CharGo Electric Bicycle System

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Submitted to the College of Engineering
in partial fulfillment of the requirements for the
Bachelor degree in Mechatronics Engineering

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Palestine Polytechnic University
Collage of Engineering and Technology
Mechanical Engineering Department
Hebron - Palestine

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Abstract

The project aims to design and build a device “Called CharGO” that can be connected to bicycles and electrical bicycle, so that it is able to generate energy through the movement of the bike. CharGO uses the movement of the bike and convert the kinetic energy to electric energy, the resulting energy of the generator is saved in a lithium-ion battery. When installing the device on an electric bike, the system charges the bike battery from the battery in the device, and also can benefit the driver from this battery in charging phones and laptops etc.

The CharGO system consists of two modes: manual and automatic. The manual mode is activated by the driver when he wants to practice sport by moving the pedals, where he can choose the charging rate as he wants. The automatic mode is activated when the bicycle speed is suitable in a way that increases the speed of charging. The aim of this project is to build and implement first charging intelligent system at bicycle at Palestine Polytechnic University.

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Introduction

1.1 Introduction

A bicycle is pedal-driven, single-track, and has two wheels attached to a frame, one behind the other. Bicycles were introduced in the late 19th century in Europe, and by the early 21st century, more than 1 billion bicycles were already on the streets. These numbers far exceed the number of cars in total models produced.

Normal and electric Bicycles are considered suitable for those who do not travel fast and are ideal for children and aged people. However, the main problem of an electric bike is the short driving range. Therefore, how to generate and store the electricity more efficiently is an issue worthy of investigation, mainly to increase the driving range and to rely on an environmentally-friendly energy source.

In this project, we work on a solution to the issue of short driving range and limited use of bicycles, so that new system design is provided to charge the bike battery while driving. It is called "CharGO", and it is built considering the following:

1) Adding an intelligent system that contains a generator, sensors, and a controller to generate electricity when the bike is going down on an inclined slope.

2) Using the power of the driver's leg pushing the pedal, which in turn drives the generator to generate energy.
In this context, the system was designed to be added to any bicycle easily. See Figure 1.1.

Figure 1.1: The CharGO system connected to the electric bicycle

1.2 Project Importance

The importance of self-charging of the electric bicycle is due to the following features and characteristics:

● Taking advantage of the movement of the bike by using the untapped energy in bicycles to charge the battery.

● Saving the charging time.

● This system will increase people's interest in electric bicycles and will, therefore, make them more popular than cars and motorcycles that pollute the environment.

● The CharGO system creates a new future for electric bikes, in terms of "self-sufficiency" because there is no need for an external charging source so that the driver does not need to stop and search about electricity to charge the bike. In addition, the intelligent systems can control bicycles in terms of charging rate, the speed of the bike, and they can maintain the balance of the bike. All of these can be achieved by adding a CharGO system.

1.3 Project Objectives and Specifications

The idea of the CharGO project is to design a system that can be attached to the electric bike and be removed easily. The system will charge the electric bike battery with an electric voltage by transforming the movement energy into electric energy through the movement of the bike wheel itself.

CharGO is a system that consists of a generator that generates an electric signal that feeds the bike battery more efficiently than charging the battery from an external electric source. The objectives of the CharGO project are summarized as follows:

1. Charging the electric bike battery instead of using an electrical source.

2. Taking advantage of the electric bicycle movement to generate energy.

3. It is also possible to generate energy in CharGO system by using the pedals of the bike when the driver wants to exercise sport cycling.

4. The CharGO system controls the charging rate of the battery based on the velocity of the bike. If the speed of the bike is not enough to generate power from the generator, the system will be automatically deactivated.

5. CharGO system can be removed from the electric bike easily upon arriving at the house or other places. To keep it from theft or tampering, it is an independent bike device. The size is small; thus, it can be easily carried, and it contains a battery able to charge the phone.

The main objective is to provide an efficient charging source for battery by using both the bike wheel motion and the pedaling motion. This will be done using the proposed CharGO, which consists of the following:

- **Bike motion and electricity generation:**

In the CharGO system, there are two sensors, one is for speed measurement and the other is for inspecting whether the bike is being driven in a downward angle or not. The function of these sensors is to send a signal to the control system about the angle and speed of the bike, then control whether to activate the CharGO to the wheel or not.

- **Generating electricity using the driver's hand motion:**

This mode is activated when the driver selects from the three options which activate the CharGO system to start charging according to the degree of the driver's power on the pedals.

1.4 Literature Review

This section presents the most important papers published in IEEE/ASME documents on Mechatronics about this subject. And will present them in terms of designing, applying, function specification and equipment used in each work [12].

1.4.1 Design and Development of Solar Hybrid Bicycle

The hybrid bike relies on the addition of solar cells that produce enough energy to charge the battery, and there is a generator that generates electricity with enough power to charge the battery through the movement of pedals produced by the driver [1]. See Figure 1.2 for design concept.

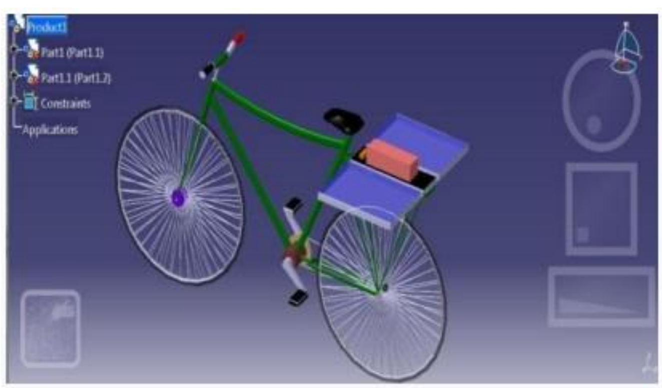

Figure 1.2: CAD model for solar bicycle

1.4.2 Design and Implementation of a Regenerative Braking System for Electric Bicycles Based on a digital signal processor DSP

In this project, the proposed kinetic energy is converted into electric energy and stored in batteries in case of braking. This project is based on a digital signal processor and a brushless DC motor; when the driver uses the breaks of the bicycle, the processor converts the DC brushless motor from the motor mode to the generator mode to charge the battery [2].

1.4.3 Alternator Charging System for Electric Motorcycles

This project deals with the use of the rotational energy of the wheels to convert it back to the batteries. It transfers the rotational energy from wheels using the chain sprockets installed in the back wheel of the bicycle to the alternator generator [4]. See Figure 1.3.

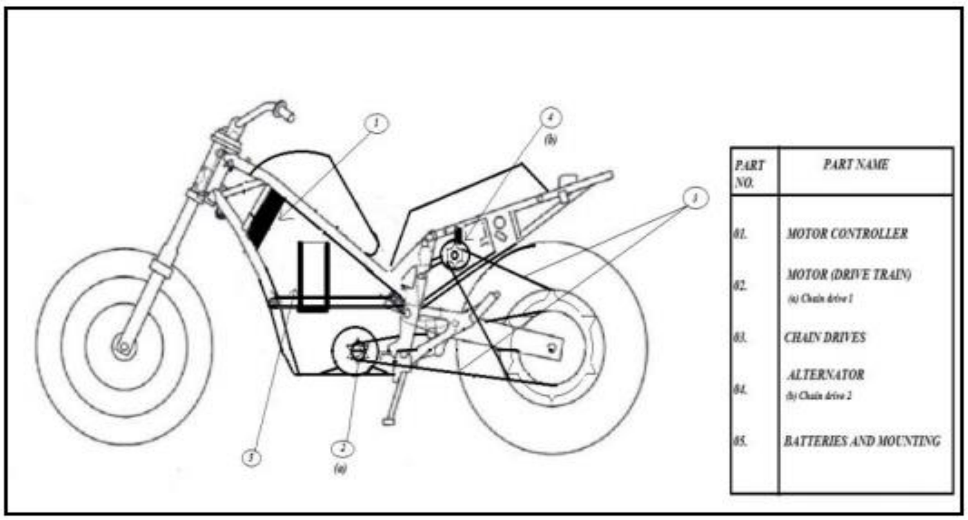

Figure 1.3: Electric motorcycle

1.4.4 Bilateral control of SeNZA—A series hybrid electric bicycle

This paper presents the design and control of SeNZA: a series hybrid bicycle. The bicycle is characterized by the lack of a mechanical transmission; the powertrain is composed of a generator connected to the pedals, a battery pack, and a traction motor [3].

1.5 Alternative Design

It can be seen from the literature review and existing solutions, that the existing method of energy generation from bicycles does not fit with the current situation in society. So, there is a need of designing an intelligent system to take advantage of the movement of the electric bike to recharge the battery with high efficiency which, normally, depends on the speed of the bicycle, road situation and user selection.

In this section, there is a list of alternative designs that are suggested to help to solve the problem. These ideas are results of questions, brainstorming and YouTube watching. In order to get clients a design that gives the highest charge efficiency, the following ideas should be taken into consideration

1.5.1 Charging Using the Front Wheel of the Bicycle

The concept of this idea is implemented in Figure 1.4. The energy is generated by adding generators to the front wheel of the bike which is designed to generate electric current to charge the electric bicycle battery. It consists of the following:

● Two generators of type "WindZilla 12V/24V DC Permanent Magnet Motor Generator for Wind Turbine PMA". See Figure 1.5.

● PWM charge controller. See Figure 1.6.

● Bicycle wheel size 26" or 66 cm.

Figure 1.4: Front wheel

Figure 1.5: "WindZilla 12V/24V DC permanent magnet motor generator for wind turbine PMA"

Figure 1.6: PWM charge controller

1.6 Proposed Design

Based on the brainstorming and alternative designs, it is proposed that the existing solutions do not meet the needs so a new design has been created. the design idea was taken from "Rubbee Device" see Figure 1.7. Its mechanical frame is going to be used. In addition, the idea will be improved to meet the project needs [6].

Figure 1.7: Rubbee device

Charging Using Solar Hybrid Bicycle This idea, as shown in Figure 1.2, uses a solar cell to take advantage of the solar energy and uses a generator that is connected with pedals. This approach provides acceptable efficiency, but it is effective in India’s sunny climate within a period of nine months [1]. This alternative does not meet our needs.

1.7 Project Outline

Depending on the Mechatronics project design by Shetty, the project distributed on these three levels, modeling/simulation, prototyping and then deployment. The first one is separated into the recognition of the need, the conceptual design, the function specification, sensors and actuator, mathematical modeling, control system design and optimizing the design. The second level is separated into the hardware in the loop simulation and optimizing designs. Finally, the third level consists of the deployment of embedded software and life cycle optimization. See Figure 1.8.

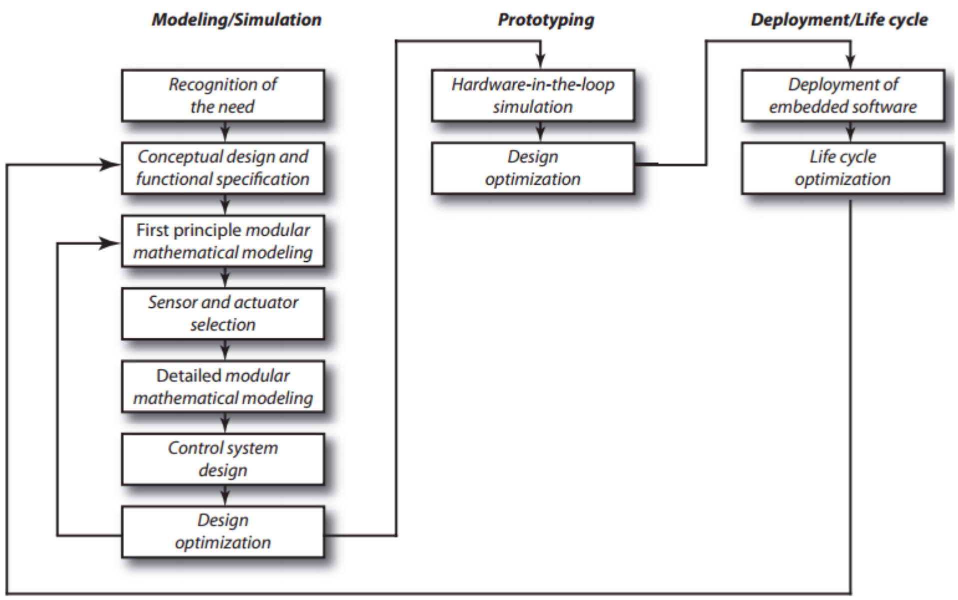

Figure 1.8: Mechatronics project design by shetty

1.8 Project Schedule and Time Plan

- **Task 1: Selecting the idea.**

Determine the project's idea, motivation, and what to be done in the project.

- **Task 2: Collecting data**

Look for open-source design files, understanding the concept of the design, and then collect information.

- **Task 3: Selecting the mechanical and electrical parts.**

In this step, the required components (hardware and software) and their costs should be calculated and provided.

- **Task 4: Dynamic modeling.**

A mathematical model that describes the system motion should be done at this stage.

- **Task 5**: **Documentation.**

Documenting all work steps from the first to last.

- **Task 6: Design and assembly.**

Start designing the modules, and then assemble the parts.

- **Task 7: Testing and calibration.**

Each module by itself, then for the whole collected design.

- **Task 8: Implementation and validation.**

By reaching this step, the design is completely assembled, and it should be implemented and verified.

- **Task 9: Code improvement.**

After the machine works well, try to develop the code.

- **Task 10: Writing a final graduation report.**

Write notes and make any necessary addition and modification for the project documentation.

- **Task 11: Preparing the final presentation.**

Finally, you should be ready for the project discussion day.

First Semester:

Table 1: First semester time plane

Week / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
T1																
T2																
T3																
T4																
T5																

Second Semester:

Table 2: Second semester time plane

Week / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
T6																
T7																
T8																
T9																
T10																
T11																

1.9 Final Approximate Cost

Table 3: Cost table

Name	Number	Price	Total Price (NIS)
Generator	1	100	100
Timing Belt	1	40	40
Base of prototype	1	50	50
Bicycle	1	550	550
Plastic Frame	7	10	70
Timing Pulley	2	50	100
CNC aluminum	-	-	150
Battery	1	120	120
Aluminum material	1	50	50
Electrics component	6	10	160
Screws	-	10	10
CNC Plastic	-	-	100

Total cost=1500 NIS

Chapter 2

Mechatronics Design Approach

2.1 Introduction

This section describes the CharGO device workflow, including the system components, parts functions and relations among elements.

CharGO system is a device that can be plugged easily with different types of bicycles. It converts the bicycle to a chargeable one able to charge phone, electric bike battery and other applications. It has a smart system contains a microcontroller, speed sensor, angle sensor. Figure 2.1 shows the features of the CharGO system.

Figure 2.1: The features of the CharGO system

2.2 Conceptual Design

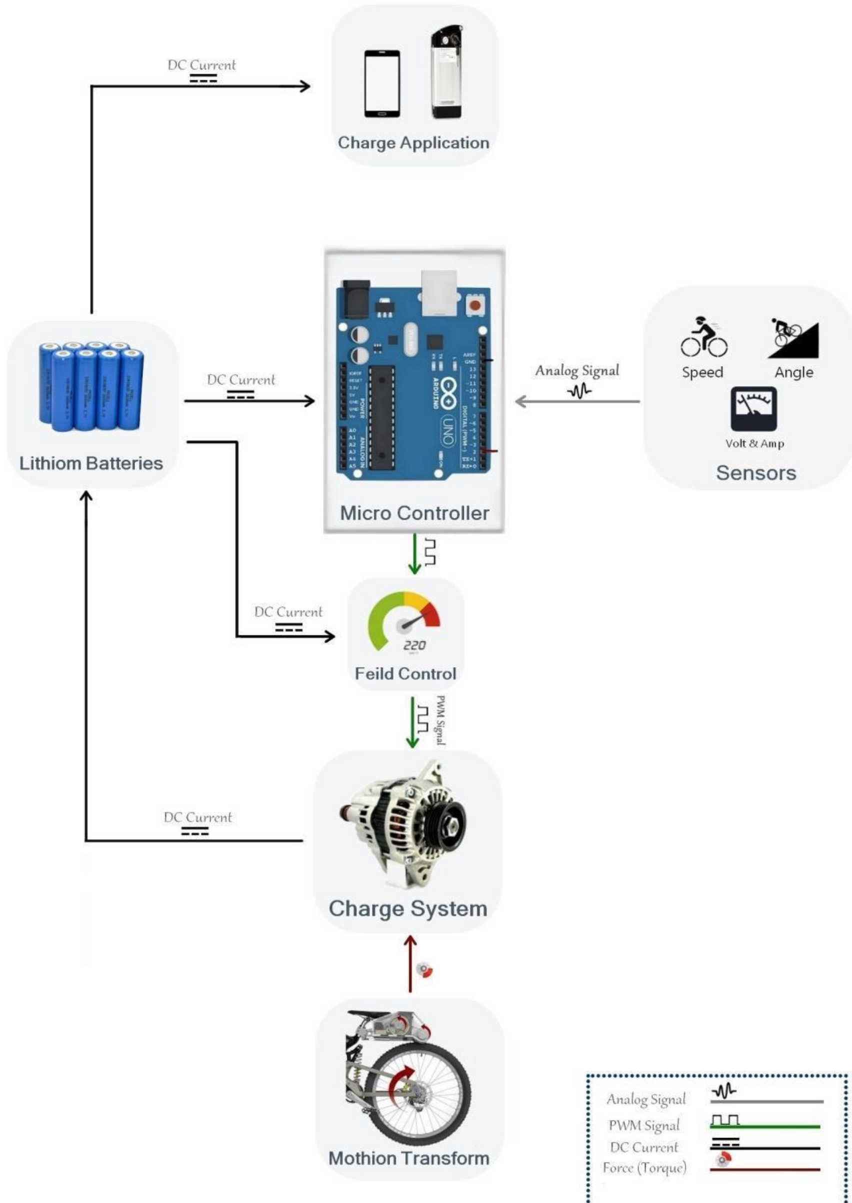

Figure 2.2: The main three part in system.

Figure 2.2 shows the main parts of CharGO system and the type of relation between the parts.

2.3 CharGO System Component

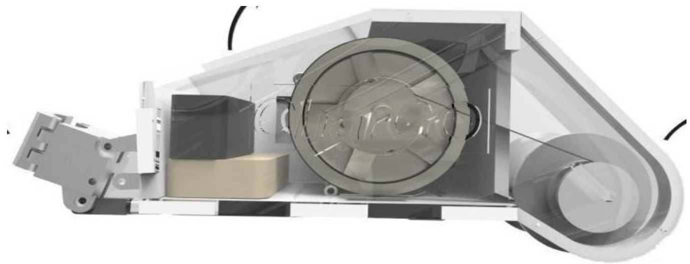

Figure 2.3: The system part.

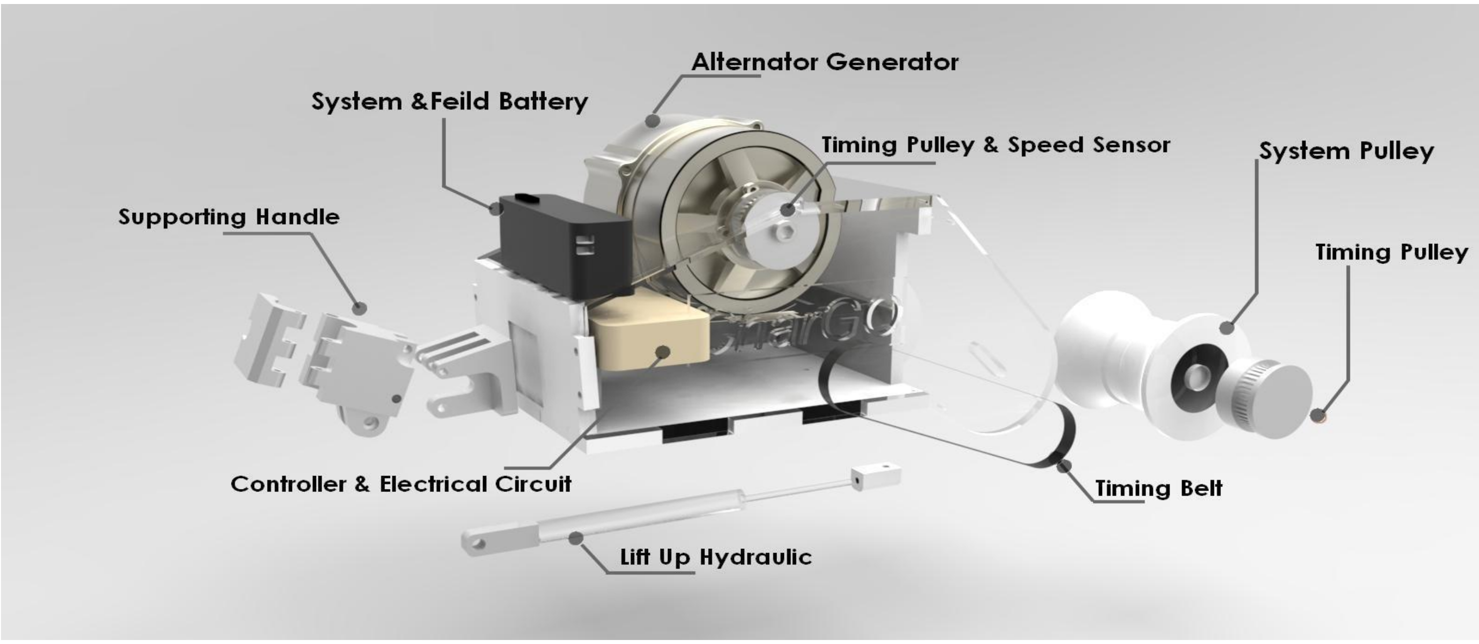

Figure 2.4: The parts of the CharGO device

This Figure 2.4 shows all the parts and locations of the parts that make the CharGO device with the names of these parts.

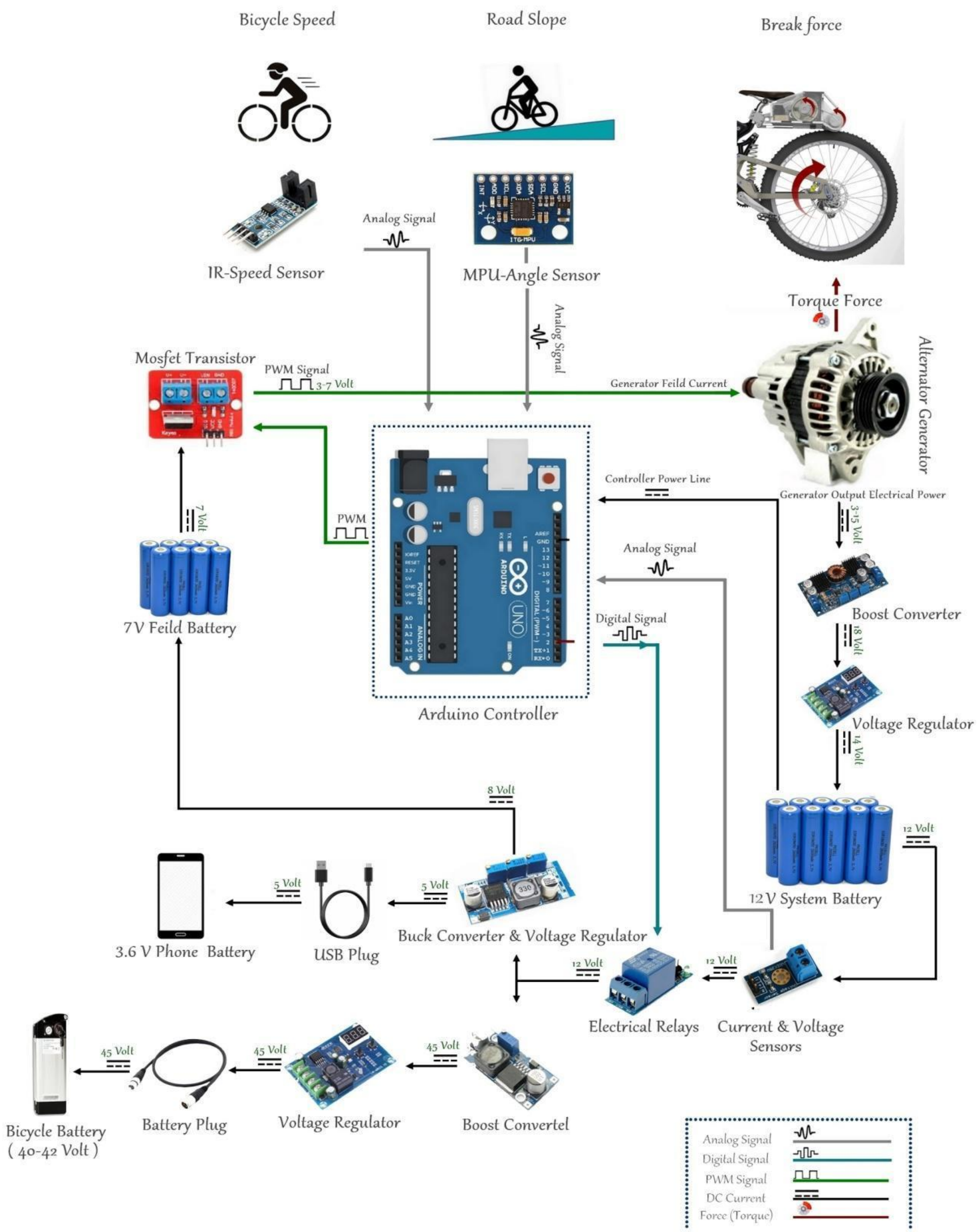

Figure 2.5: Electrical parts of CharGO system

Figure 2.5 shows all electrical parts of CharGO system and the type of relation between the parts.

2.4 Motion Transformer Part:

The main purpose of this part is to transfer the rotational motion from a bicycle pedal to the generator into CharGO system, this process is done by four steps shown in (Figure 2.6).

1: Bicycle paddle rotation.

2: Wheel rotation

3: System pulley rotation.

4: System generator rotation.

In CharGO system, the purpose is transforming the bicycle wheel rotation to the generator to charge a battery by using pulley and timing pulley system as shown in Figure 2.6, step three. Figure 2.7, shows the motion transform part in CharGO system

Figure 2.6: The steps to transfer rotational force from paddle to generator.

Figure 2.7: The mechanical part inside CharGO device

2.4.1 System Pulley

Akulon Was selected to transfer the kinetic energy from the wheel to CharGO device, it is characterized by temperature tolerance, load, and ease to form [Appendix B]. Then being plugged in system generator by using timing belt with pulley with high efficiency up to 98% as shown in Figure 2.8 and Figure 2.9. The system pulley is designed to fit most types of tires bike, to convert rotational force from the bike.

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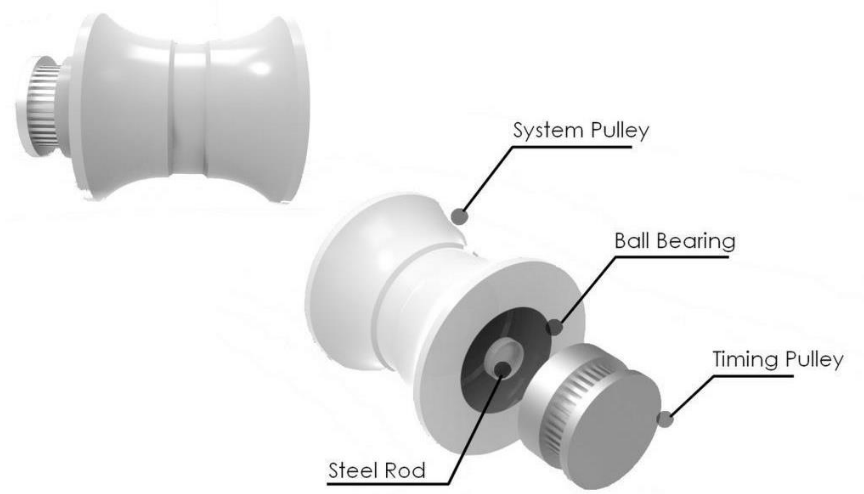


Figure 2.8: The system pulley design.

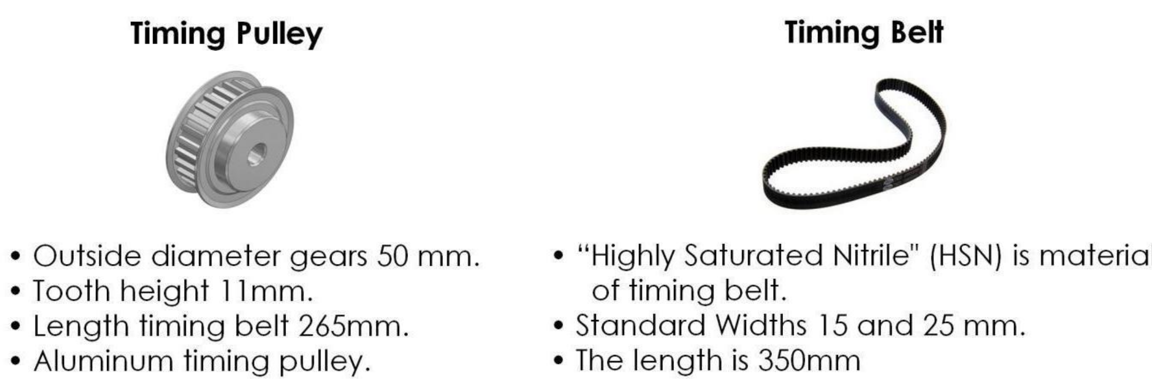


Figure 2.9: The time pulley and belt specification.

2.5 Electrical Components and Battery

As shown in Figure 2.5, CharGO system had many electrical components placed on one wood case shown in Figure 2.10 to make a system more useful and maintainable.

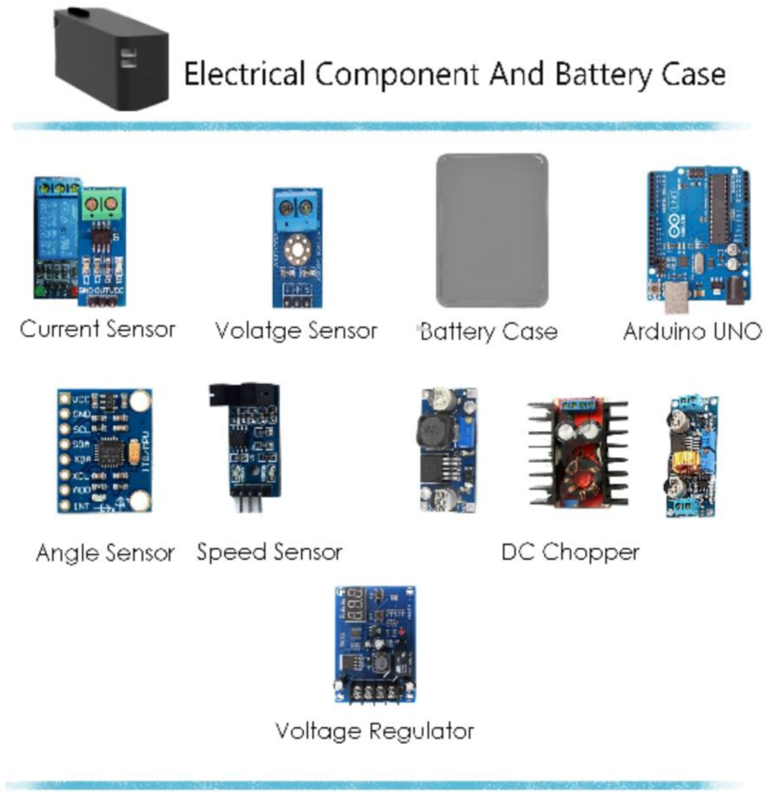


Figure 2.10: Electrical component and battery case

2.6 Supporting Handle

Supporting Handle is the mechanism used to install the CharGO device on the seat post of the bicycle as shown in Figure 2.11. The Seat post should be between 22mm and 35mm in diameter, that’s most of the standard seat tubes.

Figure 2.11: The supporting handle

2.7 CharGO Frame

The plastic frame is designed to be like the LEGO game for easy installation, so there is a possibility to open the device easily for maintenance as Shown in Figure 2.12 and Figure 2.13.

Figure 2.12: Assemble of CharGO device

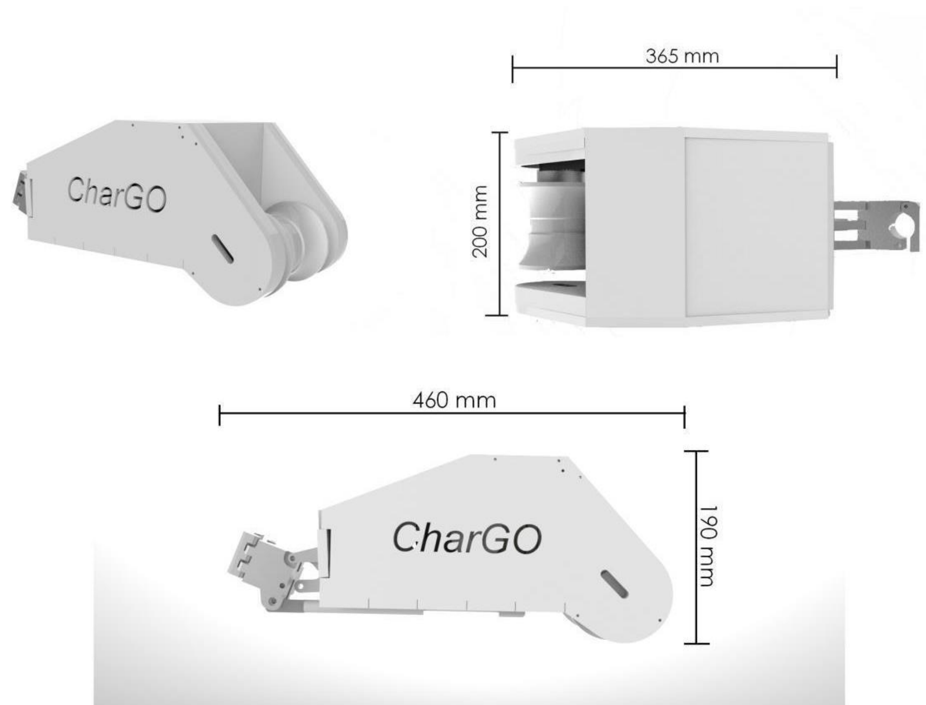


Figure 2.13: Dimension of CharGO device

2.8 Operating Modes

CharGO device provides two modes of operation selected by the driver.

2.8.1 Automatic Mode

When the device turned on. CharGO system starts charging battery automatically without any human interaction. The smart system in CharGO work depends on the working of the angle sensor and speed sensor to apply a braking system to charge a battery.

2.8.2 Manual Mode

When the driver wants to exercise through the bicycle pedal. He can select the level of a pedal for an in turn charge the battery.

2.9 Mathematical Model

This section explains the mathematical calculation for CharGO system to find the amount of torque produced by the bicycle and driver to select the useful generator for the system.

CharGO Dynamic Model

In this section, talking about deriving the dynamic model for system CharGO to study the efficiency, ability, and choice of the system based on the mathematical model.

First, start by finding torque that can humans apply on a bicycle pedal, then calculating the value of the transformed torque to the generator starting from Figure 2.14.

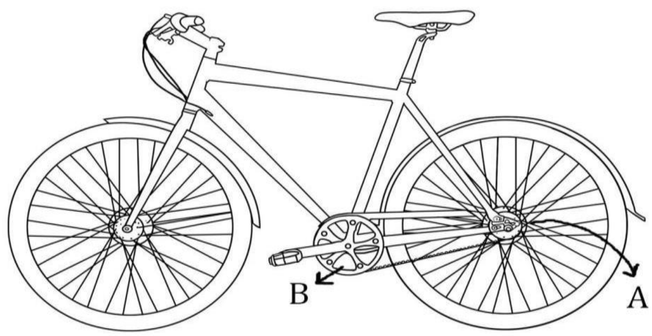


Figure 2.14: Normal bicycle section: A. Rear sprocket، B. Front sprocket

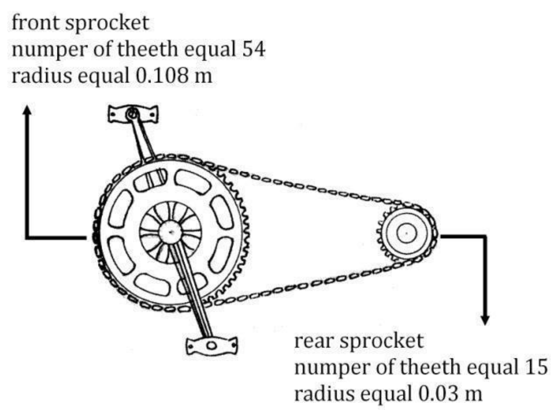


Figure 2.15: Dimension of front sprocket, and rear sprocket

Step1: Calculate pedaling torque produced by the driver:

Step1, calculating the energy generated by the driver from moving the pedals at 10 km/hour (linear velocity that is assumed in the model) to calculate the transformed torque produced from pedal to the rear sprocket then to the wheel and finally to the generator, see in Figure 2.16.

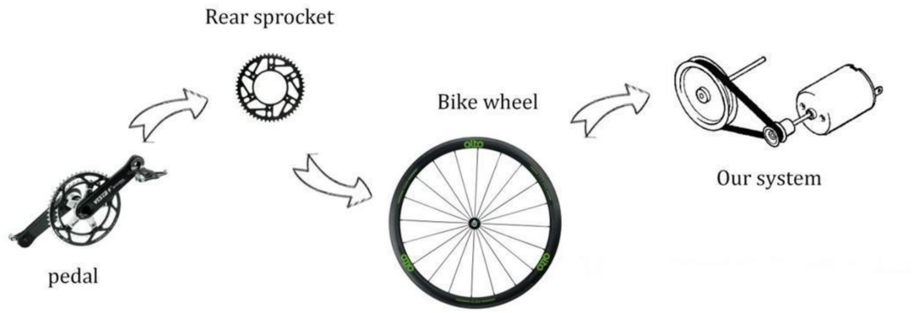


Figure 2.16: Transmission of movement from the wheels to generator

The torque (T) from the pedal is expressed as:

$$T_{Pedal} = \frac{P_{human}}{w_{pedal}} \quad (1)$$

When P_{human}: human applied power (watt), w_{pedal}: pedal angel velocity (rad/sec)

In order to know the value of T_{pedal} , poth P_{human} and w_{pedal} has to be known considering that the linear velocity is 10km/h as a design specification, and the rear wheel has a reading of 0.34 m then the angular velocity of the rear wheel.

$$w_{RW} = \frac{v_{linear}}{R_{RW}} \quad (2)$$

When w_{RW}: Rear Wheel angular velocity (rad/sec), v_{linear}: linear velocity (m/s), R_{RW}: Rear Wheel radius (m).

$$w_{RW} = \frac{2.7}{0.34} = 8.16\ (rad/sec\ )$$

Remembering that $w_{RW} = w_{RS}$, then the rear sprocket speed v_{RS} can be calculated using w_{RS} and the radius of the wheel sprocket R_{WS} as:

$$v_{RS} = w_{RS} * \ R_{RS} \quad (3)$$

Where v_{RS}: Rear Sprocket velocity (m/s), w_{RS}: Rear Sprocket angular velocity (rad/sec), R_{RS}: Rear Sprocket radius (m).

For R_{RS}=0.03m, then v_{RS}=0.245m/s.

Which is the same speed at the front sprocket.

For v_{FS}=v_{RS}=0.245m/s, where v_{FS}: Front Sprocket velocity (m/s)

Using the value of v_{FS} and the radius of the front sprocket R_{FS}=0.108m, then the angular velocity of the front sprocket equal:

$$w_{FS} = \frac{v_{FS}}{R_{FS}} \tag{4}$$

$$w_{FS} = \frac{0.245}{0.108} = 0.268\ (rad/sec)$$

Then, w_{FS} is considered as the same as $w_{pedal.}$

The driver applied power at 100.6 watt at angular velocity at 2.268 rad/s (21.65 rpm), according to the study [9].

Then the exerted torque (T_P) for the drive is 44.35 N.m on the pedal at velocity at 10kN/h.

According to the number of teeth at the front and rear sprocket, the torque of the rear sprocket is given by:

$$T_{RS} = T_P \frac{Teeth_{RS}}{Teeth_{FS}} \tag{5}$$

$$T_{RS} = 44.35 \frac{15}{54} = 12.3 (N.m)$$

The preview value by T_{RS} has to be mapped to the generator as in Figure 2.17.

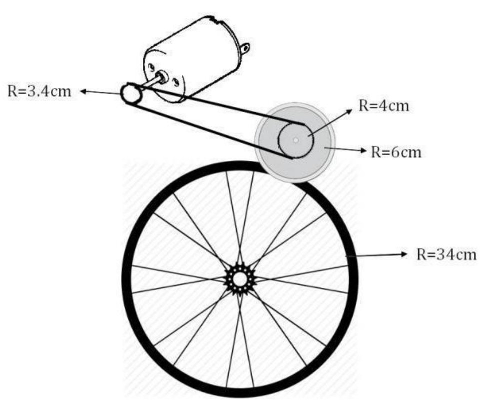


Figure 2.17: The generator connection with the wheel

The torque of wheel is 12.3N.m is transferred to pulley as shown in Figure 2.18, using a pully as in Figure 2.19.

Figure 2.18: Wheel torque transferred to roller

Figure 2.19: Pulley bearing

Assuming the average efficiency of the pulley is 87.5%, the radius of the pulley R_p=6cm and R_{RW}=0.34m, then the torque at the pulley T_p is:

$$T_p = \frac{R_p}{R_{RW}} * T_{RS} * Efficiency(\%) \quad (3)$$

Where T_p: The torque of pulley (N.m), R_p: The radius of pully (m), so T_p=1.9 N.m.

The transferred torque to generator T_g is:

$$T_g = \frac{R_g}{R_p} * T_p * Efficiency(\%) \quad (4)$$

When T_g: The torque of generator (N.m), R_g: The radius of pulley generator (m)

The torque transfer from the pedal torque is 0.4655N.m at the linear bike velocity is 10km/h.

Generator torque:

As see in Eq (4) the transferred torque to the generator is 0.4655 N.m. When activating the generator at 100% work efficiency it produces an extra load force for the driver pedaling. Assuming the extra load came from the generator.

$$\frac{4}{3} * T_{human@10\frac{km}{s}} = T_{Extra} \tag{5}$$

$$\frac{4}{3} * T_{human@10\frac{km}{s}} = \frac{4}{3} * 0.4655(N.m) = 0,62(N.m)$$

The generator must have 0.62N.m maximum torque when bike has linear velocity equal to10km/h. Now calculate maximum generator power at linear velocity (v) bike 10km/h.

$$P_g = T_g * w_g \tag{6}$$

Where P_g: The power of generator (watt), w_g: The angular velocity of the generator (rad/sec).

To find the generator power, angular velocity for the generator should be found using:

$$\frac{R_{BW}}{R_P} = \frac{w_p}{w_{BW}} \tag{7}$$

The pulley angular velocity is 92.57 rad/s, to find angular velocity from generator use:

$$\frac{R_p}{R_g} = \frac{w_g}{w_p} \tag{8}$$

The angular velocity of the generator is 1039.9rpm (108.14 rad/s). the maximum power can take it from the generator at 10km/s linear velocity is 72.77 watt.

So, the system needs the generator can out power 72.77 watt at bike velocity equal to 10km/h.

Chapter 3

Electric and Electronic Component

3.1 Introduction

This chapter introduces the design of the electrical circuits and information of all electrical components used in CharGO system. Figure 3.1 explain the five main parts, generator, sensors, charging controller, battery and microcontroller.

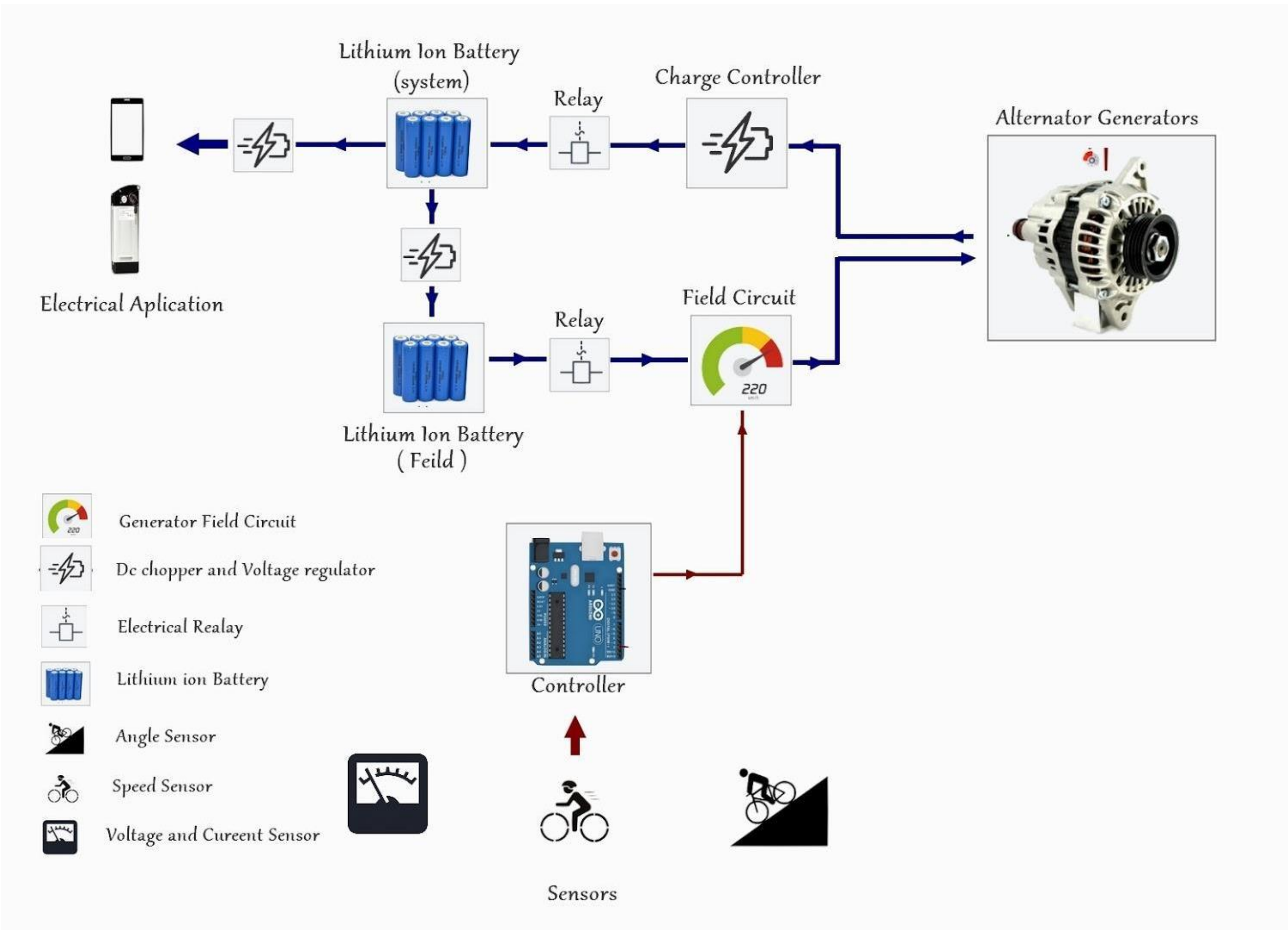


Figure 3.1: Controller system

3.2 System Components

3.2.1 Alternator Generators

Alternator Generator "is also called a synchronous generator", is an electrical generator that converts mechanical energy to electrical energy in the form of alternating current.

The Synchronous machine is used mainly for power generation. Over 97% of all electrical power generated worldwide is produced by the synchronous generator. This is due to the ability of the synchronous generator to produce ac power directly without a need for conversion, and the effective and simple control of its voltage and power flow [10]. That is an exploitation of power produced by the driver to electrical power with high efficiency

Figure 3.2: Hyundai alternator generator (TA000A55601)

All charging systems use the principle of electromagnetic induction to generate electrical power, Electromagnetic principle states that a voltage will be produced if motion between a conductor and a magnetic field occurs. The amount of voltage produced is affected by:

- The speed at which the conductor passes through the magnetic field.
- The strength of the magnetic field.
- The number of conductors passing through the magnetic field [11].

The alternator generator has a constant number of conductors.
The output voltage of the generator is proportional to the power of the bike brake.

Then it can take control of the output electrical power and system braking by changing the magnetic field.

Alternator generator contains two circuit:

- Internal Diode Rectifier Bridge (DRB)

  The Lithium batteries cannot store AC voltage [11]. For the vehicles and CharGO electrical system to be able to use the voltage and current generated in the AC generator, the AC current needs to be converted to DC current. This process is called the rectification voltage regulator Figure 3.3.

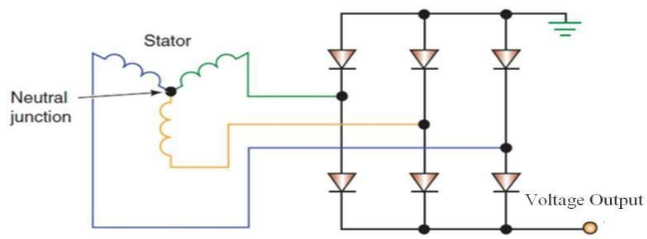


Figure 3.3: Simplified schematic of the AC generator connected to the internal diode rectifier bridge

- Internal voltage regulator

  The voltage regulator controls the amount of voltage being output by the vehicle's alternator in the car of the amount of voltage bigger than 12 volts.

  In CharGO system. It has been removed from the internal voltage regulator in the generator, to allow the use of the largest amount of energy generated by the generator when the out voltage from the generator is less than 12 volts.

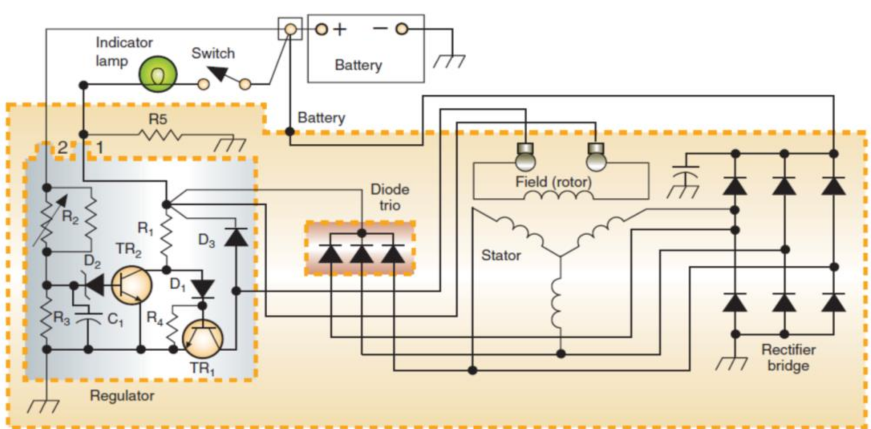


Figure 3.4: Schematic of a charging system and alternator generator in car.

In the design of the CharGO system was selected an Automotive motor alternator (HYUNDAI ALTERNATOR TA000A55601), shown in Figure 3.4. Its main specification is:

- Volts: 15V
- Current: 60A
- Weight: 4350g
- integrated regulator

3.2.2 Lithium-ion Battery

Compared with traditional battery technology, lithium-ion batteries charge faster, last longer, and have a higher power density for more battery life in a lighter package, from an electrical bicycle that's used two famous types of lithium-ion battery

- 36-volt battery.
- 48-volt battery.

In CharGO system the system is designed to charging 36 voltage of electric bike battery.
CharGO device contains two lithium ion batteries:

- System battery.
- Field battery.

The alternator generator will charge directly the (system battery). Then, the system battery charges the electric bicycle battery and field battery in the CharGO device as in Figure 3.5.

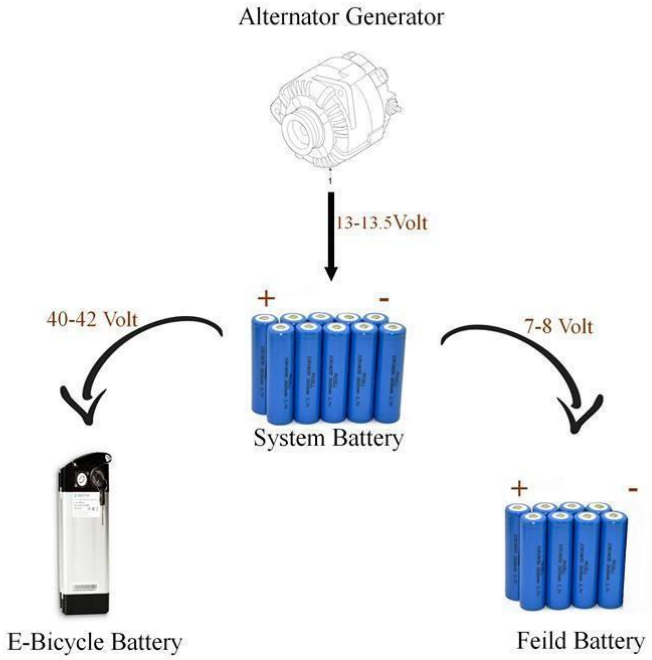


Figure 3.5: Charging process in CharGO system

E-Bicycle Battery:

Most of electrical bicycles use lithium ion battery. The basic specification of the battery that is used in CharGO:

- Voltage 36V
- Capacity 10A.h
- Working temperature 20℃-60℃
- Battery Size (mm) 390×110×75
- Weight (with all parts and package) 3.25KG
- Cut-off voltage: 45V
- Discharge cycle life: 500 times
- Max Charging voltage: 42V
- Maximum Charging Current 5000 mA

Basic characteristics for lithium ion battery /cell:

- Nominal Voltage 3.7 Volt.
- Capacity 2200mA.
- Max Charge Voltage 4.2Volatge.
- Standard Discharge Current 0.5 C. Rate.
- Rapid Discharge Current 1 C. Rate.
- Diameter 18.3mm.
- Height 56mm.

Field Battery (Primary Battery):

Field battery is used to support the field circuit in alternator generator to generate and excite the magnetic field in a generator. the same type of system battery is used to get (7.4Volt-5A.h).

3.2.3 Charging Controller

CharGO system is able to charge three batteries in different voltage and capacity, every battery must have a certain voltage value to be able to be charge. Then the charging process is needed by using a voltage regulator with different types of dc choppers like step up boost converter and step-down (buck) converter.

- **Step up Boost Converter**

Step-up switching converters also called boost switching regulators, provide a higher voltage output than the input voltage. The output voltage is regulated, as long as the power draw is within the output power specification of the circuit. CharGO system used two steps up post converts for charging.

- **Charging system battery from the generator**

The alternator generator produces a voltage between (3-15 voltage and 1-6 A) to charge a 15-volt battery. This requires 16-16.8 voltage to the battery.

Then, the system needs a step-up converter with minimum voltage 3 volt and has the ability to reserve 6 A to convert it to 18 volts to voltage regulator shown in Figure 3.6.

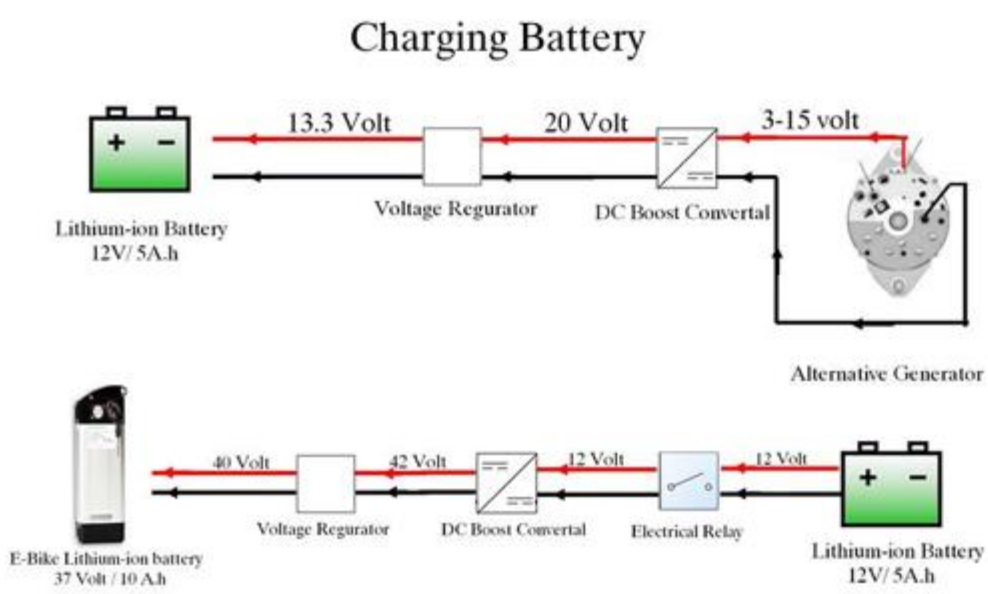


Figure 3.6: Charging process from system battery.

Voltage Regulator:

Voltage regulator controls the battery charging as in (Figure 3.7), it has:

- Model: XH-M603
- Input Voltage: DC 10-30V
- Display Precision:0.1V
- Control Precision:0.1V
- Output Type: direct output
- Voltage Tolerance: +/-0.1V
- Application Fields:12-24V storage battery
- Diminution 82mm×58mm×18mm

Figure 3.7: XH-M603 voltage regulator module

Charging field battery from system battery

CharGO system contains two batteries, primary (system battery) and secondary (field battery). The primary battery is charged at a rate 12v/5Ah, where its job is to feed the secondary battery and the battery of the bike.

To charge the secondary battery, the voltage should pass through Voltage regulator Module to converts the output voltage to rate of charge in the secondary battery 7v/5 Ah. As in (Figure 3.8)

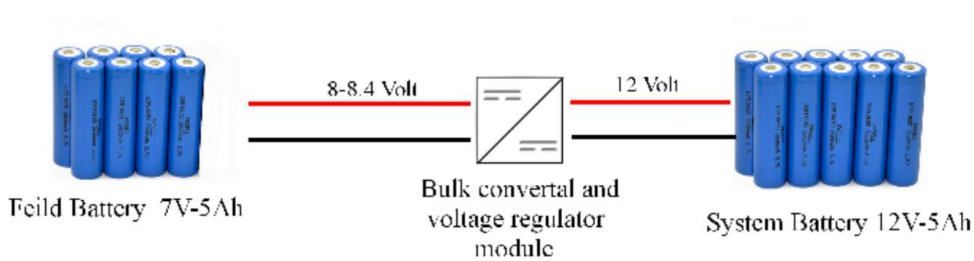


Figure 3.8: Charging process from system battery

DC Buck Converter Step Down with voltage regulator:

The details of the buck converter and the voltage regulator

- Input Telangana: DC 4-38V.
- Output Telangana: DC 1.25-36V (Adjustable).
- Output Current maximum 5A
- Output Power: 75W.
- Efficiency > 92%.
- Built in thermal shutdown function.
- Built in current limit function.
- Built in output short protection function.
- Input reverse polarity protection.
- Dimension: 61.7mm x 26.2mm x 15mm.

Charging phone battery from system battery:

Most phones have a 3.7-volt lithium-ion battery, starting charging requires 7 volts and a 2 A to get a fast charging rate.

For this percentage of charging, it is possible to use dc-dc bulk and voltage regulator from system buttery to phone battery, shown in Figure 3.9. It Can use the same type of bulk used for charge field battery.

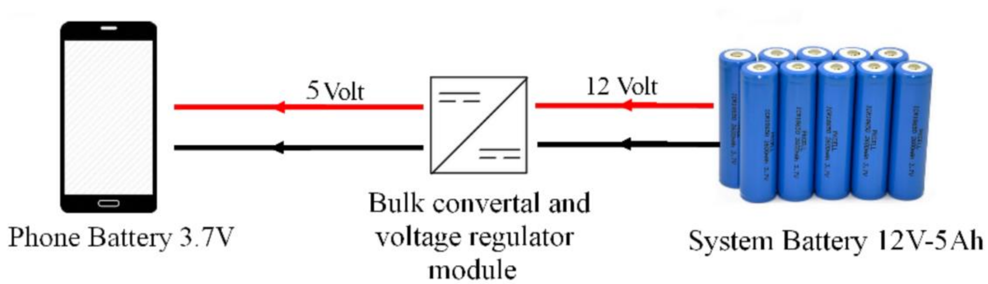


Figure 3.9: Charging phone processes

Charging electric bicycle battery from system battery:

As mentioned earlier, the primary battery is used to charge the secondary battery and the bike battery.
To charging 37 Volt lithium ion bike battery must be feed 40-42 volt to the voltage regulator. So, it needs the step-down converter with the ability to reserve 5 A and 15 volts to convert it to 40-42 volt and max 5 A. Then feed this voltage to the voltage regulator to get voltage in rate 37v/5Ah. Shown in Figure 3.10.

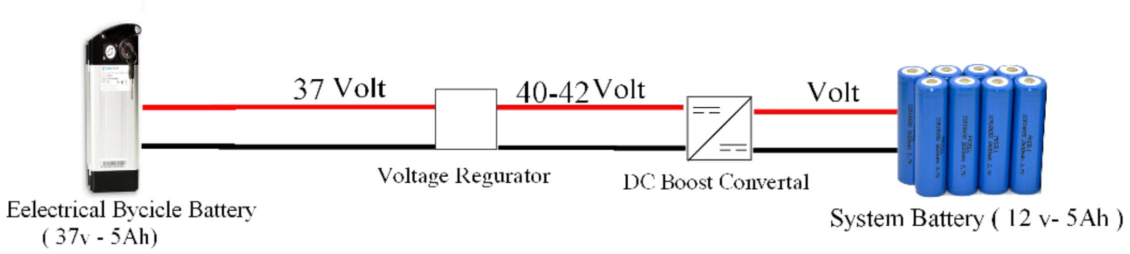


Figure 3.10: Electrical bicycle battery from system battery

Step up voltage converter:

Component Specification: see Figure 3.11

Model GK1382902
Input Range: 3.5 - 32 Volt DC.
Output Range: 5 – 46.5 Volt DC.
Max Output: 2.5 Amp.

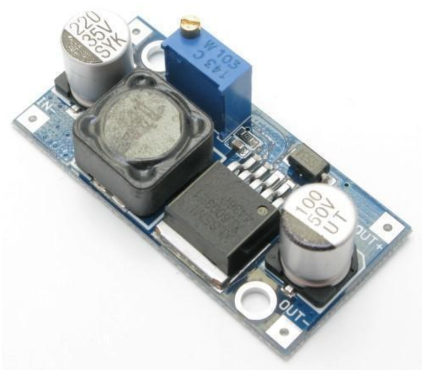


Figure 3.11: XTW-SY-8 S step-up voltage converter

3.2.4 Field Control Circuit for Generator

It is possible to control the efficiency of the system braking and amount of the output power, by changing the magnetic field. When dc current passes through the coil (1.5 to 3.0 Ampere), a magnetic field is produced. The strength of the magnetic field depends on the amount of current flowing through the coil and the number of windings. Shown in Figure 3.12.

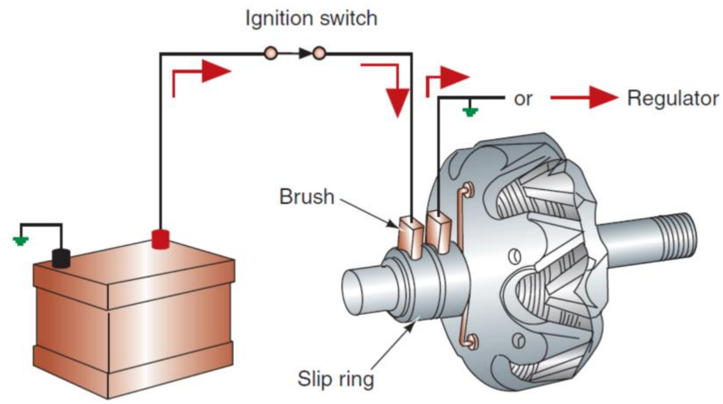


Figure 3.12: The slip rings and brushes provide a current path to rotor coil

The insulated stationary carbon brush passes field current into a slip ring, then through the field coil, and back to the other slip ring. Current then passes through a grounded stationary brush or to a voltage regulator. In the CharGO system, replace the ignition switch to the control field circuit depending on MOSFET transistor that controls field current feeder to the generator by changing the PWM duty cycle. See Figure 3.13.

Connection:

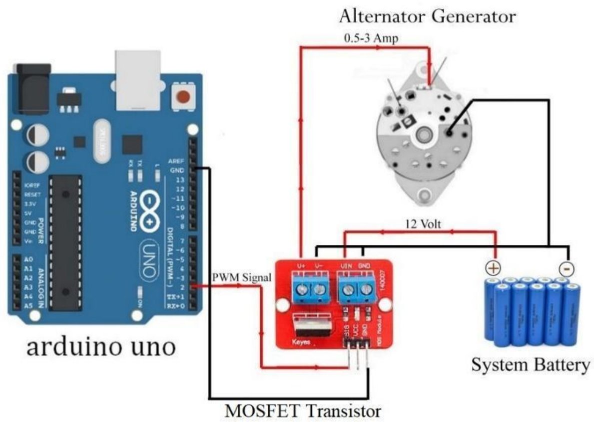


Figure 3.13: Field control circuit

3.2.4 Sensors

Speed Sensor:

Measuring the rotational speed of the generator is important in the CharGO system, because the amount of magnetic field in the generator controls the braking power of the bike depending in the speed of the bicycle, and from generator rotational the speed of bicycle was known. See Figure 3.14.

- Current: Around 15mA
- Operating voltage DC 3.3V - 5V
- Output signal: Digital switching outputs (0 and 1)
- Dimensions: 3.8 cm x 1.4 cm x 0.7 cm

Figure 3.14: Speed sensor

Used speed sensor disk has two slits as Figure 3.15
Slit per minute = (slit × 60)
Revolutions per minute = slits per minute / 2
Rpm generator = slits × 30

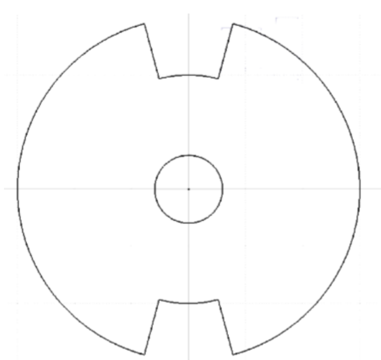


Figure 3.15: Speed sensor disk

Connection:

Figure 3.16 shows the electric circuit of the sensor connected to Arduino.

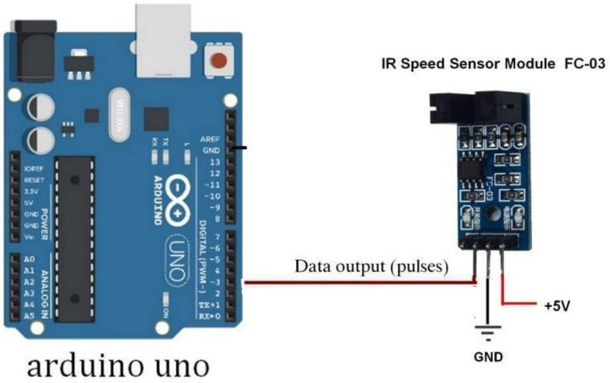


Figure 3.16: Electric circuit for the sensor connected to Arduino.

Angle sensor:

For measuring the actual pitch angle of the platform, the 3-axis accelerometer & gyroscope chip MPU6050 is installed. From pitch angle the slope the road can be known when the bicycle is used to control the magnetic field and breaking power of bicycle in the automatic situation. Shown in Figure 3.17.

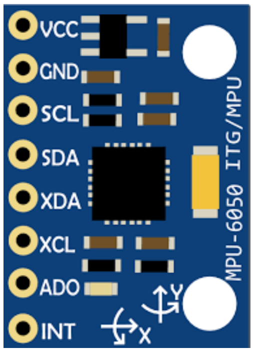


Figure 3.17: Angle sensor

- Chip: MPU-6050
- Power supply 3~5V Onboard regulator
- Interface Type I2C, SPI
- Operating Temperature Range -40°C to 85°C
- 3-Axis Gyroscope.
- 3-Axis accelerometer.

3.2.6 Voltage, Current Sensor and Electromagnetic Relay

Through these sensors, the system has the ability to read and know the value of the voltage or the value of the current by introducing it to the Arduino controller for processing, CharGO system contains two voltage sensors and one current sensor.

Voltage Sensor:

- Two voltage sensors are used in system battery and field battery to know the charging percent of battery. Show in Figure 3.18.
- Make alarm when field or system battery is less than 30%.
- Control of charging prosses between system battery and field battery by using an electromagnetic relay.
- Input voltage range: DC0-25V
- Voltage detection range: DC0.02445V-25V
- Voltage analog resolutions: 0.00489V

Figure 3.18: Voltage sensor

Current Sensor:

- The Bicycle driver cannot use bicycle motor when the CharGO system is turned on in an electrical bicycle. Show in Figure 3.19
- Current sensor chip: ACS712ELC-30A
- Requires 5V power supply, on-board power indicator
- Measures both positive and negative 30A

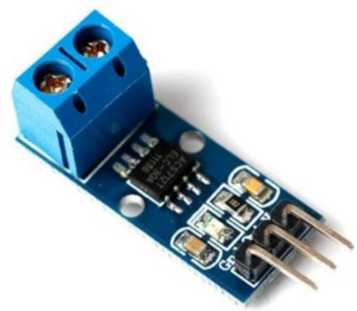


Figure 3.19: Current sensor

3.3 Circuit Design

This section explains how and where to connect every electric part in the electric circuit, to create a control circuit. Show in Figure 3.20.

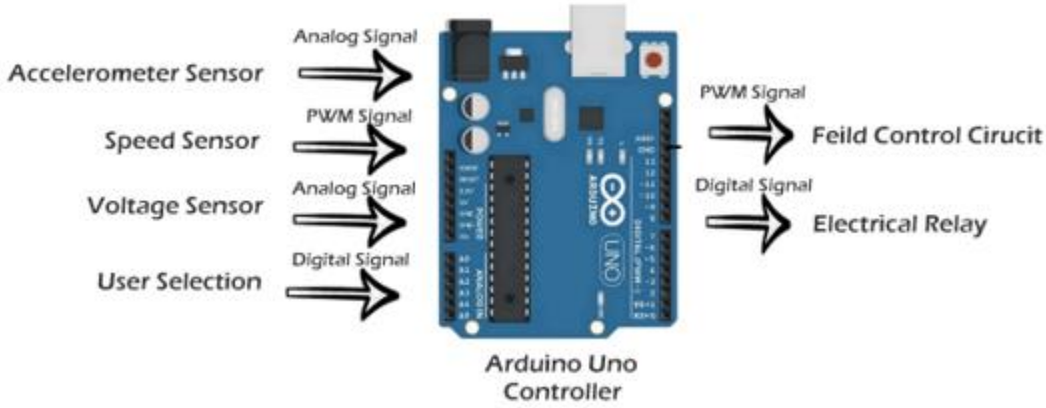


Figure 3.20: Control circuit

how to connect the control circuit with the other circuit parts to create the control circuit of the generator its Shown in Figure 3.21.

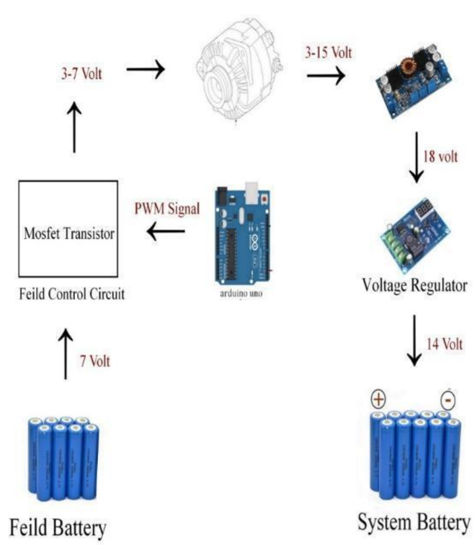


Figure 3.21: Control circuit of generator

Figure 3.22 explains how to connect the system charging process of CharGO.

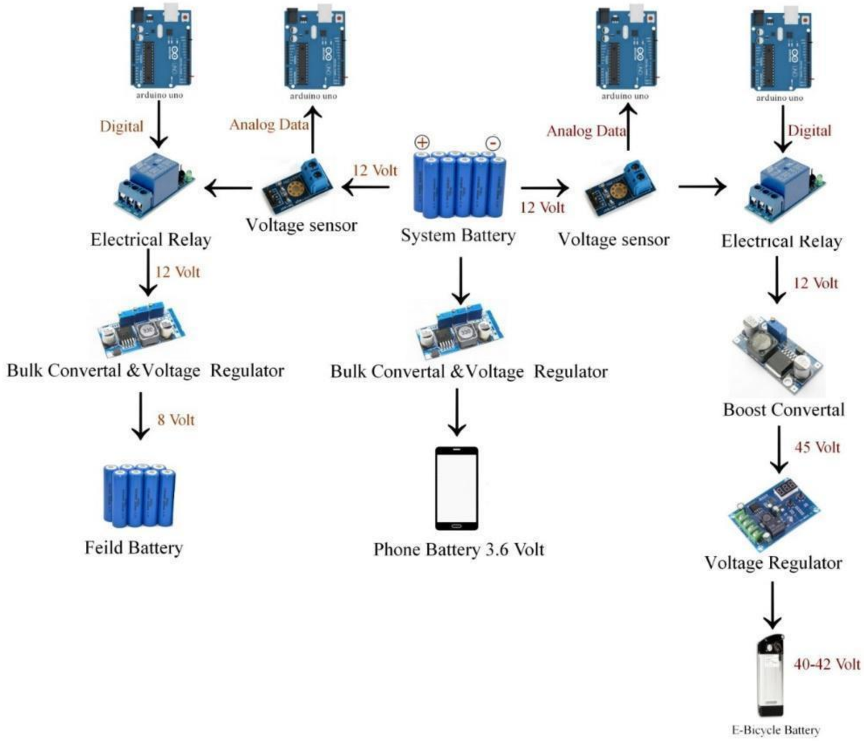


Figure 3.22: System charging process

Finally, Figure 3.23 explains how CharGO connected, and how works.

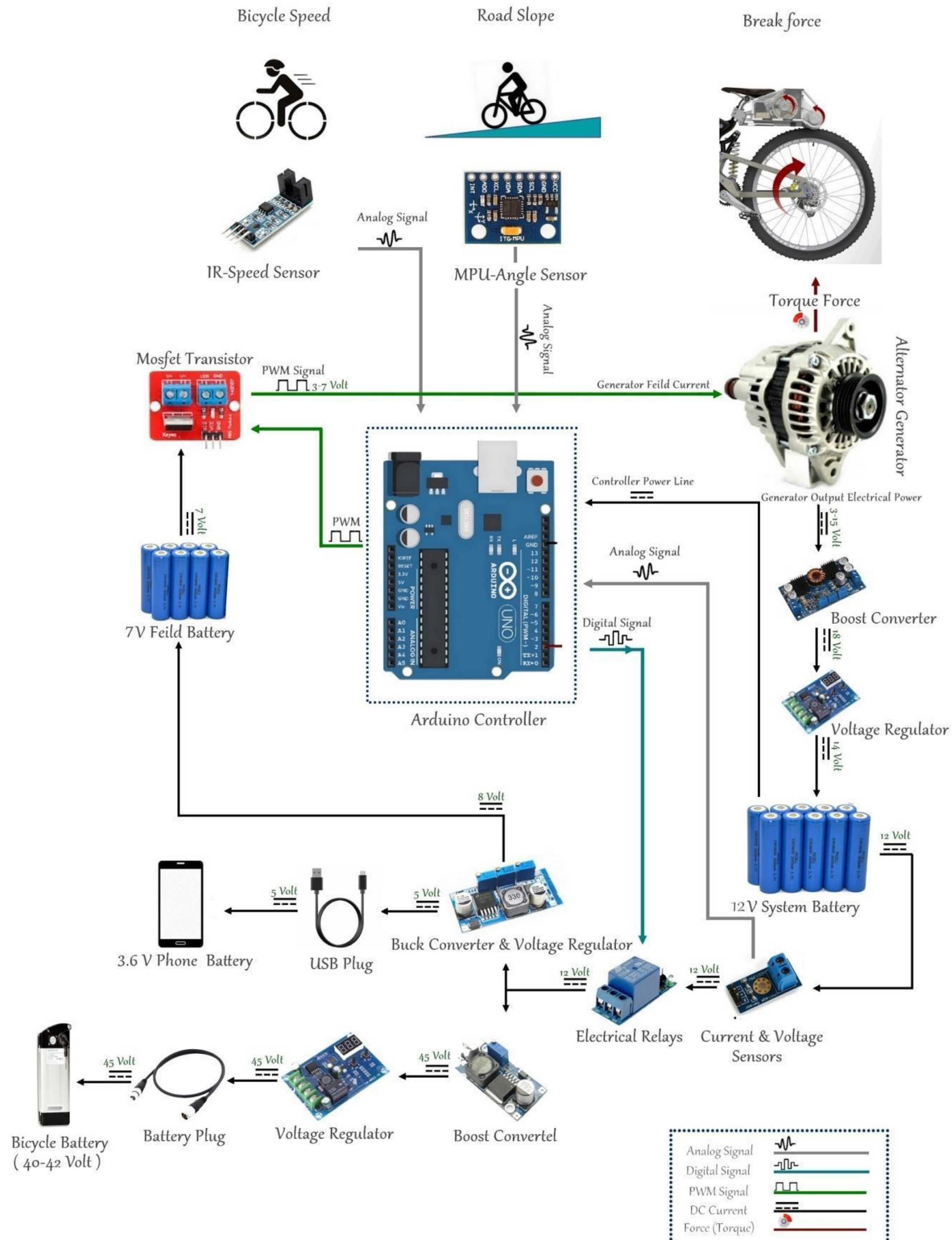


Figure 3.23: The network system of CharGO

Chapter 4

Achievements and Results

4.1 Introduction

This chapter includes the results of the experiments and the practical implementation of the CharGO System in the manual mode.

4.2 Achievements

- We have designed and built a plug-and-play device that works on a normal bicycle. This device is called the CharGO system.
- We provided the driver with the ability of controlling the charging process.
- Charging the battery better is now possible.
- This system takes advantage of the movement better.

The real experiment was conducted on the normal bicycle (MTB COOBRA), type Downhill, which has a wheel diameter of 68 cm. The data was recorded using a laptop and an Arduino software along with a multimeter.

The CharGO system is connected to the bicycle as can be seen in Figure 4.1.

The Arduino microcontroller is used to control the field current, read the generator speed, and generator output current.

Figure 4.1: CharGO with bicycle

4.3 Results

The first experiment is to inverse the effect of the field current on the relation between the generator velocity and the output current as in Figure 4.2. In addition, the value of the field current is 0.5, 1, 1.5 and 2 amperes. Moreover, the relation between the field current and the output current is directly proportional in the presence of a constant generator speed, and the relation between the output current and the generator speed is directly proportional in the presence of constant field current.

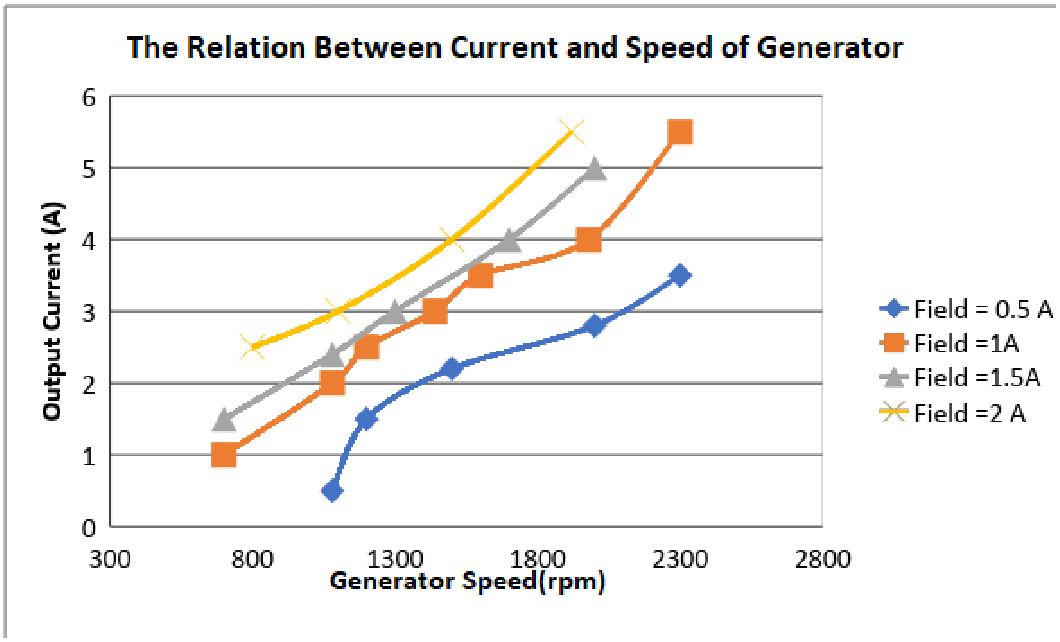


Figure 4.2: Relation between output current (ampere) and generator velocity (RPM)

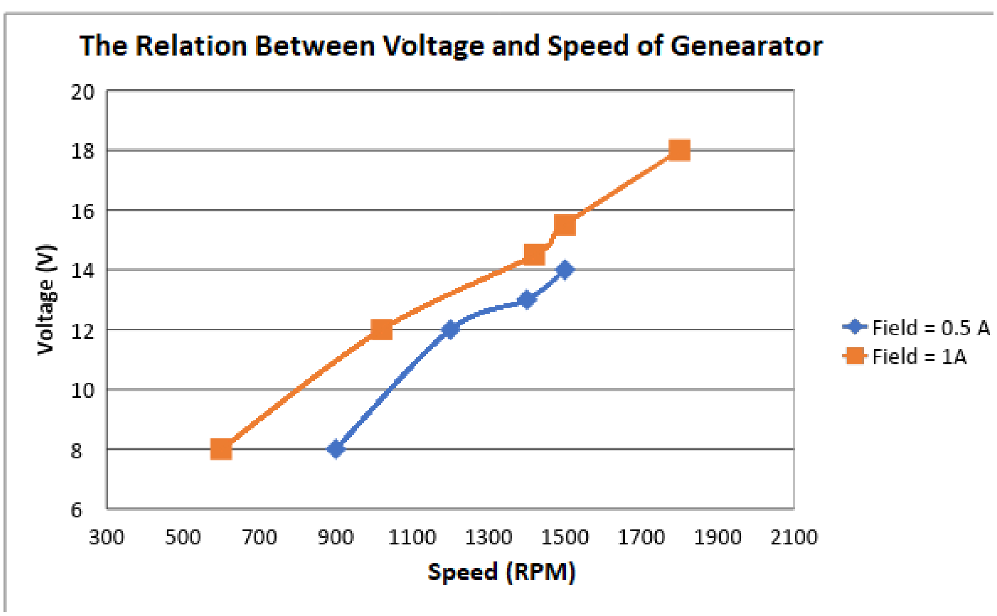


Figure 4.3: Relation between output voltage (volt) and generator velocity (RPM)

The charging and discharging performance measure for batteries is called C-rate. The C-rate is calculated as follows:

$$C_{charge} rate = \frac{I_{Charger}\,(A)}{I_{battary}(A.h)} \tag{9}$$

And

$$C_{discharging} rate = \frac{I_{load}(A)}{I_{battary}(A.h)} \tag{10}$$

This is for charging and discharging respectively.

1. Field battery:

Field battery discharging by the generator field:

As shown in (Section 3.2.2) the battery field has 7.2 voltage value and 5 Ah; then:

- **Field current equals 0.5A:**

When C = 1/h.

$$C_{discharging}\ rate = \frac{0.5\ A}{5\ A.h} = 0.1\left(\frac{1}{h}\right) or\ 0.1C$$

$$Time\ of\ discharging = \frac{1}{0.1C} = 10\ h$$

The CharGO can work with field current that equals 0.5 ampere for 10 hours when the field battery is fully charged.

Field current equals 1A:

$$Discharging\ rate = \frac{1\ A}{5\ A.h} = 0.2\left(\frac{1}{h}\right) or\ 0.2\ C$$

$$Time\ of\ discharging = \frac{1}{0.2C} = 5\ h$$

The CharGO can work with field current that equals 1 ampere for 5 hours when the field battery is fully charged.

- **Field current equals 1.5A:**

$$Discharging\ rate = \frac{1.5A}{5\ A.h} = 0.3\left(\frac{1}{h}\right)\ or\ 0.3C$$

$$Time\ of\ discharging = \frac{1}{0.3C} = 3.3h$$

The CharGO can work with field current that equals 1.5 ampere for 3.3 hours when field battery is fully charged.

- **Field current equals 2A:**

$$Discharging\ rate = \frac{2A}{5\ A.h} = 0.4\left(\frac{1}{h}\right) or\ 0.4C$$

$$Time\ of\ discharging = \frac{1}{0.4C} = 2.5\ h$$

CharGO can work with field current that equals 2 amperes for 2.5 hours when field battery is fully charged.

Field battery charging from the system battery:

As shown in (Figure 3.11), the field battery is charged from the system battery with 8 Volts and 2.5 amperes.

$$Charging\ rate = \frac{2.5A}{5\ A.h} = 0.5\left(\frac{1}{h}\right) or\ 0.5C$$

$$Time\ of\ discharging = \frac{1}{0.5C} = 2\ h$$

Hence, the field battery needs 2 hours to be fully charged from the system battery when it is empty.

Table 4: Field battery discharging by the generator field

Field current (A)	Discharging Rate (C or 1/h)	Time (h)	Explain
0.5	0.1	10	The CharGO can work with field current that equals 0.5 ampere for 10 hours when the field battery is fully charged.
1	0.2	5	The CharGO can work with field current that equals 1 ampere for 5 hours when the field battery is fully charged.
1.5	0.3	3.3	The CharGO can work with field current that equals 1.5 ampere for 3.3 hours when the field battery is fully charged.
2	0.4	2.5	The CharGO can work with field current that equals 2 amperes for 2.5 hours when the field battery is fully charged.
2.5	0.5	2	Field battery needs 2 hours to be fully charged from the system battery when it is empty.

2. **System battery:**

As shown in (chapter 3, section 3.2.2), system battery has 12 volts and 5 Ah.

System battery discharging:

The System battery will be discharged by the charging field battery, the electric bicycle battery, and by the phone battery as shown below

- By the charging field battery:

$$Discharging\ rate = \frac{2.5\ A}{5\ A.h} = 0.5\left(\frac{1}{h}\right) or\ 0.5C$$

$$Time\ of\ discharging = \frac{1}{0.5C} = 2\ h$$

- By the charging electric bike battery:

$$Discharging\ rate = \frac{3\ A}{5\ A.h} = 0.6\left(\frac{1}{h}\right) or\ C$$

$$Time\ of\ discharging = \frac{1}{0.6C} = 1.6\ h$$

- By the charging phone battery:

$$Discharging\ rate = \frac{1.5\ A}{5\ A.h} = 0.3\left(\frac{1}{h}\right) or\ C$$

$$Time\ of\ discharging = \frac{1}{0.3C} = 3.3\ h$$

The system battery is charged by the generator power of the CharGO device as shown in (Chapter3).

In this experiment, the manual operation mode is used to charge the system battery to determine the bicycle's minimum and maximum speed that is capable of charging the system battery with different values of field current as shown below.

- **Field current equals 0.5 A:**

As shown in Figure 4.2, the minimum charging rate for the system battery is when the generator is at 1080 rpm with output current that equals 0.5 A.

$$Charging\ rate = \frac{0.5A}{5\ A.h} = 0.1C\ (10\ h)$$

$$Time\ of\ charging = \frac{1}{0.1C} = 10\ h$$

The maximum charging rate for the system battery at a safe C rate for a lithium battery is (0.7-0.8 C rate).
This took place when the generator was at 2300 rpm and the output current was 3.5 A.

$$Charging\ C.rate = \frac{3.5A}{5A.h} = 0.7C$$

$$Time\ of\ charging = \frac{1}{0.7C} = 1.4\ h$$

- **Field current equals 1 A:**

As shown in Figure 4.2, the minimum charging rate for the system battery is when the generator is at 700 rpm with an output current that equals 1 A.

$$Charging\ rate = \frac{1A}{5A.h} = 0.2C\ (5\ h\ )$$

$$Time\ of\ charging = \frac{1}{0.2C} = 5\ h$$

The maximum charging rate for the system battery at a field current that equals 1ampere is when the generator is at 1980 rpm with an output current that equals 4 A.

$$Charging\ \ rate = \frac{4A}{5A.h} = 0.8C$$

$$Time\ of\ charging = \frac{1}{0.8C} = 1.25\ h$$

- **Field current equals 1.5 A:**

As shown in Figure 4.2, the minimum charging rate for the system battery is when the generator is at 700 rpm with an output current that equals 1.5 A.

$$Charging\ \ rate = \frac{1.5\ \ A}{5\ A.h} = 0.3C$$

$$Time\ of\ charging = \frac{1}{0.3C} = 3.3\ h$$

The maximum charging rate for the system battery at a field current that equals 1.5 ampere is when the generator is at 1700 rpm with an output current that equals 4A.

$$Charging\ rate = \frac{4\ A}{5\ A.h} = 0.8C$$

$$Time\ of\ charging = \frac{1}{0.8C} = 1.25\ h$$

- **Field current equals 2A:**

As shown in Figure 4.2, the minimum charging rate for the system battery is when the generator is at 700 rpm with an output current that equals 2A.

$$Charging\ rate = \frac{1.5A}{5A.h} = 0.3C$$

$$Time\ of\ charging = \frac{1}{0.3C} = 3.3\ h$$

The maximum charging rate for the system battery at a field current that equals 2 amperes is when the generator is at 1500 rpm with an output current that equals 4 A.

$$Charging\ C.rate = \frac{4\ A}{5\ A.h} = 0.8C\ (1.25\ h\ )$$

Table 5: Charging the system battery from the generator

Field current (ampere)	Speed range (rpm)	Charging Rate (C or 1/h)	Time (h)	Explain
0.5	1080	0.1	10	The CharGO can work with a field current that equals 0.5 ampere for 10 hours when the field battery is fully charged.
	2300	0.7	1.4	
1	700	0.2	5	The CharGO can work with a field current that equals 1 ampere for 5 hours when the field battery is fully charged.
	1980	0.8	1.25	
1.5	700	0.3	3.3	The CharGO can work with a field current that equals 1.5 ampere for 3.3 hours when field battery is fully charged.
	1700	0.8	1.25	
2	700	0.3	3.3	The CharGO can work with a field current that equals 2 amperes for 2.5 hours when field battery is fully charged.
	1500	0.8	1.25	

4.4 Conclusion

- This project is one of the new projects in the field of power generation using traffic, which depends on the use of the bike to convert kinetic energy to electric energy through an electric generator.
- The charging system in CharGO depends on a linear relationship between the speed and the output current.
- The CharGO system is not limited to producing power only for an electric bicycle battery, but it can be used as an external power source.
- The CharGO system contributes to clean power generation without the need to use external energy sources, which makes it environmentally friendly.
- It can be seen from the concluding data of the system, that the braking force can be coped with an impact on the speed of the bike.

Appendix A

PALGLAS Flat Extruded Acrylic Sheet

Overview:

PALGLAS flat extruded acrylic sheet offers light transmission that surpasses glass, but at only half the weight of glass.

Inherently UV resistant, PALGLAS is an excellent choice for both indoor and outdoor applications. Its high clarity and formability offer designers a world of options, from small fabricated items and displays, to signs, railings, and more.

For maximum yield and convenience, PALGLAS can be ordered in custom sizes and thicknesses as part of Palram's "Run-to-Size" program.

Main Benefits:

- Up to 92% light transmission.
- Inherently UV resistant.
- Stronger than glass and less than half its weight.
- High gloss appearance.
- Easily formed and fabricated.
- Good chemical resistance.
- Good thermal insulation.

Typical Applications:

- Illuminated and 3D signage.
- Digital and screen-printed signs.
- Lightweight high clarity glazing.
- Attractive fabricated items & displays.
- Transparent furniture.
- Light fixtures.

Standard Specifications:

Shown in Table Standard Specifications of PALGLAS

Dimensions	Inches	mm
Standard Thicknesses	0.093 0.100 0.118 0.177 0.220	2.36 2.5 3 4.5 5.5
Available Thicknesses	0.40 — .500	1 — 12.7
Standard Sheet Sizes	48 x 96 49 x 97	1220 x 2440 1245 x 2464

Table 6: Standard Specifications of PALGLAS

Weather and UV Resistance:

PALGLAS is inherently UV resistant and its wide service temperature range, -40 ˚F to 176 ˚F, makes it suitable for outdoor applications. A limited warranty against yellowing is available.

Forming and Fabrication:

PALGLAS can be fabricated, machined and thermoformed. PALGLAS is easily hot line bent and shaped into a wide variety of forms. PALGLAS can be bonded to itself and other materials.

Physical Properties:

For detailed information on PALGLAS physical properties please visit: www.PalramAmericas.com/Palglas.

Appendix B

Material Data Center Datasheet of Akulon® K222-D - PA6 – DSM

Product Texts
Low Viscosity
ISO 1043 PA6

Rheological properties	dry / cond	Unit	Test Standard
ISO Data			
Melt volume-flow rate, MVR	185 / *	cm³/10min	ISO 1133
Temperature	275 / *	°C	-
Load	5 / *	kg	-

Mechanical properties	dry / cond	Unit	Test Standard
ISO Data			
Tensile Modulus	3200 / 1000	MPa	ISO 527-1/-2
Yield stress	85 / 45	MPa	ISO 527-1/-2
Yield strain	4 / 25	%	ISO 527-1/-2
Nominal strain at break	20 / >50	%	ISO 527-1/-2
Charpy impact strength, +23°C	N / N	kJ/m²	ISO 179/1eU
Charpy impact strength, -30°C	N / N	kJ/m²	ISO 179/1eU
Charpy notched impact strength, +23°C	8 / 35	kJ/m²	ISO 179/1eA
Charpy notched impact strength, -30°C	5 / 5	kJ/m²	ISO 179/1eA

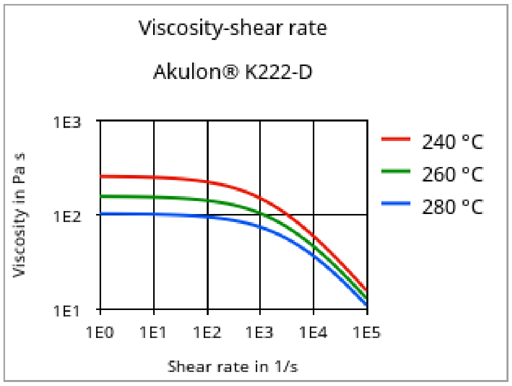
Thermal properties	dry / cond	Unit	Test Standard
ISO Data			
Melting temperature, 10°C/min	220 / *	°C	ISO 11357-1/-3
Temp. of deflection under load, 1.80 MPa	60 / *	°C	ISO 75-1/-2
Temp. of deflection under load, 0.45 MPa	150 / *	°C	ISO 75-1/-2
Vicat softening temperature, 50°C/h 50N	195 / *	°C	ISO 306
Coeff. of linear therm. expansion, parallel	90 / *	E-6/K	ISO 11359-1/-2
Coeff. of linear therm. expansion, normal	90 / *	E-6/K	ISO 11359-1/-2
Burning Behav. at 1.5 mm nom. thickn.	V-2 / *	class	IEC 60695-11-10
Thickness tested	1.5 / *	mm	-
Yellow Card available	yes / *	-	-
Burning Behav. at thickness h	V-2 / *	class	IEC 60695-11-10
Thickness tested	3.0 / *	mm	-
Yellow Card available	yes / *	-	-
Oxygen index	26 / *	%	ISO 4589-1/-2

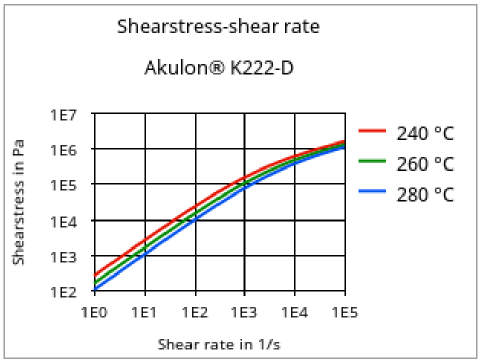
Electrical properties	dry / cond	Unit	Test Standard
ISO Data			
Relative permittivity, 100Hz	3.2 / 14	-	IEC 60250
Relative permittivity, 1MHz	3 / 4.5	-	IEC 60250
Dissipation factor, 100Hz	50 / 3000	E-4	IEC 60250
Dissipation factor, 1MHz	150 / 1200	E-4	IEC 60250
Volume resistivity	1E13 / 1E10	Ohm*m	IEC 60093
Surface resistivity	* / 1E14	Ohm	IEC 60093
Electric strength	25 / 20	kV/mm	IEC 60243-1
Comparative tracking index	* / 600	-	IEC 60112

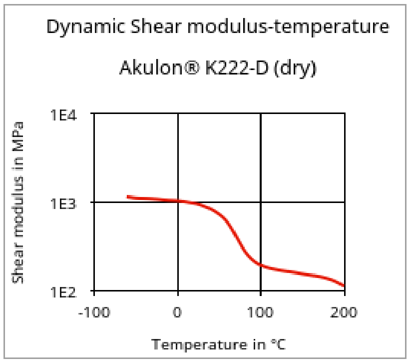
Other properties	dry / cond	Unit	Test Standard
ISO Data			
Water absorption	9 / *	%	Sim. to ISO 62
Humidity absorption	2.5 / *	%	Sim. to ISO 62
Density	1130 / -	kg/m³	ISO 1183

Rheological calculation properties	Value	Unit	Test Standard
ISO Data			
Density of melt	960	kg/m³	-
Thermal conductivity of melt	0.23	W/(m K)	-
Spec. heat capacity of melt	2680	J/(kg K)	-
Eff. thermal diffusivity	8.82E-8	m²/s	-

Diagrams







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