master/resource/CAN_Baudrate_CalcV1.3.zip

Note

This software supports Windows system only. If you can't open it, please feel free to contact loovee@seeed.cc for support.

Open the software, what you need to do is to set the baud rate you want, and then do some simple setting, then click **calculate**.

Then you will get some data, cfg1, cfg2 and cfg3.

You need to add some code to the library.

Open **mcp_can_dfs.h**, you need to add below code at about line 272:

```
#define MCP_16MHz_xxxkBPS_CFG1 (cfg1)    // xxx is the baud rate you need
#define MCP_16MHz_xxxkBPS_CFG2 (cfg2)
#define MCP_16MHz_xxxkBPS_CFG3 (cfg2)
```

Then let's go to about line 390, add below code:

```
#define CAN_xxxKBPS NUM        // xxx is the baudrate you need, and NUM is a number, you need to get a
different from the other rates.
```

Open **mcp_can.cpp**, goto the function **mcp2515_configRate**(at about line 190), then add below code:

```
case (CAN_xxxKBPS):
    cfg1 = MCP_16MHz_xxxkBPS_CFG1;
    cfg2 = MCP_16MHz_xxxkBPS_CFG2;
    cfg3 = MCP_16MHz_xxxkBPS_CFG3;
    break;
```

Then you can use the baud rate you need. And please give me a pull request at github when you use a new rate, so I can add it to the library to help other guys.

Projects

If you want to make some awesome projects with CAN-BUS shield, here are some projects for reference.

Volkswagen CAN BUS Gaming

Ever wanted to play a car/truck simulator with a real dashboard on your PC? Me too! I'm trying to control a VW Polo 6R dashboard via CAN Bus with an Arduino Uno and a Seeed CAN Bus Shield. Inspired by Silas Parker. Thanks Sepp and Is0-Mick for their great support!

Hack your vehicle CAN-BUS

Modern Vehicles all come equipped with a CAN-BUS Controller Area Network, Instead of having a million wires running back and forth from various devices in your car to the battery, its making use of a more clever system.

All electronic functions are connected to the TIPM, (Totally integrated Power Module), such as solenoids/relays to lock the doors or mini motors to wind the windows etc.

From each node (IE Switch pod that controls your windows or electric door locks) it broadcasts a message across the CAN. When the TIPM detects a valid message it will react accordingly like, lock the doors, switch on lights and so on.

FAQ

Q1: I can't get data from other CAN device.

- Check if the connection is right
- Check if the baud rate setting is right

Q2: The serial monitor print Init Fail.

- Check if the CS pin setting is matched with the code. For CAN Bus Shield V1.1/1.2, CS pin is connected to D9, others are to D10.

Q3. Where can I find technical support if I have some other issues.

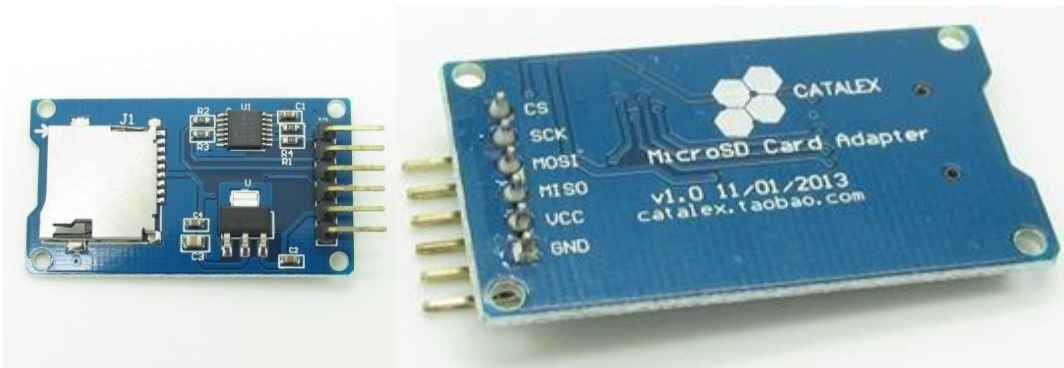
- You can post a question to Seeed Forum or send an email to **techsupport@seeed.cc**.

Help us make it better

Welcome to the new documentation system of Seeed Studio. We have made a lot of progress comparing to the old wiki system and will continue to improve it to make it more user friendly and helpful. The improvement can't be done without your kindly feedback. If you have any suggestions or findings, you are most welcome to submit the amended version as our contributor via Github or give us suggestions in the survey below, it would be more appreciated if you could leave your email so that we can reply to you. Happy Hacking!

eBay Search:

Micro SD Card Micro SDHC Mini TF Card Adapter Reader Module for Arduino



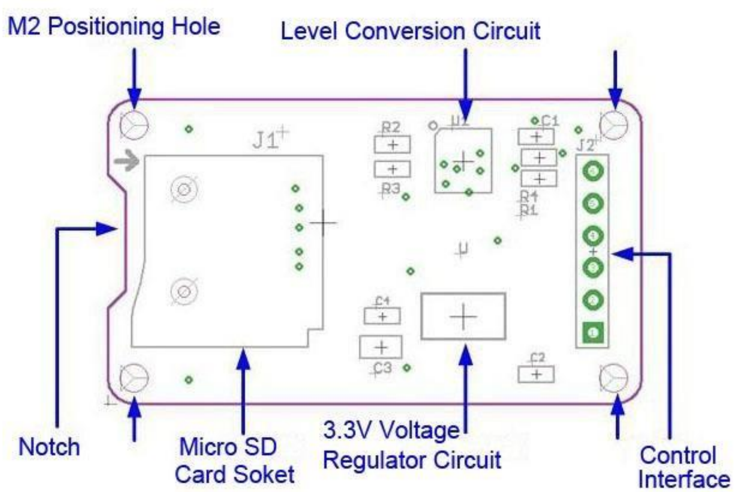
Description

- The module (MicroSD Card Adapter) is a Micro SD card reader module for reading and writing through the file system and the SPI interface driver, SCM system can be completed within a file MicroSD card
- Support Micro SD Card, Micro SDHC card (high speed card)
- Level conversion circuit board that can interface level is 5V or 3.3V
- Power supply is 4.5V ~ 5.5V, 3.3V voltage regulator circuit board
- Communications interface is a standard SPI interface
- 4 M2 screws positioning holes for easy installation
- Control Interface: A total of six pins (GND, VCC, MISO, MOSI, SCK, CS), GND to ground, VCC is the power supply, MISO, MOSI, SCK for SPI bus, CS is the chip select signal pin;
- 3.3V regulator circuit: LDO regulator output 3.3V for level conversion chip, Micro SD card supply;
- Level conversion circuit: Micro SD card to signal the direction of converts 3.3V, MicroSD card interface to control the direction of the MISO signal is also converted to 3.3V, general AVR microcontroller systems can read the signal;
- Micro SD card connector: self bomb deck, easy card insertion.
- Positioning holes: 4 M2 screws positioning holes with a diameter of 2.2mm, so the module is easy to install positioning, to achieve inter-module combination.

Interface Parameters:

Items	Min	Typical	Max	Unit
Power Voltage VCC	4.5	**5**	5.5	V
Current	0.2	**80**	200	mA
Interface Electrical Potential	3.3 or 5			V
Support Card Type	Micro SD Card(<=2G)，Mirco SDHC Card(<=32G)			—
Size	42X24X12			mm
Weight	5			g

Mirco SD Card Interface Module:



FAIRCHILD SEMICONDUCTOR®

March 2008

LM78XX/LM78XXA
3-Terminal 1A Positive Voltage Regulator

Features

- Output Current up to 1A
- Output Voltages of 5, 6, 8, 9, 10, 12, 15, 18, 24
- Thermal Overload Protection
- Short Circuit Protection
- Output Transistor Safe Operating Area Protection

General Description

The LM78XX series of three terminal positive regulators are available in the TO-220 package and with several fixed output voltages, making them useful in a wide range of applications. Each type employs internal current limiting, thermal shut down and safe operating area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents.

Ordering Information

Product Number	Output Voltage Tolerance	Package	Operating Temperature
LM7805CT	±4%	TO-220	-40°C to +125°C
LM7806CT			
LM7808CT			
LM7809CT			
LM7810CT			
LM7812CT			
LM7815CT			
LM7818CT			
LM7824CT			
LM7805ACT	±2%		0°C to +125°C
LM7806ACT			
LM7808ACT			
LM7809ACT			
LM7810ACT			
LM7812ACT			
LM7815ACT			
LM7818ACT			
LM7824ACT			

Block Diagram

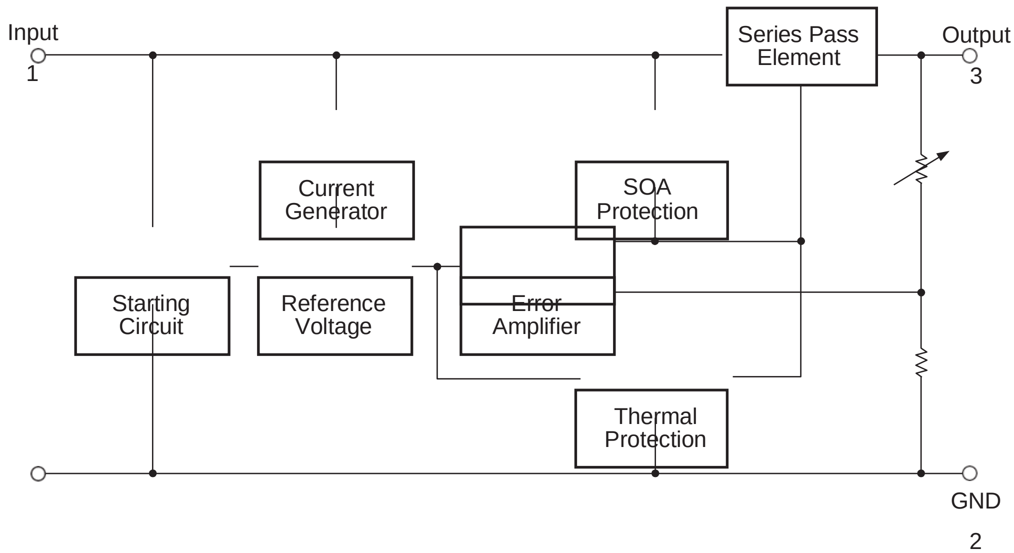


Figure 1.

Pin Assignment

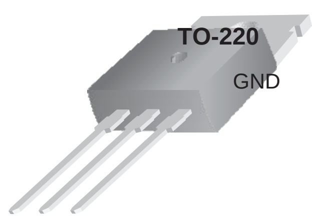


Figure 2.

Absolute Maximum Ratings

Absolute maximum ratings are those values beyond which damage to the device may occur. The datasheet specifications should be met, without exception, to ensure that the system design is reliable over its power supply, temperature, and output/input loading variables. Fairchild does not recommend operation outside datasheet specifications.

Symbol	Parameter		Value	Unit
V_I	Input Voltage	V_O = 5V to 18V	35	V
		V_O = 24V	40	V
$R_{\theta JC}$	Thermal Resistance Junction-Cases (TO-220)		5	°C/W
$R_{\theta JA}$	Thermal Resistance Junction-Air (TO-220)		65	°C/W
T_{OPR}	Operating Temperature Range	LM78xx	-40 to +125	°C
		LM78xxA	0 to +125	

T_{STG}	Storage Temperature Range	-65 to +150	°C

Electrical Characteristics (LM7805)

Refer to the test circuits. -40°C < T_J < 125°C, I_O = 500mA, V_I = 10V, C_I = 0.1µF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_O	Output Voltage	T_J = +25°C		4.8	5.0	5.2	V
		5mA ≤ I_O ≤ 1A, P_O ≤ 15W, V_I = 7V to 20V		4.75	5.0	5.25	
Regline	Line Regulation(1)	T_J = +25°C	V_O = 7V to 25V	–	4.0	100	mV
			V_I = 8V to 12V	–	1.6	50.0	
Regload	Load Regulation(1)	T_J = +25°C	I_O = 5mA to 1.5A	–	9.0	100	mV
			I_O = 250mA to 750mA	–	4.0	50.0	
I_Q	Quiescent Current	T_J = +25°C		–	5.0	8.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	0.03	0.5	mA
		V_I = 7V to 25V		–	0.3	1.3	
$\Delta V_O/\Delta T$	Output Voltage Drift(2)	I_O = 5mA		–	-0.8	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	42.0	–	µV/V_O
RR	Ripple Rejection(2)	f = 120Hz, V_O = 8V to 18V		62.0	73.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance(2)	f = 1kHz		–	15.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	230	–	mA
I_{PK}	Peak Current(2)	T_J = +25°C		–	2.2	–	A

Notes:

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
2. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7806) (Continued)

Refer to the test circuits. $-40°C < T_J < 125°C$, $I_O = 500mA$, $V_I = 11V$, $C_I = 0.33\mu F$, $C_O = 0.1\mu F$, unless otherwise specified.

Symbol	Parameter	Conditions		Min	Typ.	Max.	Unit
V_O	Output Voltage	$T_J = +25°C$		5.75	6.0	6.25	V
		$5mA \leq I_O \leq 1A$, $P_O \leq 15W$, $V_I = 8.0V$ to 21V		5.7	6.0	6.3	
Regline	Line Regulation(3)	$T_J = +25°C$	$V_I = 8V$ to 25V	–	5.0	120	mV
			$V_I = 9V$ to 13V	–	1.5	60.0	
Regload	Load Regulation(3)	$T_J = +25°C$	$I_O = 5mA$ to 1.5A	–	9.0	120	mV
			$I_O = 250mA$ to 750mA	–	3.0	60.0	
I_Q	Quiescent Current	$T_J = +25°C$		–	5.0	8.0	mA
ΔI_Q	Quiescent Current Change	$I_O = 5mA$ to 1A		–	–	0.5	mA
		$V_I = 8V$ to 25V		–	–	1.3	
$\Delta V_O/\Delta T$	Output Voltage Drift(4)	$I_O = 5mA$		–	-0.8	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, $T_A = +25°C$		–	45.0	–	$\mu V/V_O$
RR	Ripple Rejection(4)	f = 120Hz, $V_O = 8V$ to 18V		62.0	73.0	–	dB
V_{DROP}	Dropout Voltage	$I_O = 1A$, $T_J = +25°C$		–	2.0	–	V
r_O	Output Resistance(4)	f = 1kHz		–	19.0	–	mΩ
I_{SC}	Short Circuit Current	$V_I = 35V$, $T_A = +25°C$		–	250	–	mA
I_{PK}	Peak Current(4)	$T_J = +25°C$		–	2.2	–	A

Notes:

3. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
4. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7808) (Continued)

Refer to the test circuits. -40°C < T_J < 125°C, I_O = 500mA, V_I = 14V, C_I = 0.33µF, C_O = 0.1µF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_O	Output Voltage	T_J = +25°C		7.7	8.0	8.3	V
		5mA ≤ I_O ≤ 1A, P_O ≤ 15W, V_I = 10.5V to 23V		7.6	8.0	8.4	
Regline	Line Regulation(5)	T_J = +25°C	V_I = 10.5V to 25V	–	5.0	160	mV
			V_I = 11.5V to 17V	–	2.0	80.0	
Regload	Load Regulation(5)	T_J = +25°C	I_O = 5mA to 1.5A	–	10.0	160	mV
			I_O = 250mA to 750mA	–	5.0	80.0	
I_Q	Quiescent Current	T_J = +25°C		–	5.0	8.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	0.05	0.5	mA
		V_I = 10.5V to 25V		–	0.5	1.0	
$\Delta V_O/\Delta T$	Output Voltage Drift(6)	I_O = 5mA		–	-0.8	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	52.0	–	µV/V_O
RR	Ripple Rejection(6)	f = 120Hz, V_O = 11.5V to 21.5V		56.0	73.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance(6)	f = 1kHz		–	17.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	230	–	mA
I_{PK}	Peak Current(6)	T_J = +25°C		–	2.2	–	A

Notes:

5. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
6. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7809) (Continued)

Refer to the test circuits. -40°C < T_J < 125°C, I_O = 500mA, V_I = 15V, C_I = 0.33μF, C_O = 0.1μF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_O	Output Voltage	T_J = +25°C		8.65	9.0	9.35	V
		5mA ≤ I_O ≤ 1A, P_O ≤ 15W, V_I = 11.5V to 24V		8.6	9.0	9.4	
Regline	Line Regulation(7)	T_J = +25°C	V_I = 11.5V to 25V	–	6.0	180	mV
			V_I = 12V to 17V	–	2.0	90.0	
Regload	Load Regulation(7)	T_J = +25°C	I_O = 5mA to 1.5A	–	12.0	180	mV
			I_O = 250mA to 750mA	–	4.0	90.0	
I_Q	Quiescent Current	T_J = +25°C		–	5.0	8.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	–	0.5	mA
		V_I = 11.5V to 26V		–	–	1.3	
$\Delta V_O/\Delta T$	Output Voltage Drift(8)	I_O = 5mA		–	-1.0	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	58.0	–	μV/V_O
RR	Ripple Rejection(8)	f = 120Hz, V_O = 13V to 23V		56.0	71.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance(8)	f = 1kHz		–	17.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	250	–	mA
I_{PK}	Peak Current(8)	T_J = +25°C		–	2.2	–	A

Notes:

7. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
8. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7810) (Continued)

Refer to the test circuits. -40°C < T_J < 125°C, I_O = 500mA, V_I = 16V, C_I = 0.33µF, C_O = 0.1µF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_O	Output Voltage	T_J = +25°C		9.6	10.0	10.4	V
		5mA ≤ I_O ≤ 1A, P_O ≤ 15W, V_I = 12.5V to 25V		9.5	10.0	10.5	
Regline	Line Regulation(9)	T_J = +25°C	V_I = 12.5V to 25V	–	10.0	200	mV
			V_I = 13V to 25V	–	3.0	100	
Regload	Load Regulation(9)	T_J = +25°C	I_O = 5mA to 1.5A	–	12.0	200	mV
			I_O = 250mA to 750mA	–	4.0	400	
I_Q	Quiescent Current	T_J = +25°C		–	5.1	8.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	–	0.5	mA
		V_I = 12.5V to 29V		–	–	1.0	
$\Delta V_O/\Delta T$	Output Voltage Drift(10)	I_O = 5mA		–	-1.0	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	58.0	–	µV/V_O
RR	Ripple Rejection(10)	f = 120Hz, V_O = 13V to 23V		56.0	71.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance(10)	f = 1kHz		–	17.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	250	–	mA
I_{PK}	Peak Current(10)	T_J = +25°C		–	2.2	–	A

Notes:

9. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
10. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7812) (Continued)

Refer to the test circuits. -40°C < T_J < 125°C, I_O = 500mA, V_I = 19V, C_I = 0.33µF, C_O = 0.1µF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_O	Output Voltage	T_J = +25°C		11.5	12.0	12.5	V
		5mA ≤ I_O ≤ 1A, P_O ≤ 15W, V_I = 14.5V to 27V		11.4	12.0	12.6	
Regline	Line Regulation[11]	T_J = +25°C	V_I = 14.5V to 30V	–	10.0	240	mV
			V_I = 16V to 22V	–	3.0	120	
Regload	Load Regulation[11]	T_J = +25°C	I_O = 5mA to 1.5A	–	11.0	240	mV
			I_O = 250mA to 750mA	–	5.0	120	
I_Q	Quiescent Current	T_J = +25°C		–	5.1	8.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	0.1	0.5	mA
		V_I = 14.5V to 30V		–	0.5	1.0	
$\Delta V_O/\Delta T$	Output Voltage Drift[12]	I_O = 5mA		–	-1.0	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	76.0	–	µV/V_O
RR	Ripple Rejection[12]	f = 120Hz, V_I = 15V to 25V		55.0	71.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance[12]	f = 1kHz		–	18.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	230	–	mA
I_{PK}	Peak Current[12]	T_J = +25°C		–	2.2	–	A

Notes:

11. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
12. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7815) (Continued)

Refer to the test circuits. -40°C < T_J < 125°C, I_O = 500mA, V_I = 23V, C_I = 0.33μF, C_O = 0.1μF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_O	Output Voltage	T_J = +25°C		14.4	15.0	15.6	V
		5mA ≤ I_O ≤ 1A, P_O ≤ 15W, V_I = 17.5V to 30V		14.25	15.0	15.75	
Regline	Line Regulation(13)	T_J = +25°C	V_I = 17.5V to 30V	–	11.0	300	mV
			V_I = 20V to 26V	–	3.0	150	
Regload	Load Regulation(13)	T_J = +25°C	I_O = 5mA to 1.5A	–	12.0	300	mV
			I_O = 250mA to 750mA	–	4.0	150	
I_Q	Quiescent Current	T_J = +25°C		–	5.2	8.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	–	0.5	mA
		V_I = 17.5V to 30V		–	–	1.0	
$\Delta V_O/\Delta T$	Output Voltage Drift(14)	I_O = 5mA		–	-1.0	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	90.0	–	μV/V_O
RR	Ripple Rejection(14)	f = 120Hz, V_I = 18.5V to 28.5V		54.0	70.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance(14)	f = 1kHz		–	19.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	250	–	mA
I_{PK}	Peak Current(14)	T_J = +25°C		–	2.2	–	A

Notes:

13. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
14. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7818) (Continued)

Refer to the test circuits. -40°C < T_J < 125°C, I_O = 500mA, V_I = 27V, C_I = 0.33μF, C_O = 0.1μF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_O	Output Voltage	T_J = +25°C		17.3	18.0	18.7	V
		5mA ≤ I_O ≤ 1A, P_O ≤ 15W, V_I = 21V to 33V		17.1	18.0	18.9	
Regline	Line Regulation[15]	T_J = +25°C	V_I = 21V to 33V	–	15.0	360	mV
			V_I = 24V to 30V	–	5.0	180	
Regload	Load Regulation[15]	T_J = +25°C	I_O = 5mA to 1.5A	–	15.0	360	mV
			I_O = 250mA to 750mA	–	5.0	180	
I_Q	Quiescent Current	T_J = +25°C		–	5.2	8.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	–	0.5	mA
		V_I = 21V to 33V		–	–	1.0	
$\Delta V_O/\Delta T$	Output Voltage Drift[16]	I_O = 5mA		–	-1.0	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	110	–	μV/V_O
RR	Ripple Rejection[16]	f = 120Hz, V_I = 22V to 32V		53.0	69.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance[16]	f = 1kHz		–	22.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	250	–	mA
I_{PK}	Peak Current[16]	T_J = +25°C		–	2.2	–	A

Notes:

15. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
16. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7824) (Continued)

Refer to the test circuits. -40°C < T_J < 125°C, I_O = 500mA, V_I = 33V, C_I = 0.33μF, C_O = 0.1μF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_O	Output Voltage	T_J = +25°C		23.0	24.0	25.0	V
		5mA ≤ I_O ≤ 1A, P_O ≤ 15W, V_I = 27V to 38V		22.8	24.0	25.25	
Regline	Line Regulation(17)	T_J = +25°C	V_I = 27V to 38V	–	17.0	480	mV
			V_I = 30V to 36V	–	6.0	240	
Regload	Load Regulation(17)	T_J = +25°C	I_O = 5mA to 1.5A	–	15.0	480	mV
			I_O = 250mA to 750mA	–	5.0	240	
I_Q	Quiescent Current	T_J = +25°C		–	5.2	8.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	0.1	0.5	mA
		V_I = 27V to 38V		–	0.5	1.0	
$\Delta V_O/\Delta T$	Output Voltage Drift(18)	I_O = 5mA		–	-1.5	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	60.0	–	μV/V_O
RR	Ripple Rejection(18)	f = 120Hz, V_I = 28V to 38V		50.0	67.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
rO	Output Resistance(18)	f = 1kHz		–	28.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	230	–	mA
I_{PK}	Peak Current(18)	T_J = +25°C		–	2.2	–	A

Notes:

17. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
18. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7805A) (Continued)

Refer to the test circuits. $0°C < T_J < 125°C$, $I_O = 1A$, $V_I = 10V$, $C_I = 0.33\mu F$, $C_O = 0.1\mu F$, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_O	Output Voltage	$T_J = +25°C$		4.9	5.0	5.1	V
		$I_O = 5mA$ to 1A, $P_O \leq 15W$, $V_I = 7.5V$ to 20V		4.8	5.0	5.2	
Regline	Line Regulation(19)	$V_I = 7.5V$ to 25V, $I_O = 500mA$		–	5.0	50.0	mV
		$V_I = 8V$ to 12V		–	3.0	50.0	
		$T_J = +25°C$	$V_I = 7.3V$ to 20V	–	5.0	50.0	
			$V_I = 8V$ to 12V	–	1.5	25.0	
Regload	Load Regulation(19)	$T_J = +25°C$, $I_O = 5mA$ to 1.5A		–	9.0	100	mV
		$I_O = 5mA$ to 1A		–	9.0	100	
		$I_O = 250mA$ to 750mA		–	4.0	50.0	
I_Q	Quiescent Current	$T_J = +25°C$		–	5.0	6.0	mA
ΔI_Q	Quiescent Current Change	$I_O = 5mA$ to 1A		–	–	0.5	mA
		$V_I = 8V$ to 25V, $I_O = 500mA$		–	–	0.8	
		$V_I = 7.5V$ to 20V, $T_J = +25°C$		–	–	0.8	
$\Delta V_O/\Delta T$	Output Voltage Drift(20)	$I_O = 5mA$		–	-0.8	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, $T_A = +25°C$		–	10.0	–	$\mu V/V_O$
RR	Ripple Rejection(20)	f = 120Hz, $I_O = 500mA$, $V_I = 8V$ to 18V		–	68.0	–	dB
V_{DROP}	Dropout Voltage	$I_O = 1A$, $T_J = +25°C$		–	2.0	–	V
r_O	Output Resistance(20)	f = 1kHz		–	17.0	–	mΩ
I_{SC}	Short Circuit Current	$V_I = 35V$, $T_A = +25°C$		–	250	–	mA
I_{PK}	Peak Current(20)	$T_J = +25°C$		–	2.2	–	A

Notes:

19. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
20. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7806A) (Continued)

Refer to the test circuits. 0°C < T_J < 125°C, I_O = 1A, V_I = 11V, C_I = 0.33μF, C_O = 0.1μF, unless otherwise specified.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_O	Output Voltage	T_J = +25°C	5.58	6.0	6.12	V
		I_O = 5mA to 1A, $P_O \leq$ 15W, V_I = 8.6V to 21V	5.76	6.0	6.24	
Regline	Line Regulation[21]	V_I = 8.6V to 25V, I_O = 500mA	–	5.0	60.0	mV
		V_I = 9V to 13V	–	3.0	60.0	
		T_J = +25°C, V_I = 8.3V to 21V	–	5.0	60.0	
		T_J = +25°C, V_I = 9V to 13V	–	1.5	30.0	
Regload	Load Regulation[21]	T_J = +25°C, I_O = 5mA to 1.5A	–	9.0	100	mV
		I_O = 5mA to 1A	–	9.0	100	
		I_O = 250mA to 750mA	–	5.0	50.0	
I_Q	Quiescent Current	T_J = +25°C	–	4.3	6.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A	–	–	0.5	mA
		V_I = 19V to 25V, I_O = 500mA	–	–	0.8	
		V_I = 8.5V to 21V, T_J = +25°C	–	–	0.8	
$\Delta V_O/\Delta T$	Output Voltage Drift[22]	I_O = 5mA	–	-0.8	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C	–	10.0	–	μV/V_O
RR	Ripple Rejection[22]	f = 120Hz, I_O = 500mA, V_I = 9V to 19V	–	65.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C	–	2.0	–	V
r_O	Output Resistance[22]	f = 1kHz	–	17.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C	–	250	–	mA
I_{PK}	Peak Current[22]	T_J = +25°C	–	2.2	–	A

Notes:

21. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
22. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7808A) (Continued)

Refer to the test circuits. 0°C < T_J < 125°C, I_O = 1A, V_I = 14V, C_I = 0.33µF, C_O = 0.1µF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_O	Output Voltage	T_J = +25°C		7.84	8.0	8.16	V
		I_O = 5mA to 1A, $P_O \leq$ 15W, V_I = 10.6V to 23V		7.7	8.0	8.3	
Regline	Line Regulation(23)	V_I = 10.6V to 25V, I_O = 500mA		–	6.0	80.0	mV
		V_I = 11V to 17V		–	3.0	80.0	
		T_J = +25°C	V_I = 10.4V to 23V	–	6.0	80.0	
			V_I = 11V to 17V	–	2.0	40.0	
Regload	Load Regulation(23)	T_J = +25°C, I_O = 5mA to 1.5A		–	12.0	100	mV
		I_O = 5mA to 1A		–	12.0	100	
		I_O = 250mA to 750mA		–	5.0	50.0	
I_Q	Quiescent Current	T_J = +25°C		–	5.0	6.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	–	0.5	mA
		V_I = 11V to 25V, I_O = 500mA		–	–	0.8	
		V_I = 10.6V to 23V, T_J = +25°C		–	–	0.8	
$\Delta V_O/\Delta T$	Output Voltage Drift(24)	I_O = 5mA		–	-0.8	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	10.0	–	µV/V_O
RR	Ripple Rejection(24)	f = 120Hz, I_O = 500mA, V_I = 11.5V to 21.5V		–	62.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance(24)	f = 1kHz		–	18.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	250	–	mA
I_{PK}	Peak Current(24)	T_J = +25°C		–	2.2	–	A

Notes:

23. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
24. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7809A) (Continued)

Refer to the test circuits. 0°C < T_J < 125°C, I_O = 1A, V_I = 15V, C_I = 0.33μF, C_O = 0.1μF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Units
V_O	Output Voltage	T_J = +25°C		8.82	9.0	9.16	V
		I_O = 5mA to 1A, $P_O \leq$ 15W, V_I = 11.2V to 24V		8.65	9.0	9.35	
Regline	Line Regulation[25]	V_I = 11.7V to 25V, I_O = 500mA		–	6.0	90.0	mV
		V_I = 12.5V to 19V		–	4.0	45.0	
		T_J = +25°C	V_I = 11.5V to 24V	–	6.0	90.0	
			V_I = 12.5V to 19V	–	2.0	45.0	
Regload	Load Regulation[25]	T_J = +25°C, I_O = 5mA to 1.5A		–	12.0	100	mV
		I_O = 5mA to 1A		–	12.0	100	
		I_O = 250mA to 750mA		–	5.0	50.0	
I_Q	Quiescent Current	T_J = +25°C		–	5.0	6.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	–	0.5	mA
		V_I = 12V to 25V, I_O = 500mA		–	–	0.8	
		V_I = 11.7V to 25V, T_J = +25°C		–	–	0.8	
$\Delta V_O/\Delta T$	Output Voltage Drift[26]	I_O = 5mA		–	-1.0	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	10.0	–	$\mu V/V_O$
RR	Ripple Rejection[26]	f = 120Hz, I_O = 500mA, V_I = 12V to 22V		–	62.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance[26]	f = 1kHz		–	17.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	250	–	mA
I_{PK}	Peak Current[26]	T_J = +25°C		–	2.2	–	A

Notes:

25. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
26. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7810A) (Continued)

Refer to the test circuits. $0°C < T_J < 125°C$, $I_O = 1A$, $V_I = 16V$, $C_I = 0.33\mu F$, $C_O = 0.1\mu F$, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Units
V_O	Output Voltage	$T_J = +25°C$		9.8	10.0	10.2	V
		$I_O = 5mA$ to 1A, $P_O \leq 15W$, $V_I = 12.8V$ to 25V		9.6	10.0	10.4	
Regline	Line Regulation(27)	$V_I = 12.8V$ to 26V, $I_O = 500mA$		–	8.0	100	mV
		$V_I = 13V$ to 20V		–	4.0	50.0	
		$T_J = +25°C$	$V_I = 12.5V$ to 25V	–	8.0	100	
			$V_I = 13V$ to 20V	–	3.0	50.0	
Regload	Load Regulation(27)	$T_J = +25°C$, $I_O = 5mA$ to 1.5A		–	12.0	100	mV
		$I_O = 5mA$ to 1A		–	12.0	100	
		$I_O = 250mA$ to 750mA		–	5.0	50.0	
I_Q	Quiescent Current	$T_J = +25°C$		–	5.0	6.0	mA
ΔI_Q	Quiescent Current Change	$I_O = 5mA$ to 1A		–	–	0.5	mA
		$V_I = 12.8V$ to 25V, $I_O = 500mA$		–	–	0.8	
		$V_I = 13V$ to 26V, $T_J = +25°C$		–	–	0.5	
$\Delta V_O/\Delta T$	Output Voltage Drift(28)	$I_O = 5mA$		–	-1.0	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, $T_A = +25°C$		–	10.0	–	$\mu V/V_O$
RR	Ripple Rejection(28)	f = 120Hz, $I_O = 500mA$, $V_I = 14V$ to 24V		–	62.0	–	dB
V_{DROP}	Dropout Voltage	$I_O = 1A$, $T_J = +25°C$		–	2.0	–	V
r_O	Output Resistance(28)	f = 1kHz		–	17.0	–	mΩ
I_{SC}	Short Circuit Current	$V_I = 35V$, $T_A = +25°C$		–	250	–	mA
I_{PK}	Peak Current(28)	$T_J = +25°C$		–	2.2	–	A

Notes:

27. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
28. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7812A) (Continued)

Refer to the test circuits. 0°C < T_J < 125°C, I_O = 1A, V_I = 19V, C_I = 0.33µF, C_O = 0.1µF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Units
V_O	Output Voltage	T_J = +25°C		11.75	12.0	12.25	V
		I_O = 5mA to 1A, $P_O \leq$ 15W, V_I = 14.8V to 27V		11.5	12.0	12.5	
Regline	Line Regulation(29)	V_I = 14.8V to 30V, I_O = 500mA		–	10.0	120	mV
		V_I = 16V to 22V		–	4.0	120	
		T_J = +25°C	V_I = 14.5V to 27V	–	10.0	120	
			V_I = 16V to 22V	–	3.0	60.0	
Regload	Load Regulation(29)	T_J = +25°C, I_O = 5mA to 1.5A		–	12.0	100	mV
		I_O = 5mA to 1A		–	12.0	100	
		I_O = 250mA to 750mA		–	5.0	50.0	
I_Q	Quiescent Current	T_J = +25°C		–	5.1	6.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	–	0.5	mA
		V_I = 14V to 27V, I_O = 500mA		–	–	0.8	
		V_I = 15V to 30V, T_J = +25°C		–	–	0.8	
$\Delta V_O/\Delta T$	Output Voltage Drift(30)	I_O = 5mA		–	-1.0	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	10.0	–	$\mu V/V_O$
RR	Ripple Rejection(30)	f = 120Hz, I_O = 500mA, V_I = 14V to 24V		–	60.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance(30)	f = 1kHz		–	18.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	250	–	mA
I_{PK}	Peak Current(30)	T_J = +25°C		–	2.2	–	A

Note:

29. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
30. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7815A) (Continued)

Refer to the test circuits. 0°C < T_J < 125°C, I_O = 1A, V_I = 23V, C_I = 0.33µF, C_O = 0.1µF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Units
V_O	Output Voltage	T_J = +25°C		14.75	15.0	15.3	V
		I_O = 5mA to 1A, $P_O \leq$ 15W, V_I = 17.7V to 30V		14.4	15.0	15.6	
Regline	Line Regulation[31]	V_I = 17.4V to 30V, I_O = 500mA		–	10.0	150	mV
		V_I = 20V to 26V		–	5.0	150	
		T_J = +25°C	V_I = 17.5V to 30V	–	11.0	150	
			V_I = 20V to 26V	–	3.0	75.0	
Regload	Load Regulation[31]	T_J = +25°C, I_O = 5mA to 1.5A		–	12.0	100	mV
		I_O = 5mA to 1A		–	12.0	100	
		I_O = 250mA to 750mA		–	5.0	50.0	
I_Q	Quiescent Current	T_J = +25°C		–	5.2	6.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	–	0.5	mA
		V_I = 17.5V to 30V, I_O = 500mA		–	–	0.8	
		V_I = 17.5V to 30V, T_J = +25°C		–	–	0.8	
$\Delta V_O/\Delta T$	Output Voltage Drift[32]	I_O = 5mA		–	-1.0	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	10.0	–	µV/V_O
RR	Ripple Rejection[32]	f = 120Hz, I_O = 500mA, V_I = 18.5V to 28.5V		–	58.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance[32]	f = 1kHz		–	19.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	250	–	mA
I_{PK}	Peak Current[32]	T_J = +25°C		–	2.2	–	A

Notes:

31. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
32. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7818A) (Continued)

Refer to the test circuits. 0°C < T_J < 125°C, I_O = 1A, V_I = 27V, C_I = 0.33μF, C_O = 0.1μF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Units
V_O	Output Voltage	T_J = +25°C		17.64	18.0	18.36	V
		I_O = 5mA to 1A, $P_O \leq$ 15W, V_I = 21V to 33V		17.3	18.0	18.7	
Regline	Line Regulation(33)	V_I = 21V to 33V, I_O = 500mA		–	15.0	180	mV
		V_I = 21V to 33V		–	5.0	180	
		T_J = +25°C	V_I = 20.6V to 33V	–	15.0	180	
			V_I = 24V to 30V	–	5.0	90.0	
Regload	Load Regulation(33)	T_J = +25°C, I_O = 5mA to 1.5A		–	15.0	100	mV
		I_O = 5mA to 1A		–	15.0	100	
		I_O = 250mA to 750mA		–	7.0	50.0	
I_Q	Quiescent Current	T_J = +25°C		–	5.2	6.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	–	0.5	mA
		V_I = 12V to 33V, I_O = 500mA		–	–	0.8	
		V_I = 12V to 33V, T_J = +25°C		–	–	0.8	
$\Delta V_O/\Delta T$	Output Voltage Drift(34)	I_O = 5mA		–	-1.0	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	10.0	–	$\mu V/V_O$
RR	Ripple Rejection(34)	f = 120Hz, I_O = 500mA, V_I = 22V to 32V		–	57.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance(34)	f = 1kHz		–	19.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	250	–	mA
I_{PK}	Peak Current(34)	T_J = +25°C		–	2.2	–	A

Notes:

33. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
34. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7824A) (Continued)

Refer to the test circuits. 0°C < T_J < 125°C, I_O = 1A, V_I = 33V, C_I = 0.33µF, C_O = 0.1µF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Units
V_O	Output Voltage	T_J = +25°C		23.5	24.0	24.5	V
		I_O = 5mA to 1A, $P_O \leq$ 15W, V_I = 27.3V to 38V		23.0	24.0	25.0	
Regline	Line Regulation[35]	V_I = 27V to 38V, I_O = 500mA		–	18.0	240	mV
		V_I = 21V to 33V		–	6.0	240	
		T_J = +25°C	V_I = 26.7V to 38V	–	18.0	240	
			V_I = 30V to 36V	–	6.0	120	
Regload	Load Regulation[35]	T_J = +25°C, I_O = 5mA to 1.5A		–	15.0	100	mV
		I_O = 5mA to 1A		–	15.0	100	
		I_O = 250mA to 750mA		–	7.0	50.0	
I_Q	Quiescent Current	T_J = +25°C		–	5.2	6.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	–	0.5	mA
		V_I = 27.3V to 38V, I_O = 500mA		–	–	0.8	
		V_I = 27.3V to 38V, T_J = +25°C		–	–	0.8	
$\Delta V_O/\Delta T$	Output Voltage Drift[36]	I_O = 5mA		–	-1.5	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	10.0	–	µV/V_O
RR	Ripple Rejection[36]	f = 120Hz, I_O = 500mA, V_I = 28V to 38V		–	54.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance[36]	f = 1kHz		–	20.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	250	–	mA
I_{PK}	Peak Current[36]	T_J = +25°C		–	2.2	–	A

Notes:

35. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
36. These parameters, although guaranteed, are not 100% tested in production.

Typical Performance Characteristics

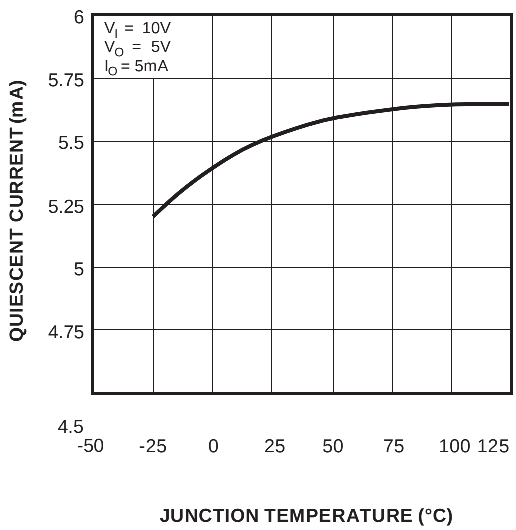


Figure 3. Quiescent Current

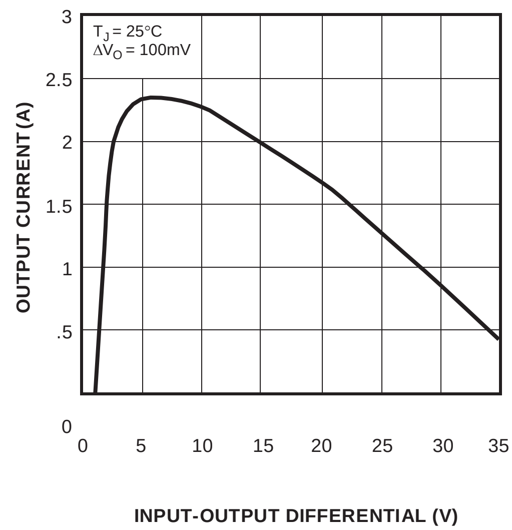


Figure 4. Peak Output Current

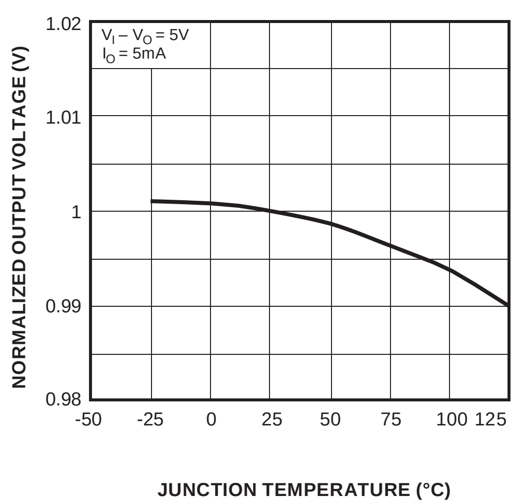


Figure 5. Output Voltage

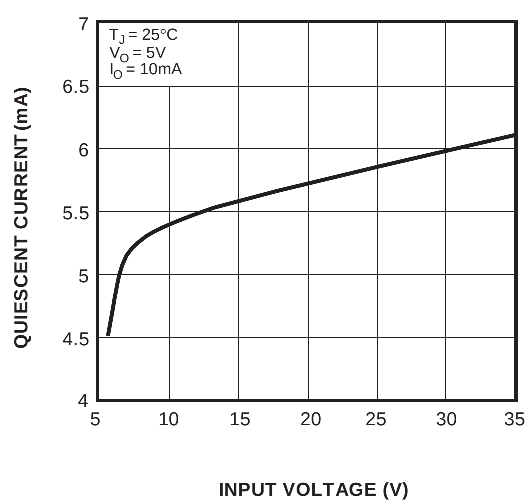


Figure 6. Quiescent Current

Typical Applications

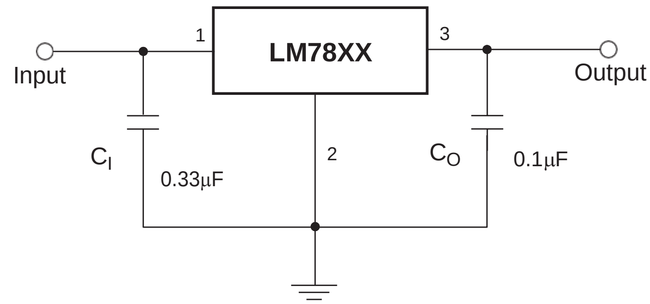


Figure 7. DC Parameters

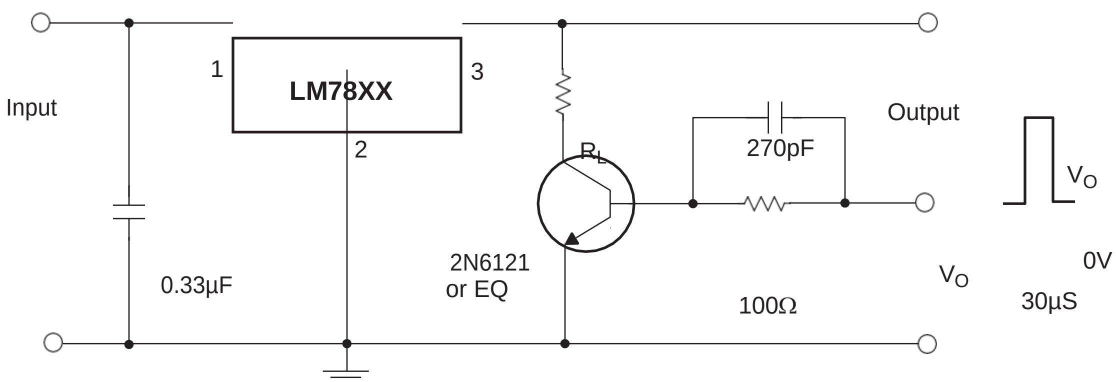


Figure 8. Load Regulation

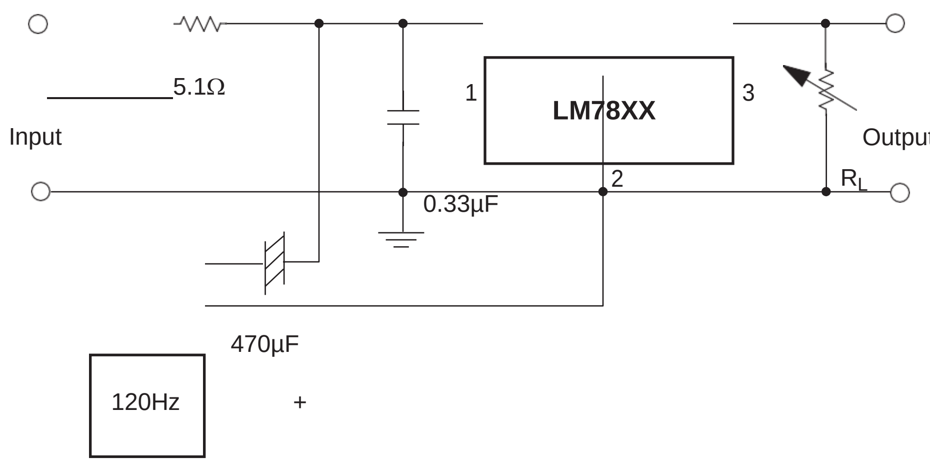


Figure 9. Ripple Rejection

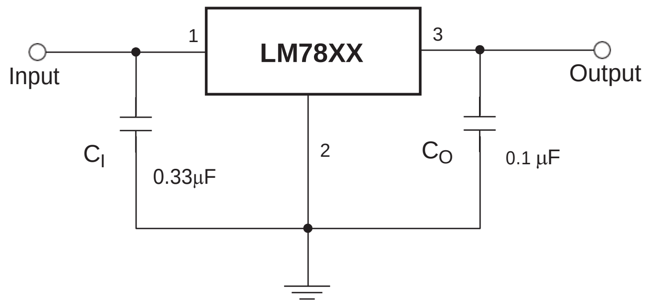
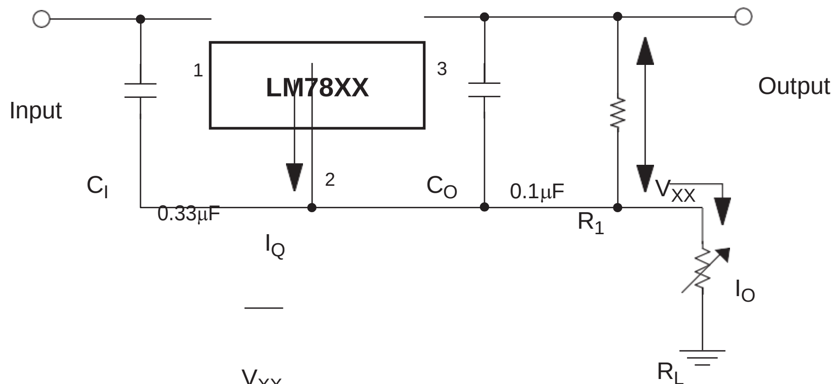


Figure 10. Fixed Output Regulator

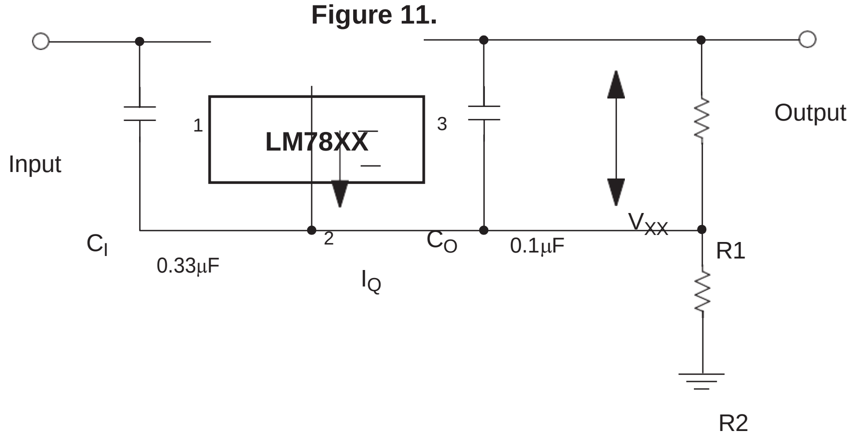


$$I_O = \frac{V_{XX}}{R_1} + I_Q$$

Notes:

1. To specify an output voltage, substitute voltage value for "XX." A common ground is required between the input and the output voltage. The input voltage must remain typically 2.0V above the output voltage even during the low point on the input ripple voltage.
2. C_I is required if regulator is located an appreciable distance from power supply filter.
3. C_O improves stability and transient response.

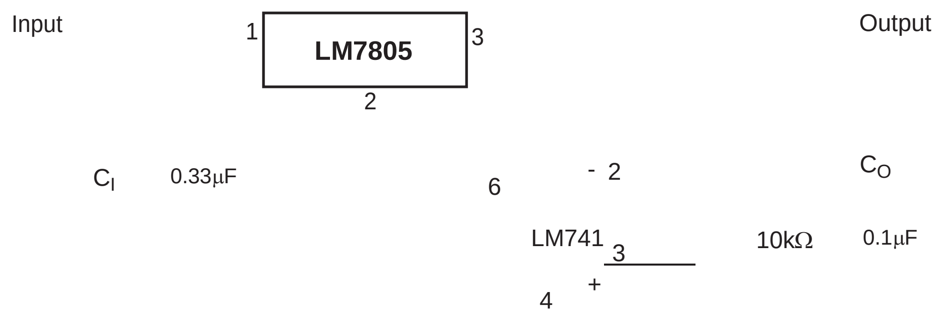
Figure 11.



$I_{RI} \geq 5\ I_Q$

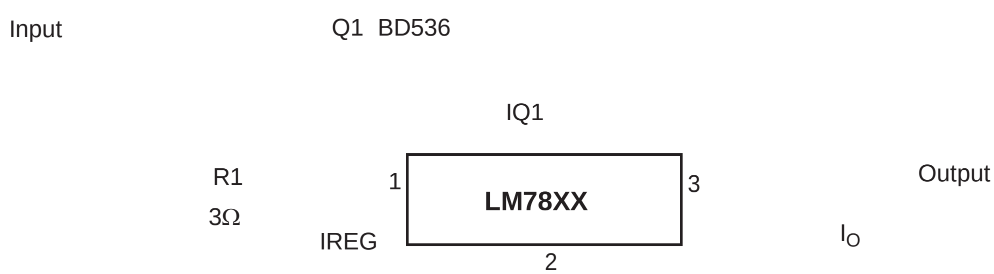
$V_O = V_{XX}(1 + R_2 / R_1) + I_Q R_2$

Figure 12. Circuit for Increasing Output Voltage



$I_{RI} \geq 5\ I_Q$
$V_O = V_{XX}(1 + R_2 / R_1) + I_Q R_2$

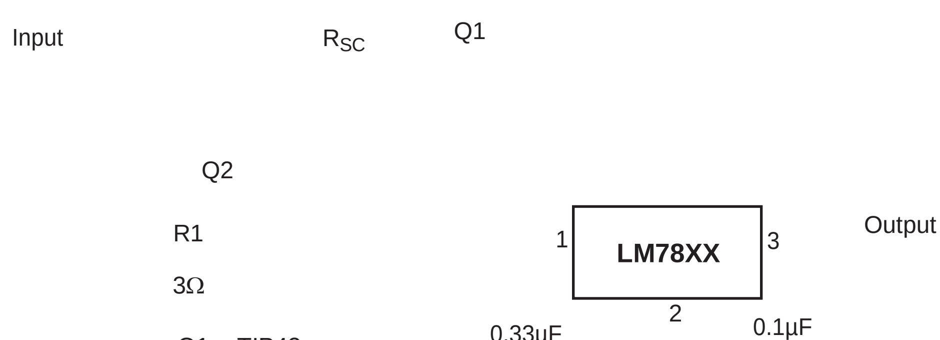
Figure 13. Adjustable Output Regulator (7V to 30V)



$$R1 = \frac{V_{BEQ1}}{I_{REG} - I_{Q1}\ B_{Q1}}$$

$I_O = I_{REG} + B_{Q1}\ (I_{REG} - V_{BEQ1}/R_1)$

Figure 14. High Current Voltage Regulator

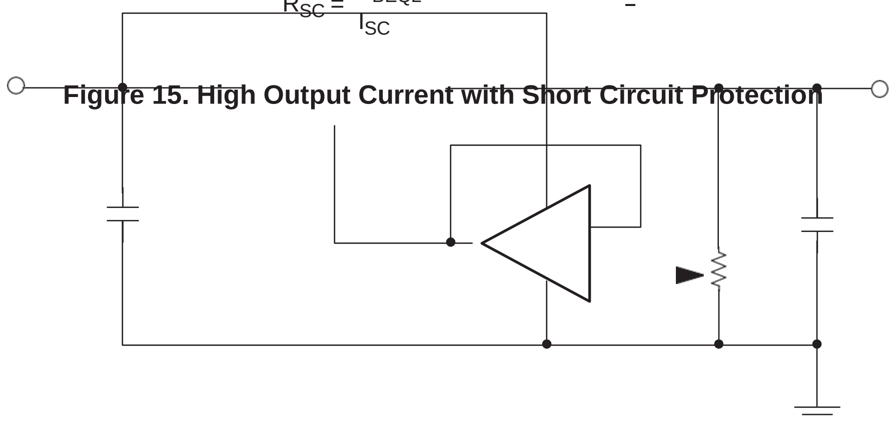


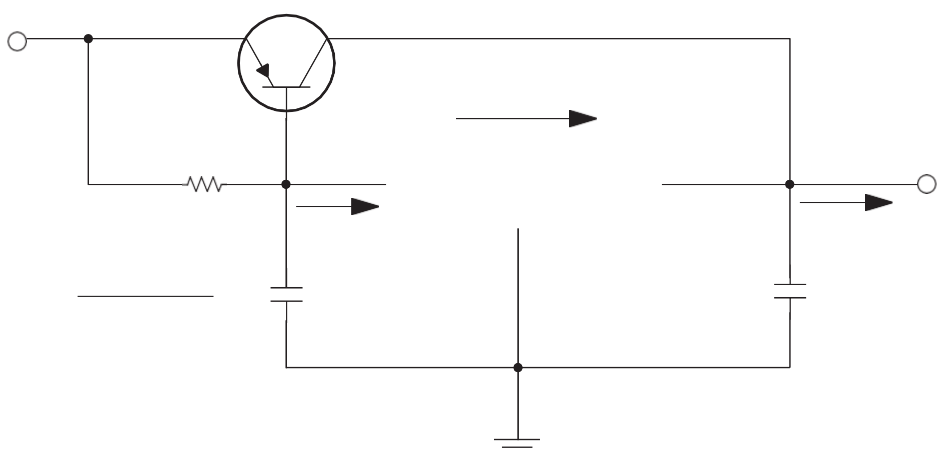
Q1 = TIP42
Q2 = TIP42

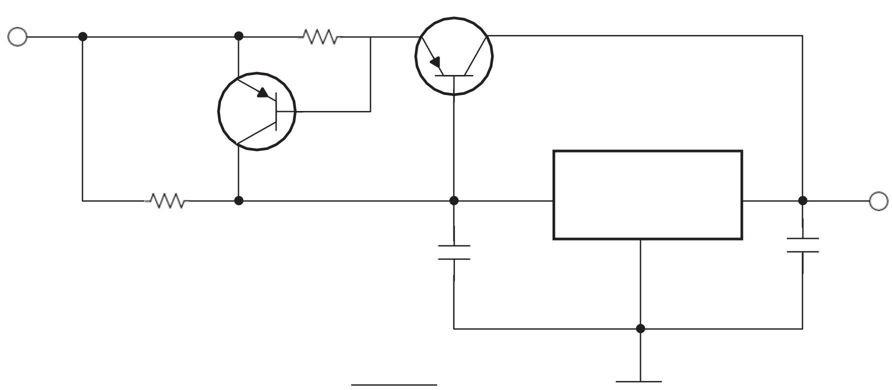
$R_{SC} = \frac{V_{BEQ2}}{I_{SC}}$

–

Figure 15. High Output Current with Short Circuit Protection







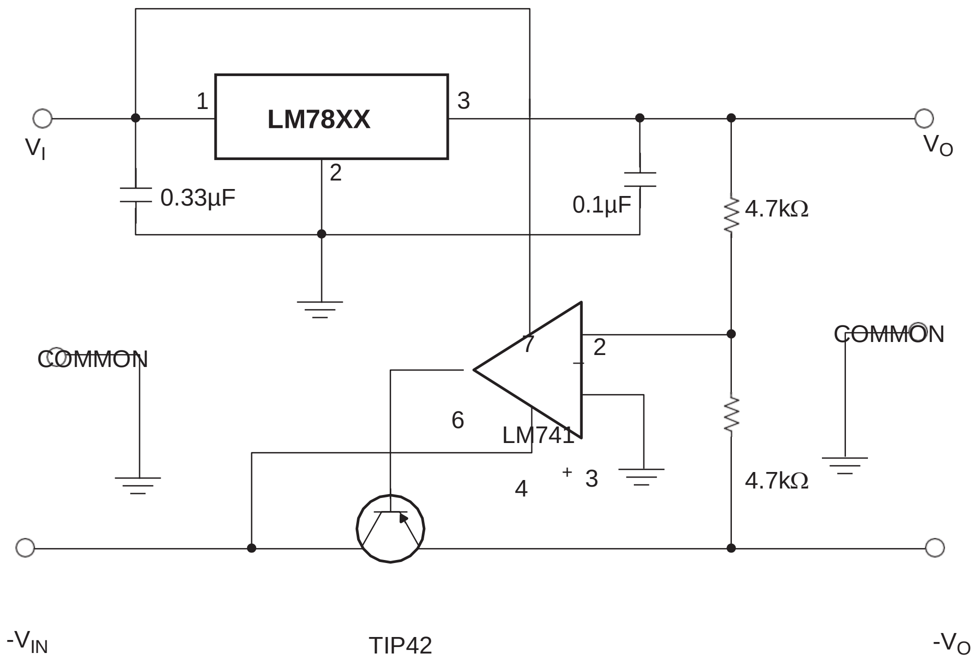


Figure 16. Tracking Voltage Regulator

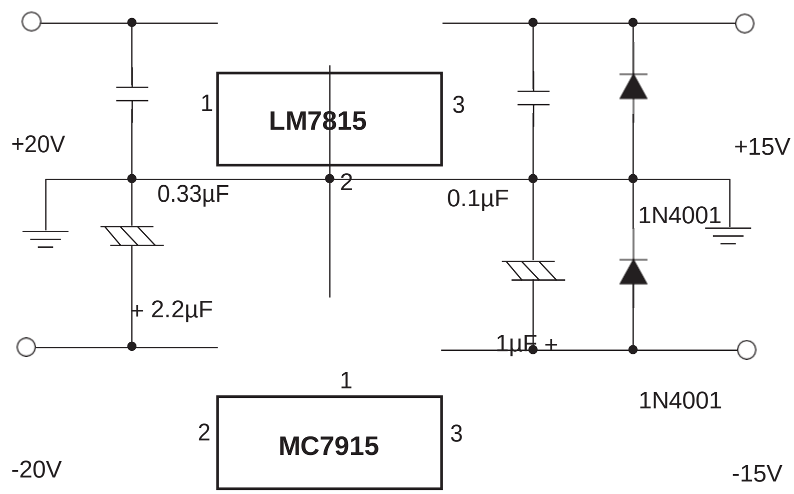


Figure 17. Split Power Supply (±15V – 1A)

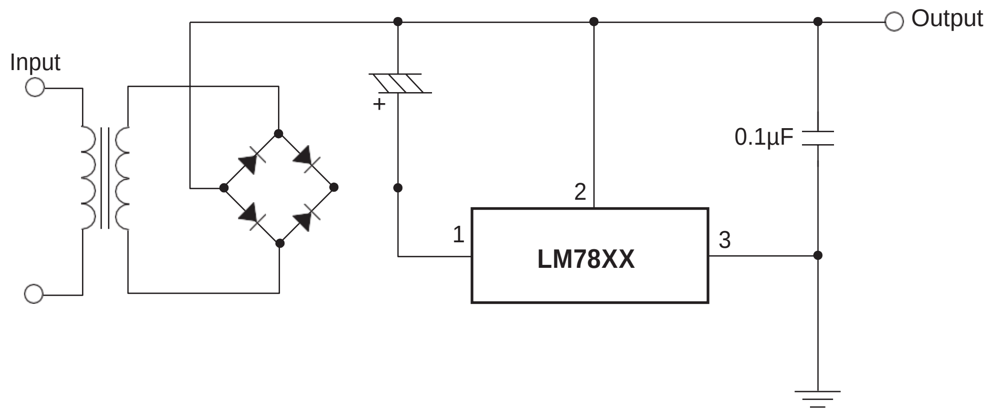


Figure 18. Negative Output Voltage Circuit

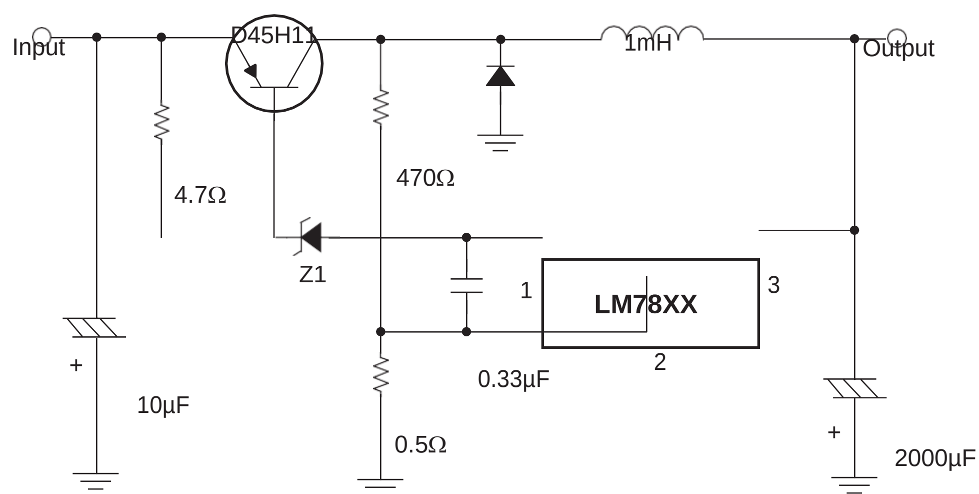
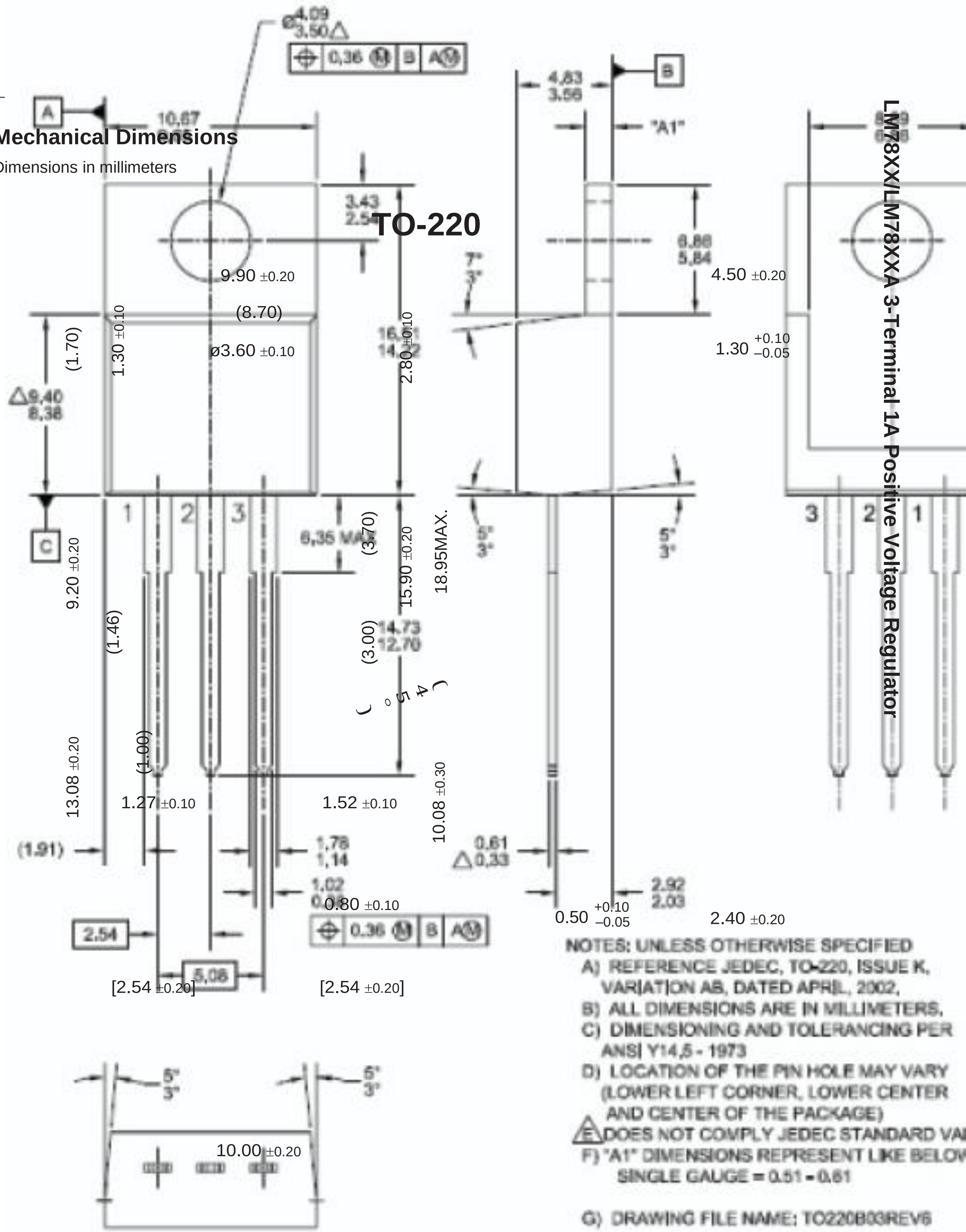


Figure 19. Switching Regulator

Mechanical Dimensions

Dimensions in millimeters

TO-220



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EnSigna™	ImpliedDisconnect™	OCXPro™	µSerDes™	UHC™
FACT™	IntelliMAX™	OPTOLOGIC®	ScalarPump™	UniFET™

FACT Quiet Series™	OPTOPLANAR™	SILENT SWITCHER®	UltraFET®
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2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

PRODUCT STATUS DEFINITIONS

Definition of Terms

Datasheet Identification	Product Status	Definition
Advance Information	Formative or In Design	This datasheet contains the design specifications for product development. Specifications may change in any manner without notice.
Preliminary	First Production	This datasheet contains preliminary data, and supplementary data will be published at a later date. Fairchild Semiconductor reserves the right to make changes at any time without notice in order to improve design.
No Identification Needed	Full Production	This datasheet contains final specifications. Fairchild Semiconductor reserves the right to make changes at any time without notice in order to improve design.

Obsolete	Not In Production	This datasheet contains specifications on a product that has been discontinued by Fairchild semiconductor. The datasheet is printed for reference information only.

Rev. I19

SINGLE-SUPPLY DUAL OPERATIONAL AMPLIFIER

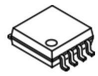
■ GENERAL DESCRIPTION

The NJM2904 consists of two independent, high gain, internally frequency compensated operation amplifiers, which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage.

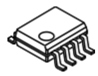
Application areas include transducer amplifiers, DC gain blocks, and all the conventional op amp circuits, which now can be more easily implemented in single power supply systems. For example, the NJM2904 can be directly operated off of the standard +5V power supply voltage, which is used in digital systems and will easily provide the required interface electronics without requiring the additional ±15V power supplies.

■ PACKAGE OUTLINE

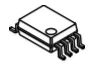
NJM2904D



NJM2904M

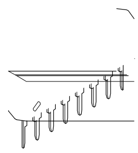


NJM2904E



NJM2904V

NJM2904R/RB1



NJM2904L

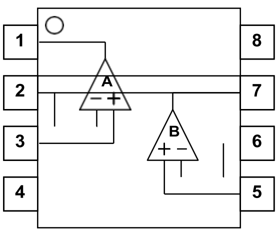
■ FEATURES

- Single Supply
- Operating Voltage +3V~+32V
- Low Operating Current 0.7mA typ.
- Slew Rate 0.5V/µs typ.
- Bipolar Technology

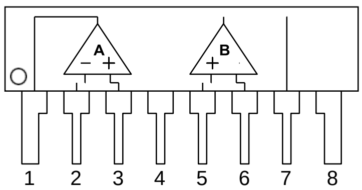
- Package Outline DIP8, DMP8, SSOP8, SIP8, SOP8 JEDEC 150mil
  MSOP8 (VSP8) MEET JEDEC MO-187-DA
  MSOP8 (TVSP8) MEET JEDEC MO-187-DA / THIN TYPE

■ PIN CONFIGURATION

(Top View)



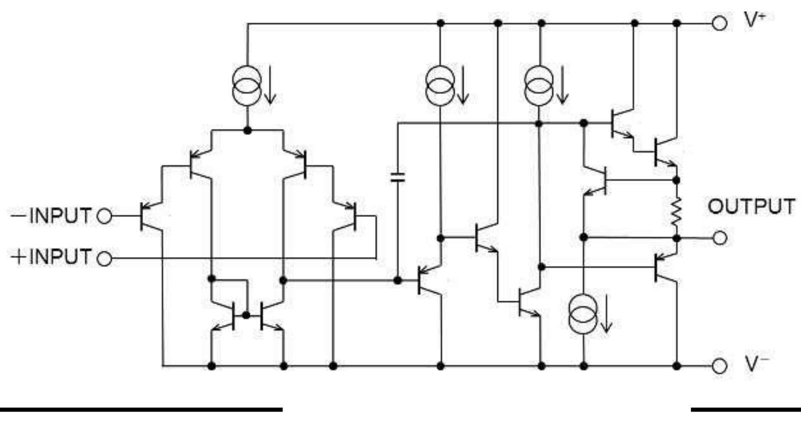
NJM2904D, NJM2904M
NJM2904E, NJM2904V
NJM2904R/RB1



NJM2904L

PIN FUNCTION
1. A OUTPUT
2. A−INPUT
3. A +INPUT
4. V^-
5. B +INPUT
6. B −INPUT
7. B OUTPUT
8. V^+

■ EQUIVALENT CIRCUIT (1/2 Shown)



■ ABSOLUTE MAXIMUM RATINGS

(Ta=25˚C)

PARAMETER	SYMBOL	RATINGS	UNIT
Supply Voltage	$V^+(V^+/V^-)$	32 (or ±16)	V
Differential Input Voltage	V_{ID}	32	V
Input Voltage	V_{IC}	-0.3~+32 (note 2)	V
Power Dissipation	P_D	(DIP8) 500 (DMP8) 300 (EMP8) 300 (SSOP8) 250 (MSOP8(VSP8/TVSP8)) 320 (SIP8) 800	mW
Operating Temperature Range	T_{opr}	-40~+85	˚C
Storage Temperature Range	T_{stg}	-50~+125	˚C

(note 1) Continuous short-circuits from output to GND is guaranteed only when $V^+ \leq 15V$.

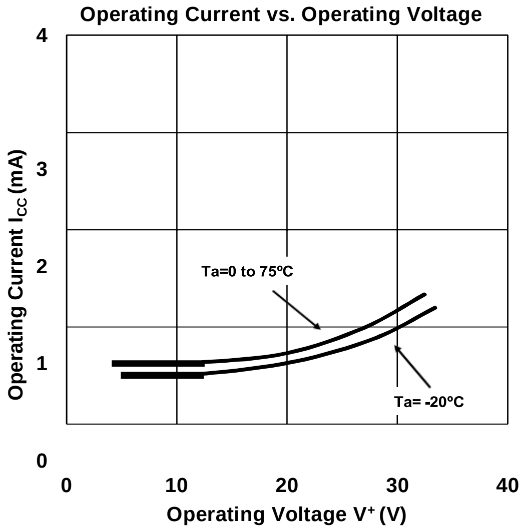
(note 2) For supply voltage less than 32V, the absolute maximum input voltage is equal to the supply voltage.

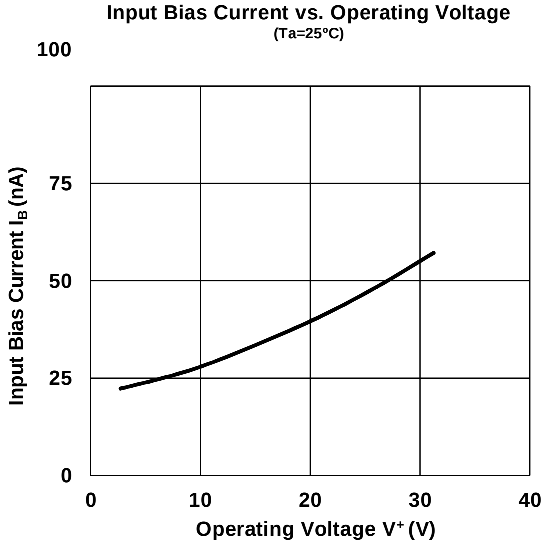
■ ELECTRICAL CHARACTERISTICS

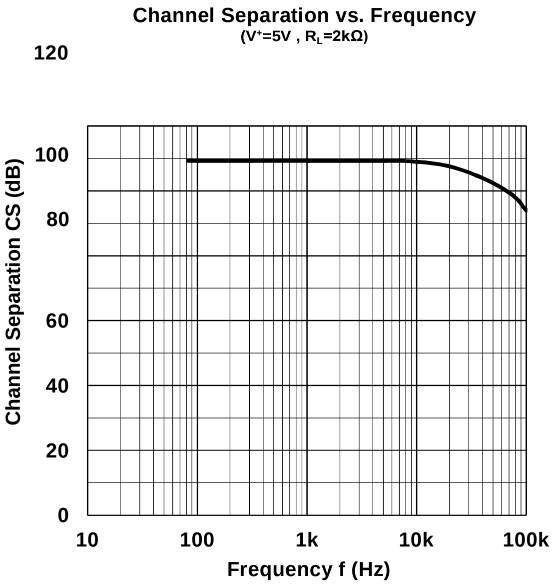
(Ta=25˚C,V⁺=5V)

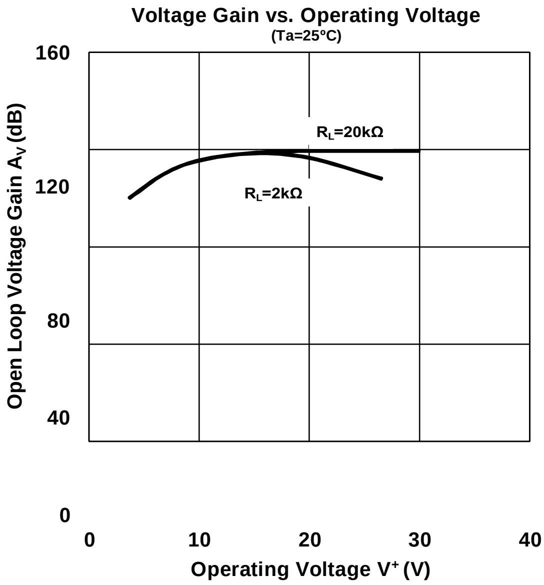
PARAMETER	SYMBOL	TEST CONDITION	MIN.	TYP.	MAX.	UNIT
Input Offset Voltage	V_{IO}	$R_S=0\Omega$	-	2	7	mV
Input Offset Current	I_{IO}		-	5	50	nA
Input Bias Current	I_B		-	25	250	nA
Large Signal Voltage Gain	A_V	$R_L \geq 2k\Omega$	-	100	-	dB
Maximum Output Voltage Swing	V_{OP}	$R_L=2k\Omega$	3.5	-	-	V
Input Common Mode Voltage Range	V_{ICM}		0~3.5	-	-	V
Common Mode Rejection Ratio	CMR		-	85	-	dB
Supply Voltage Rejection Ratio	SVR		-	100	-	dB
Output Source Current	I_{SOURCE}	$V_{IN}^+=1V, V_{IN}^-=0V$	20	30	-	mA
Output Sink Current	I_{SINK}	$V_{IN}^+=0V, V_{IN}^-=1V$	8	20	-	mA
Channel Separation	CS	f=1k~20kHz,Input Referred	-	120	-	dB
Operating Current	I_{CC}	$R_L=\infty$	-	0.7	1.2	mA
Slew Rate	SR	$V^+/V^-=\pm15V$	-	0.5	-	V/µs
Unity Gain Bandwidth	f_T	$V^+/V^-=\pm15V$	-	0.6	-	MHz

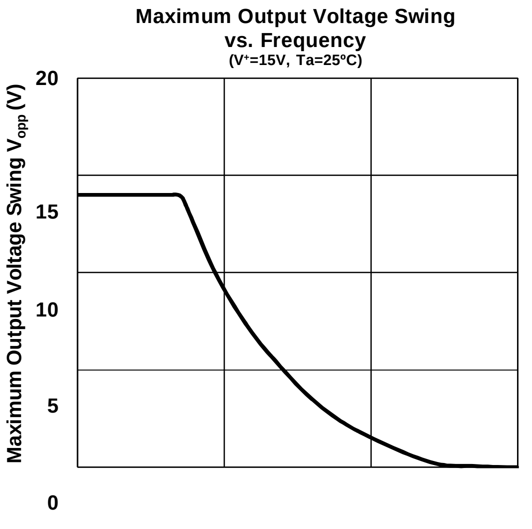
■ TYPICAL CHARACTERISTICS

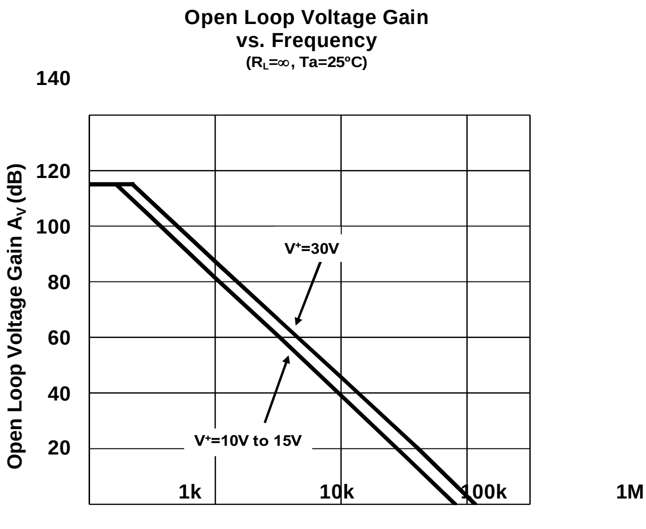








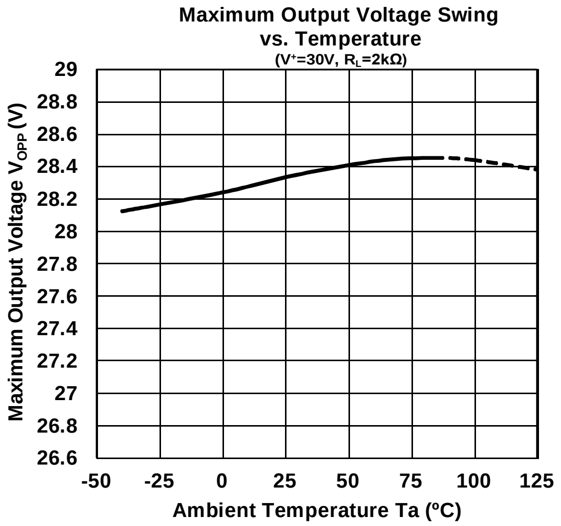


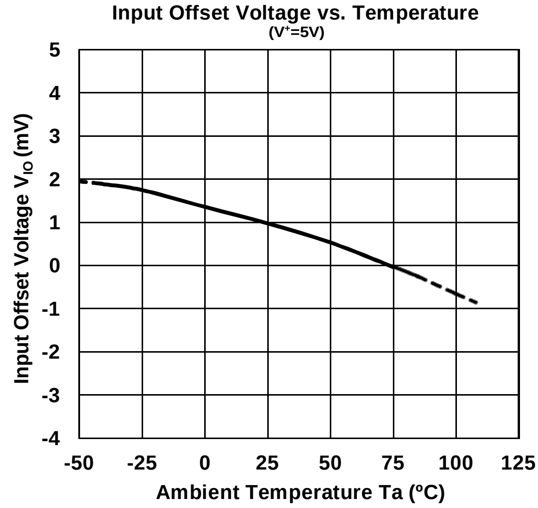


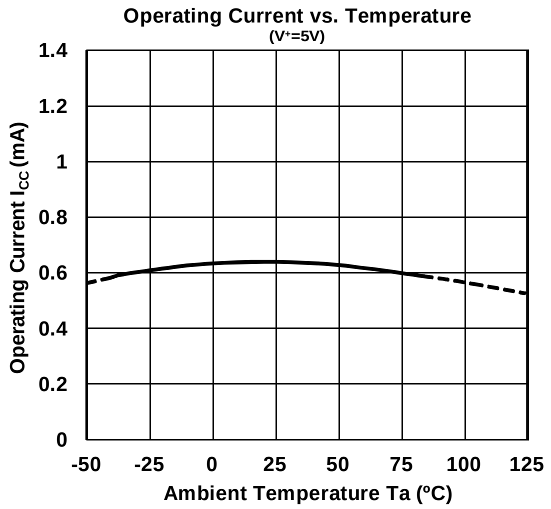
Frequency f (Hz)

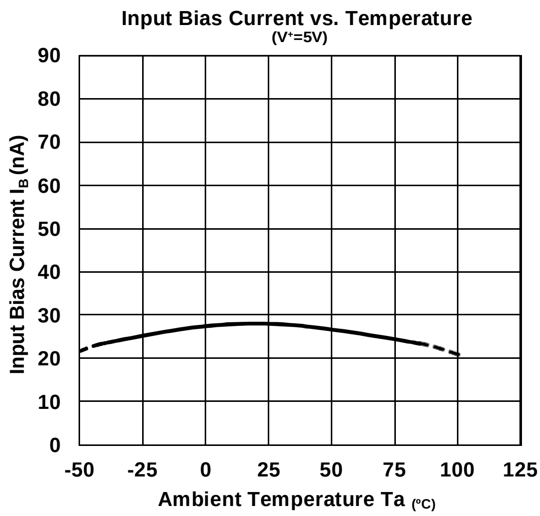
0
1 100 10k 1M
Frequency f (Hz)

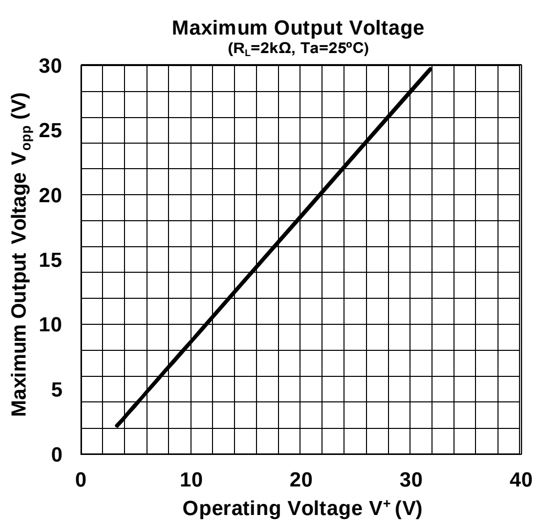
■ TYPICAL CHARACTERISTICS

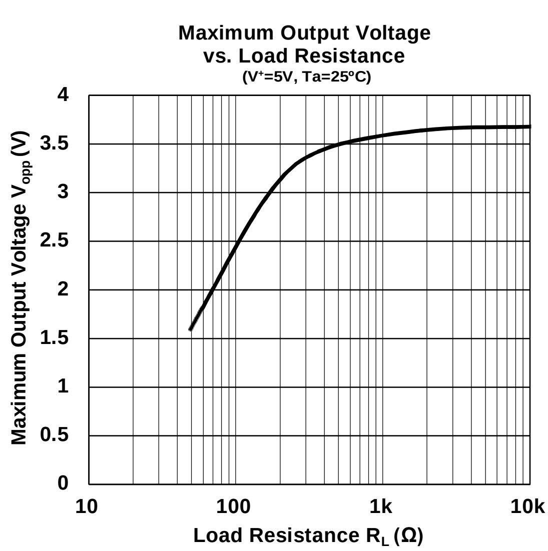






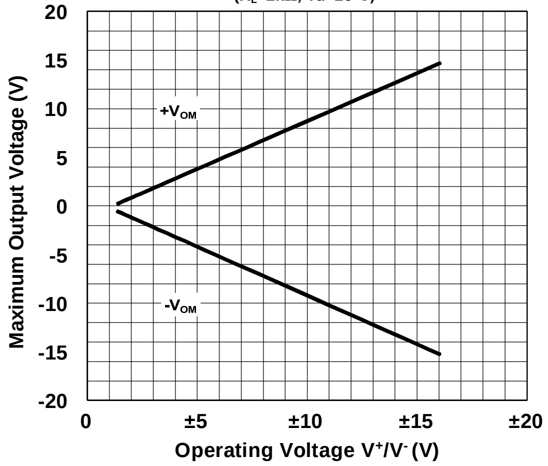




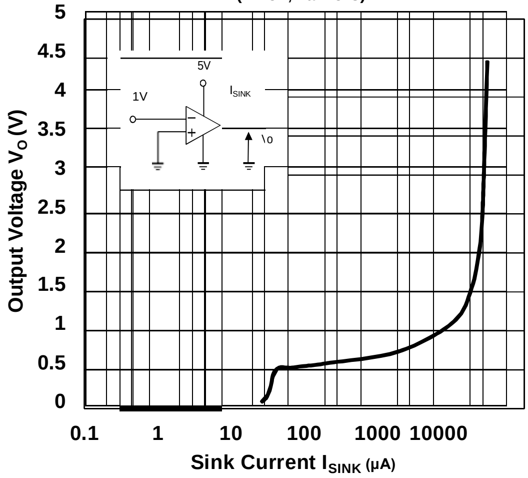


■ TYPICAL CHARACTERISTICS

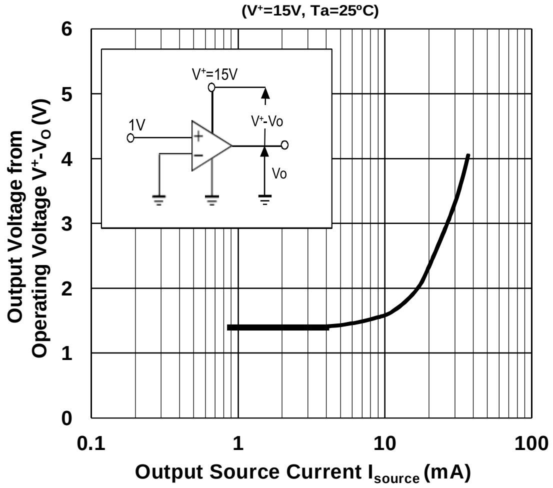
Maximum Output Voltage vs. Operating Voltage
(R_L=2kΩ, Ta=25ºC)



Output Voltage vs. Sink Current
(V+=5V, Ta=25ºC)



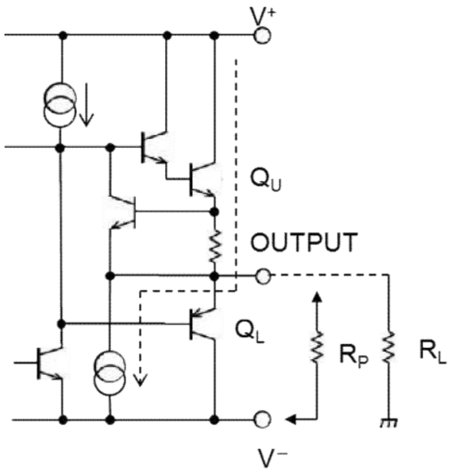
Source Current
(V+=15V, Ta=25ºC)



■ **APPLICATION**

Improvement of Cross-over Distortion

Equivalent circuit at the output stage

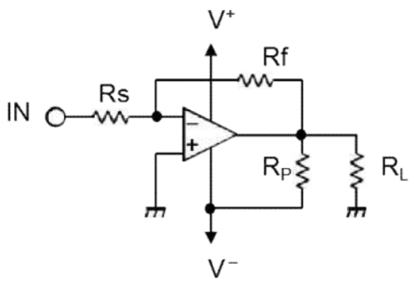


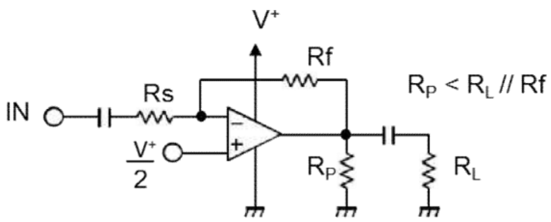
NJM2904,in its static state (No in and output condition) when design,Q_U being biassed by constant current (break down beam) yet,Q_L stays OFF.

While using with both power source mode,the cross-over distortion might occur instantly when Q_L ON.

There might be cases when application for amplifier of audio signals,not only distortion but also the apparent frequency bandwidth being narrowed remarkably.

It is adjustable especially when using both power source mode,constantly to use with higher current on Q_U than the load current (including feedback current),and then connect the pull-down resister R_P at the part between output and V^- pins.





[CAUTION]
The specifications on this databook are only given for information , without any guarantee as regards either mistakes or omissions. The application circuits in this databook are described only to show representative usages of the product and not intended for the guarantee or permission of any right including the industrial rights.

APPENDIX J

Curriculum Vitae

BARROGA, CATRINA ANDREA A.
L2 B16, Sampaloc Corner, Duhat St., San Miguel 1
Molino IV, Bacoor City, Cavite
Contact No.: 09067885213
Email Address: catrinabarroga@gmail.com

OBJECTIVE

- To look for an opportunity in a reputed company which will help develop my knowledge and skills in engineering and meet the demands of the company.

PERSONAL SKILLS

- MS Office Proficiency
- Hard working and Physically Fit
- Basic Electrical and Electronics
- Good Communication Skills
- Able to adapt effectively to challenging and emergency situation

PERSONAL INFORMATION

Date of Birth	:	January 3, 1998
Age	:	21 years old
Gender	:	Female
Height	:	5'3
Weight	:	121 lbs.
Religion	:	Roman Catholic
Civil Status	:	Single
Citizenship	:	Filipino

EDUCATIONAL ATTAINMENT

TERTIARY : TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES
Bachelor of Science in Electronics Communication Engineering
Ayala Blvd. Ermita, Manila
AY : 2014-Present

SECONDARY : ST. THOMAS MORE ACADEMY INC.
Avenida Rizal, Molino III, Bacoor City Cavite
SY : 2011-2014

LAS PIÑAS NORTH NATIONAL HIGH SCHOOL
Aurora Drive, Las Pinas City, Metro Manila
SY : 2010-2011

PRIMARY : PAMPLONA ELEMENTARY SCHOOL CENTRAL
Alabang-Zapote Road, Las Pinas City, Metro Manila
SY:2007–2010

ST. MARKS INSTITUTE, Inc.
Casimiro Ave., Casimiro Village, CAA, Las Pinas City, Metro Manila
SY : 2004-2007

AFFILIATIONS

December 2014-Present **Organization of Electronics and Communication Engineering Students (OECES)**
Member
College of Engineering
Technological University of the Philippines

December 2015-2016 **Institute of Electronics and Communication Engineer in the Philippines (IECEP)**
Member
College of Engineering
2nd Flr. Unit 2 CMC Bldg., 710 San Marcelino St, Ermita, Maynila, Kalakhang Maynila

WORK EXPERIENCE

- **USBYG FOOD CORPORATION**
  Service Crew
  2015-2016

CHARACTER REFERENCES

Engr. Lean Karlo S. Tolentino
Faculty of Electronics Engineering Dept.
Dept. Head
TUP Manila
+639161243835

Mary Ann Bugayong
USBYG Food Corporation
Accounting Head
Mcdonald's RFC Molino
+639985497308

Engr. August C. Thio-Ac
Faculty of Electronics Engineering Dept.
TUP Manila
+639338684698

I hereby certify that the above information is true and correct to the best of my knowledge and ability.

BARROGA, CATRINA ANDREA A.
Applicant's Signature

BERDERA, KYRA MARIELLA T.
B 4 t 13 Ivory St. Camella North Springville
Molino Bacoor City Cavite
Contact No.: 09973560143
Email Address: mariella.berdera@gmail.com

OBJECTIVE

- To test the knowledge I have acquired in school and to use my skills, and ability to work well with people in the field of engineering job.

- To obtain knowledge and skills about the industry and to grow professionally, while effectively utilizing my versatile skill set to help promote your corporate mission and exceed team goals.

PERSONAL SKILLS

- Software Proficiency: Microsoft offices, Multisim, MATLAB, LABVIEW, Octave, and Python
- Hardware Proficiency: Digital Logic Trainer, and Power Supply
- Able to adapt effectively to challenging and emergency situation
- Basic Electrical and Electronics
- Good Communication Skills
- Hard working and Physically Fit

PERSONAL INFORMATION

Date of Birth	:	December 9, 1997
Age	:	21 years old
Gender	:	Female
Height	:	5'2
Weight	:	130 lbs.
Religion	:	Christian
Civil Status	:	Single
Citizenship	:	Filipino

EDUCATIONAL ATTAINMENT

TERTIARY	**:**	TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES Bachelor of Science in Electronics Communication Engineering Ayala Blvd. Ermita, Manila AY : 2014-Present
SECONDARY	**:**	EASTERN BACOOR NATIONAL HIGHSCHOOL Queens Aisle St, Queensrow Central Molino Bacoor Cavite SY : 2010-2014 Valedictorian
PRIMARY	**:**	CHRIST LIFE LEARNING CENTER Purple St. Camella North Molino Bacoor City Cavite SY:2004 – 2010 Salutatorian

AFFILIATIONS

- Institute of Electronics Engineers of the Philippines Manila Member 2016-Present
- Graduating Class Officers Treasure 2018-2019
- Organization of Electronics Communication Engineers (OECES) Member 2014-Present
  Ayala Blvrd. Ermita, Manila

SEMINARS

May 31, 2017	**Tracks Orientation** P.H.A.S.E.S – Preparing the Headway for Achievement and Success of ECE Students Conference Hall, Integrated Research and Training Center, Technological University of the Philippines – Manila
February 23, 2018	**APPRECIATE 2018** Conference Hall, Integrated Research and Training Center, Technological University of the Philippines – Manila
July 30, 2018	**T.R.E.N.D.S: Topics in Research, Electronics, Networking, and Data Science** Swarm Intelligence, Research Themes and Trends in Electronics Engineering, Network Engineering College of Engineering Room 43, Technological University of the Philippines – Manila
August 18, 2018	**Photoshop Workshop 2018** College of Engineering Room 23, Technological University of the Philippines – Manila
November 24, 2018	**ACROSS BORDERS: Electronics Engineering in the Philippines and the ASEAN Economic Community** Virtual Reality of Things, Internet of Things and Telcom: The New Golden Era, Impact and Benefits of Industry 4.0: A Smart Factory Automation Multipurpose Hall, National University Annex Building – Sampaloc Manila

CERTIFICATION

- IT Passport (IP) Certification
  Philippine National IT Standard (PhilNITS) Foundation Inc.

CHARACTER REFERENCES

- **Engr. Lean Karlo S. Tolentino**
  Faculty of Electronics Engineering Dept.
  Dept. Head
  TUP Manila
  Contact No: 09958925845
  Email: leankarlo_tolentino@tup.edu.ph

- **Engr. August C. Thio-Ac**
  Faculty of Electronics Engineering Dept.
  TUP Manila
  Contact No: 09338684698

I hereby certify that the above information is true and correct to the best of my knowledge and ability.

KBerdera

BERDERA, KYRA MARIELLA T.
Applicant's Signature

PANGILINAN, RHONBERT JONATHAN G.
5155 P.Zamora Street, Bgy. Poblacion, Makati City, MM 1210
Contact No.: 09282146708
Email Address: rhonbertpangilinan@gmail.com

OBJECTIVES

- To look for an opportunity in a reputed company which will help develop my knowledge and skills in engineering and meet the demands of the company.

- To utilize my technical skills for achieving the target and developing the best performance in the organization.

- To implement my innovative ideas, skills and creativity for accomplishing the projects.

PERSONAL SKILLS

- Able to work with limited supervision.
- Ability to balance workloads efficiently. Analytical, and able to work in a constantly changing work environment. Able to learn programs and process quickly.
- Ability to maintain of confidentially in handling sensitive information
- Time Management
- Basic knowledge: Microsoft Office, Java, Python, and MATLab
- Team player

PERSONAL INFORMATION

Date of Birth	:	February 10, 1997
Age	:	21 years old
Gender	:	Male
Height	:	5'6
Weight	:	50 Kg
Religion	:	Roman Catholic
Civil Status	:	Single
Citizenship	:	Filipino

EDUCATIONAL ATTAINMENT

TERTIARY	**:**	TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES Bachelor of Science in Electronics Engineering (BSECE) Ayala Blvd. Ermita, Manila AY: 2013-Present
SECONDARY	**:**	MAKATI HIGH SCHOOL Gen. Luna Street, Bgy. Poblacion, Makati City SY: 2010-2013
		PAROCHIAL SCHOOL OF CATANAUAN Bgy. 7, Catanauan, Quezon Province SY: 2009-2010
PRIMARY	**:**	CATANAUAN CENTRAL SCHOOL Bgy. 9, Catanauan, Quezon Province SY: 2006-2009
		MAKATI ELEMENTARY SCHOOL Gen. Luna Street, Bgy. Poblacion, Makati City SY: 2003-2006

Affiliation

December 2014-Present	**Organization of Electronics and Communication Engineering Students (OECES)** Member College of Engineering Technological University of the Philippines Ayala Boulevard, Ermita, Manila
December 2015-2016	**Institute of Electronics and Communication Engineer in the Philippines (IECEP)** Member College of Engineering 2nd Flr. Unit 2 CMC Bldg., 710 San Marcelino St, Ermita, Manila City, Metro Manila

July 2017- Present | **ECE Quizzers Society**
Member
College of Engineering
Technological University of the Philippines
Ayala Boulevard, Ermita, Manila

CHARACTER REFERENCES

Engr. Lean Karlo S. Tolentino
ECE Department Head
Technological University of the Philippines
+639161243835

Engr. August C. Thio-ac
ECE Faculty
Technological University of the Philippines
+639338684698

I hereby certify that the above information is true and correct to the best of my knowledge and ability.

PANGILINAN, RHONBERT JONATHAN G.
Applicant's Signature

PELON, JOHN MICHAEL C.
#1085 DM Compound Heroes Del.97 Caloocan City
Contact No.: 09172000662
Email Address: jimjim.pelon@yahoo.com

OBJECTIVES

- To utilize my technical skills for achieving the target and developing the best performance in the organization.
- I am looking for an opportunity in a reputed organization which will help me deliver my best and upgrade my skills in engineering and meet the demands of the organization.
- To implement my innovative ideas, skills and creativity for accomplishing the projects.

PERSONAL SKILLS

- Experience working in a corporate environment.
- Able to work with limited supervision.
- Ability to balance workloads efficiently. Analytical, and able to work in a constantly changing work environment. Able to learn programs and process quickly.
- Ability to maintain of confidentially in handling sensitive information
- Time Management
- Basic knowledge: C#, Java, Python, and Matlab

PERSONAL INFORMATION

Date of Birth	:	September 18, 1997
Age	:	20 years old
Gender	:	Male
Height	:	5'8
Weight	:	209.439 lbs
Religion	:	Roman Catholic
Civil Status	:	Single
Citizenship	:	Filipino

EDUCATIONAL ATTAINMENT

TERTIARY **:** TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES
Bachelor of Science in Electronics Engineering (BSECE)
Ayala Blvd. Ermita, Manila
AY: 2016-Present

TERTIARY **:** TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES
Electronics and Communication Engineering Technology (ECET)
Ayala Blvd. Ermita, Manila
AY: 2013-2016

SECONDARY **:** CALOOCAN HIGH SCHOOL
F.Roxas, Grace Park West, Caloocan, Metro Manila
SY: 2009-2013

PRIMARY **:** GOMBURZA ELEMENTARY SCHOOL
100 Samson Rd, Caloocan, 1400 Metro Manila
SY: 2007-2009

PRIMARY **:** GENERAL VICENTE LIM ELEMENTARY SCHOOL
J.P. Rizal St, Tondo 106, Manila, 1012 Metro Manila
SY: 2003-2007

Affiliation

December 2016-Present **Organization of Electronics and Communication Engineering Students (OECES)**
Member
College of Engineering
Technological University of the Philippines

December 2015-2016 **Institute of Electronics and Communication Engineer in the Philippines (IECEP)**
Member
College of Engineering
2nd Flr. Unit 2 CMC Bldg., 710 San Marcelino St, Ermita, Manila City, Metro Manila

June 2016-Present | **Youth For Christ (YFC)**
Member
West-A Cluster 4 YFC (St. Gabriel Chapter)
Technological University of the Philippines
Araneta Ave, Southern Caloocan City, Caloocan, 1400 Metro Manila

SEMINARS

January 2015 | Papal Visit 2015
Parish Youth Ministry
El Shaddai International House of Prayer
Amvel Business Park, Ninoy Aquino Ave, Parañaque

September 2015 | 143 Emergency Response
Red Cross Youth- Manila Chapter
Technological University of the Philippines

January 2016 | Jesus and Me (JAM) Formation
St. Francis Xavier Parish
Maligaya Park Subd. Quezon City

CHARACTER REFERENCES

Engr. August C. Thio-Ac
Electronics Engineering Department, Faculty
Technological University of the Philippines
63933-868-4698

Engr. Lean Karlo S. Tolentino
Electronics Engineering Department Head
Technological University of the Philippines
+63958-925-845

I hereby certify that the above information is true and correct to the best of my knowledge and ability.

John Michael C. Pelon
Applicant's Signature

REYES, RUSSELL JOHN E.
#913 Russell Reyes St. Sampaloc, Manila
Contact No.: 639972810463
Email Address: reyesrusselljohn@gmai.com

OBJECTIVES

- To implement my known technical skills in the field of electronics and to improve it with the help of the company.
- To look for an opportunity in a reputed company which will help develop my knowledge and skills in engineering and meet the demands of the company.
- To seek a position in a company that will help my personality to adapt to different circumstances that I might face when I'm working full time.

SKILLS

- Experience working in a corporate environment.
- Able to adapt on different things with the supervision of a supervisor.
- Able to work with limited supervision.
- Can work with an interdisciplinary team.
- Able to use critical thinking to aid in decision - making.
- Able to learn programs and process quickly.
- Basic knowledge in different programming language such as C#, Java, Python, and MATLab
- Well rounded to use the Microsoft office such as Microsoft Word and Microsoft Excel

PERSONAL INFORMATION

Date of Birth	:	September 16, 1996
Age	:	21 years old
Gender	:	Male
Height	:	5'1
Weight	:	55 kgs.
Religion	:	Aglipayan
Civil Status	:	Single
Citizenship	:	Filipino

EDUCATIONAL ATTAINMENT

TERTIARY	**:**	TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES Bachelor of Science in Electronics Engineering (BSECE) Ayala Blvd. Ermita, Manila AY: 2016-Present
TERTIARY	**:**	TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES Electronics and Communication Engineering Technology (ECET) Ayala Blvd. Ermita, Manila AY: 2013-2016
SECONDARY	**:**	LUZON TECHNICAL INSTITUTE San Antonio, Zambales SY: 2009-2013
PRIMARY	**:**	SAN ANTONIO CENTRAL ELEMENTARY SCHOOL San Antonio, Zamabales SY: 2003-2009

AFFILIATION

December 2015-Present	**Organization of Electronics and Communication Engineering Students (OECES)** Member College of Engineering Technological University of the Philippines
December 2015-2016	**Institute of Electronics and Communication Engineer in the Philippines (IECEP)** Member College of Engineering 2nd Flr. Unit 2 CMC Bldg., 710 San Marcelino St, Ermita, Manila City, Metro Manila

WORK EXPERIENCE

November – March 2016 **SAMSUNG ELECTRO-MECHANICS PHILIPPINES (SEMPHIL)**
Intern
Spare parts inspector and technician training facilitator

CHARACTER REFERENCES

Engr. August C. Thio-Ac
Electronics Engineering Department, Faculty
Technological University of the Philippines
+63933-868-4698

Engr. Lean Karlo S. Tolentino
Electronics Engineering Department Head
Technological University of the Philippines
+63958-925-845

Carlito Navales
Assistant Principal
Luzon Technical Institute
+63946-587-9209

I hereby certify that the above information is true and correct to the best of my knowledge and ability.

Russell John E. Reyes
Applicant's Signature

SANTOS, ALFREDO JR A.
#13 R. Baetiong Drive, Balintawak Quezon City
Contact No.: 09984971954
Email Address: alsanjr15@gmail.co

OBJECTIVE

To obtain a challenging work opportunity that would help me to utilize my engineering skills and knowledge, to acquire new abilities and to efficiently use my capabilities for the growth of the organization and build my professional career.

PERSONAL SKILLS

- Able to work with limited supervision.
- Ability to balance workloads efficiently. Analytical, and able to work in a constantly changing work environment. Able to learn programs and process quickly.
- Ability to maintain of confidentially in handling sensitive information
- Time Management
- Basic knowledge: C#, Java, Python, and Matlab
- Teamplayer

PERSONAL INFORMATION

Date of Birth	:	May 22, 1998
Age	:	19 years old
Gender	:	Male
Height	:	5’5
Weight	:	73 Kg
Religion	:	Roman Catholic
Civil Status	:	Single
Citizenship	:	Filipino

CERTIFICATION

MAY 28 2018 **IT PASSPORT CERTIFICATION**
Philippines National IT Standards Foundation

EDUCATIONAL ATTAINMENT

TERTIARY : TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES
Bachelor of Science in Electronics Engineering (BSECE)
Ayala Blvd. Ermita, Manila
AY: 2014-Present

SECONDARY : RAMON MAGSAYSAY (CUBAO) HIGH SCHOOL
Ermin Garcia St. co Edsa Cubao, Quezon City
AY:2010-2014

PRIMARY : SAN FRANCISCO ELEMENTARY SCHOOL
117 San Pedro Bautista St. SFDM Quezon
City 2004-2010

Affiliation

December 2014-Present **Organization of Electronics and Communication Engineering Students (OECES)**
Member
College of Engineering
Technological University of the Philippines

December 2015-2016 **Institute of Electronics and Communication Engineer in the Philippines (IECEP)**
Member
College of Engineering
2nd Flr. Unit 2 CMC Bldg., 710 San Marcelino St, Ermita, Manila City, Metro Manila

June 2016-Present **Department of Science and Technology – Science Education Institute**
Junior Level Scholar
Gen. Santos Avenue Bicutan, Taguig City Metro Manila

SEMINARS ATTENDED

NOVEMBER 24, 2018 — **"ACROSS BORDERS: ELECTRONICS ENGINEERING IN THE PHILIPPINES AND THE ASEAN ECONOMIC COMMUNITY"**
National University
Multipurpose Hall, National University Annex Building,
Sampaloc, Manila, Philippines

NOVEMBER 27, 2018 — **"SYNCHRONIZE BRIDGING COMPETENT STUDENTS TO THE COMPETITIVE WORLD"**
Technological University of Philippines – Manila Campus
Ayala Blvd., San Marcelino St., Ermita, Manila

CHARACTER REFERENCES

Engr. Lean Karlo S. Tolentino
ECE Department Head
Technological University of the Philippines
+639161243835

Engr. August C. Thio-ac
ECE Faculty
Technological University of the Philippines
+639338684698

I hereby certify that the above information is true and correct to the best of my knowledge and ability.

Santos, Alfredo Jr A.
Applicant's Signature