A

Project synopsis

On

"SELF BALANCING SOLO WHEEL HOVERTRAX"

Submitted in partial fulfillment of the requirements

of the degree of

Bachelor of Engineering in Electrical Engineering

Submitted by

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CERTIFICATE

Certified that the project report entitled **“SELF BALANCING SOLO WHEEL HOVERTRAX”** is a bonafied work done under my guidance by

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Date- (Prof. YAKUB KHAN)

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CERTIFICATE OF APPROVAL

The foregoing disseration entitled **“SELF BALANCING SOLO WHEEL HOVERTRAX”** is hereby approved as a creditable study of Electrical Engineering presented by

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Internal Examiner External Examiner

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DECLARATION

I declare that this written submission represents my ideas in my own words and where others ideas or words have been included; I have adequately cited and referenced the original sources. I also declared that I have adhered to all principles of academic honesty and integrity and have not represented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission have not been taken when needed.

(Signature)

(Name of student and Roll No.)

ACKNOWLEDGEMENT

It gives me immense pleasure to present this project on “SELF BALANCING SOLO WHEEL HOVERTRAX” carried out at AIKTC, New Panvel in accordance with prescribed syllabus of University of Mumbai for Electrical Engineering. I express my heartfelt gratitude to those who directly and indirectly contributed towards the completion of this project. I would like to thanks Mr. Abdul Razzak, Head of Department Prof. Syed Kaleem for allowing me to undertake this guide Prof. Yakub Khan for continuous support. I would like to thanks all the faculty members, non-teaching staffs of Electrical Engineering of our College for their direct and indirect support and suggestion for performing the project.

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ABSTRACT

The main aim of the project is to balance a solo wheel hovertax using hub wheel motor. This is an advanced technology of the skateboard. Usually there is two or four wheel skateboard which is very easy to balance and for that general motors can be used. Thus, the proposed system is enhanced to use in industrial applications for easy working to the labours. Sensors will acknowledge to the PID controller to control the action and according to that it gives feedback to the input, comparator will compare the feedback value and the reference value. Microcontroller we are using is Arduino Uno atmega328p which will interface the sensors to the controller.

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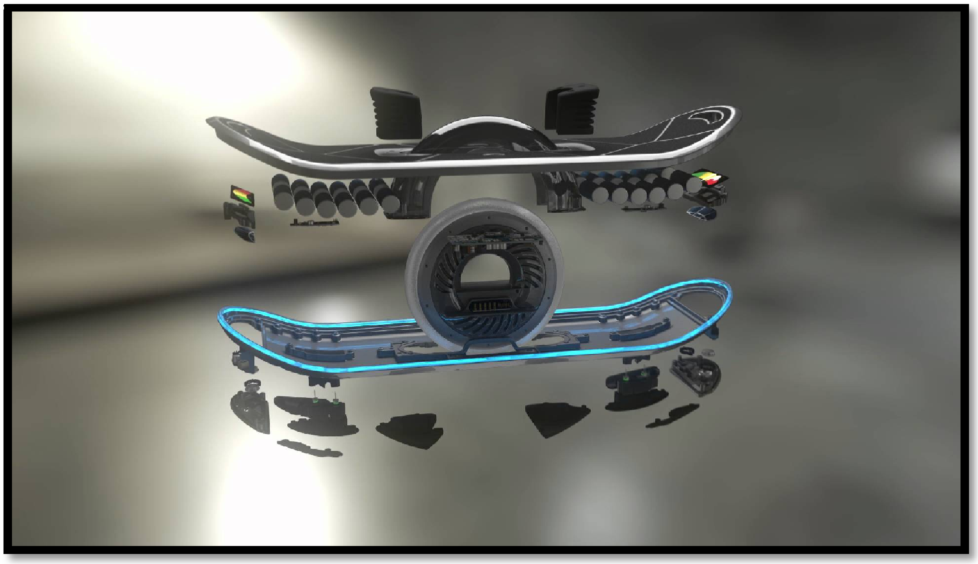
1.0 INTRODUCTION

Solo wheel hovertrax are a new and promising alternative form of urban transportation. They provide all the advantages of a regular bicycle: fun exercise, free parking, zero emissions, and freedom from gridlock. Imagine skateboarding up a hill as comfortably as riding down; what the experience is all about. In most situations in the city, riding a hovertrax will be faster and cheaper than either car or public transit.

Fundamentally, the hovertrax is just a regular skateboard with an electric motor to provide additional assistance. You can skate normally and just use the motor to help out on hills and headwinds, or use the motor all the time just to make riding easier. The experience is entirely different from riding say a gas scooter or motorbike. Here the electric assistance is perfectly smooth and it complements rather than supplants human power.

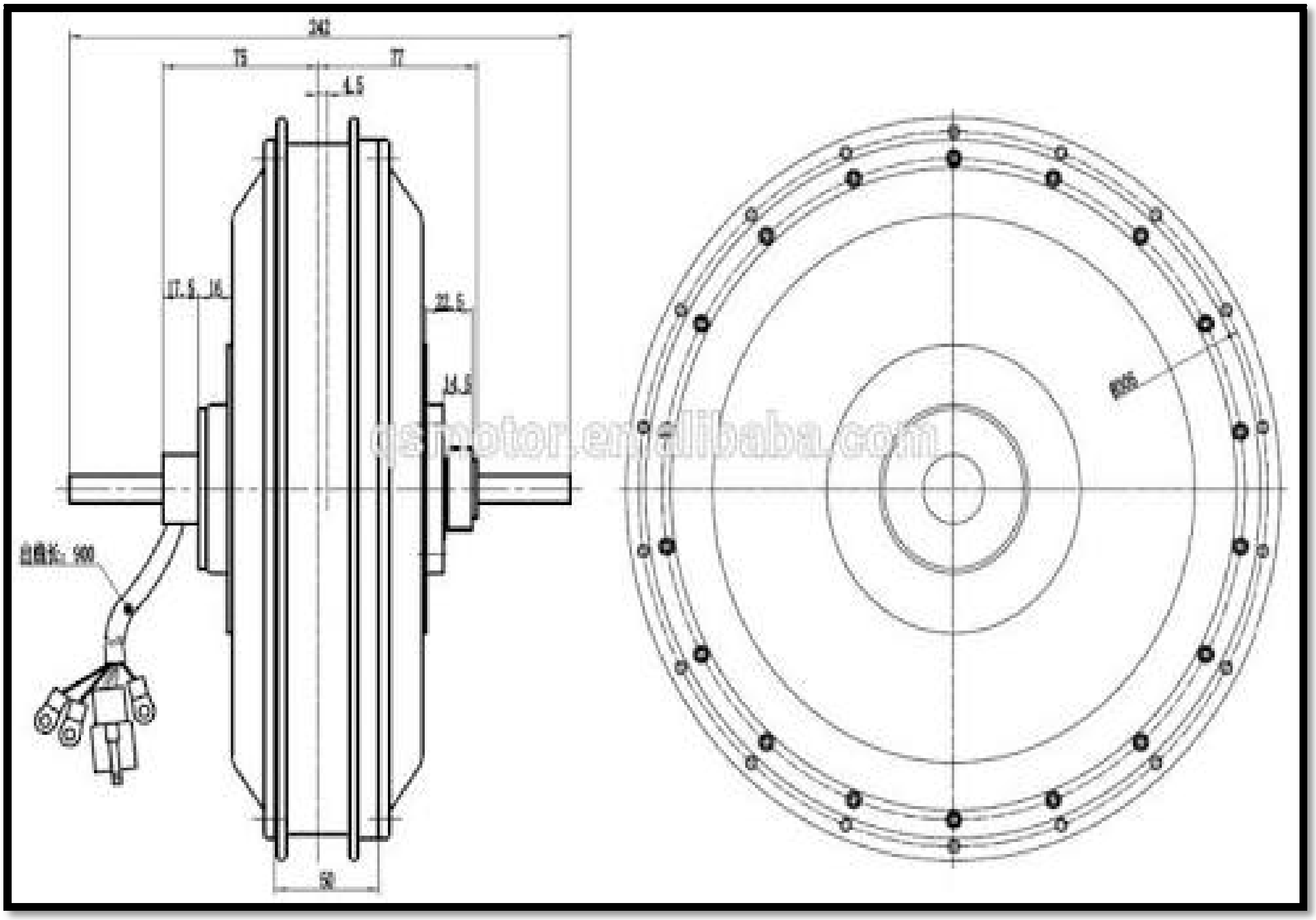
Hovertrax is born from the idea of simplifying the methods of transportation inside university campus. Throughout the years, many students have used simple methods of transportation along far distance buildings inside campus. Many students have use bicycles, skateboards, or just walking. We noticed that sometimes we need to travel long distances inside the university area, the idea of having a portable and fast transportation, which people don't have to use physical force, came to our mind while we saw a student skating and paddling constantly because he was late for class.



2.0 HUB WHEEL MOTOR

The wheel hub motor (also called wheel motor, wheel hub drive, hub motor or in-wheel motor) is an electric motor that is incorporated into the hub of a wheel and drives it directly.

Eventually the growth in power of the gasoline engine overtook the power of the electric wheel hub motors and this made up for any losses through a transmission. As a result, autos moved to gasoline engines with transmissions, but they were never as efficient as electric wheel hub motors.



2.1 What are hub motors?

Most electric-powered vehicles (skate board, electric bicycles, and wheelchairs) use onboard batteries and a single, fairly ordinary electric motor to power either one or two wheels. But some of the latest skate board and electric bicycles work a different way. Instead of having one motor powering all the wheels using gears or chains, they build a motor directly into the hub of each wheel so the motors and wheels are one and the same thing. That's what we mean by a hub motor.

The basic idea is just the same. In an ordinary motor, you have a hollow, outer, ring-shaped permanent magnet that stays static (sometimes called the stator) and an inner metallic core that rotates inside it (called the rotor). The spinning rotor has an axle running through the middle that you use to drive a machine. But what if you hold the axle firmly so it can't rotate and switch on the motor? Then the rotor and the stator have no choice but to swap roles: the normally static rotor stays still while the stator spins around it. Try it with an electric toothbrush. Instead of holding the plastic case of your toothbrush (which, broadly speaking connects to the static part of an electric motor), try holding only the bristles and then turn on the power. It's quite tricky to do, because the brush moves so fast, but if you do it right you'll find the handle slowly rocks back and forth. This is essentially what happens in a hub motor.

2.1.1 Mechanism

Hub motor electromagnetic fields are supplied to the stationary windings of the motor. The outer part of the motor follows, or tries to follow, those fields, turning the attached wheel. In a brushed motor, energy is transferred by brushes contacting the rotating shaft of the motor. Energy is transferred in a brushless motor electronically, eliminating physical contact between stationary and moving parts. Although brushless motor technology is more expensive, most are more efficient and longer-lasting than brushed motor systems.

A hub motor typically is designed in one of three configurations. Considered least practical is an axial-flux motor, where the stator windings are typically sandwiched between sets of magnets. The other two configurations are both radial designs with the motor magnets bonded to the rotor; in one, the inner rotation motor, the rotor sits inside the stator, as in a conventional motor. In the other, the outer-rotation motor, the rotor sits outside the stator and rotates around it. The application of hub motors in vehicular uses is still evolving, and neither configuration has become standard.

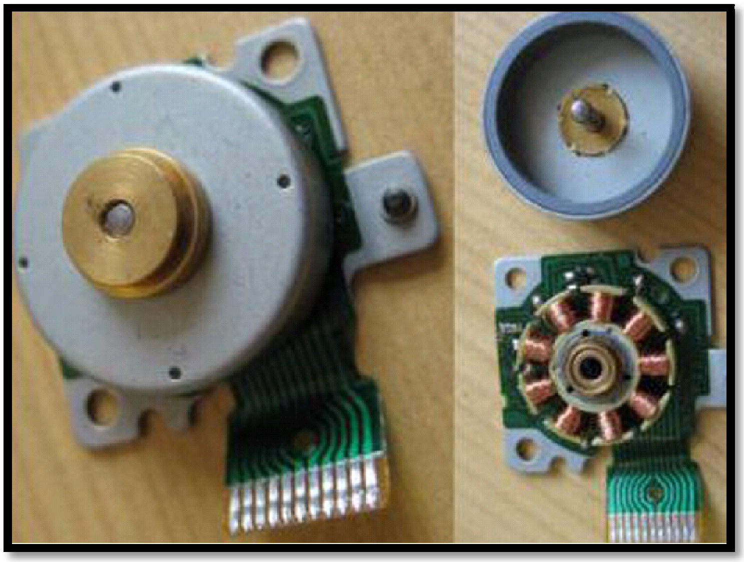
Electric motors have their greatest torque at startup, making them ideal for vehicles as they need the most torque at start up too. The idea of "revving up" so common with internal combustion engines is unnecessary with electric motors. Their greatest torque occurs as the rotor first begins to turn, which is why electric motors do not require a transmission. A gear-down arrangement may be needed, but unlike in a transmission normally paired with a combustion engine, no shifting is needed for electric motors.

Wheel hub motors are increasingly common on electric skateboard and electric scooters in some parts of the world, especially Asia.

2.1.2How does brushless DC motor work?

Hub motors are typically brushless motors (sometimes called brushless direct current motors or BLDCs), which replace the commutator and brushes with half-a-dozen or more separate coils and an electronic circuit. The circuit switches the power on and off in the coils in turn creating forces in each one that make the motor spin. Since the brushes press against the axle of a normal motor, they introduce friction, slow it down, make a certain amount of noise, and waste energy. That's why brushless motors are often more efficient, especially at low speeds. Getting rid of the brushes also saves having to replace them every so often when friction wears them down.

Here are some photos of a typical brushless DC motor. First, look at the fully assembled motor shown in the top picture. In a normal motor, you'd expect the inner coil to rotate (it's called the rotor) and the outer magnet to stay static (that's called the stator). But in this motor, the roles are reversed: the inner part with the coils is static and the gray magnet spins around it. Now look inside and you can see exactly how it works: the electronic circuit sends power round the nine copper coils in turn, making the gray outer case (which is a magnet split into a number of sections, bent round into a circle) spin around the copper coils and circuit board.



How does the circuit know which of the nine coils to switch on and off—and when? You can't really see in this photo, but there are several tiny magnetic field sensors (known as Hall-effect sensors) positioned between some of the coils. As the permanent magnets on the outer rotor sweep past them, the Hall-effect sensors figure out where the north and south magnetic poles of the rotor are and which coils to activate to make it keep spinning. The trouble with this is that it means the motor does need an electronic circuit to operate it, which is something you don't need for an ordinary DC motor.

2.2 What are the advantages of hub motors ?

It depends whether you're talking about an electric bicycle or an electric car. Adding a hub motor and batteries to a bicycle is a mixture of pro and con: you increase the bicycle's weight quite considerably but, in return, you get a pleasant and effortless ride whenever you don't feel like pedaling. Where electric cars are concerned, the benefits are more obvious. The weight of the metal in a typical car (including the engine, gearbox, and chassis) is perhaps 10 times the weight of its occupants, which is one reason why cars are so very inefficient. Swap the heavy engine and gearbox for hub motors and batteries and you have a lighter car that uses energy far more efficiently. Getting rid of the engine compartment also frees up a huge amount of space for passengers and their luggage you can just stow the batteries behind the back seat.

Vehicles powered by hub motors are a whole lot simpler (mechanically less complex) than normal ones. Suppose you want to reverse. Instead of using elaborate arrangements of gears, all you have to do is reverse the electric current. The motor spins backward and back you go! What about four wheel drive? That's quite an expensive option on a lot of vehicles you need more gears and complicated drive shafts but it's very easy to sort out with hub motors. If you have a hub motor in each of a car's four wheels, you get four-wheel drive automatically. In theory, it's easy enough to make the four motors turn at slightly different speeds (to help with cornering and steering) or torque (to move you through muddy or uneven terrain).

2.3 What are the problems with hub motors?

2.3.1 Handling

Hub motors are bigger, bulkier, and heavier than ordinary wheels and change the handling of an electric car or bike: they increase the unsprung mass (the mass not supported by the suspension), giving more shock and vibration, poorer handling, and a bumpier ride.

2.3.2 Torque

Another problem is delivering just the right amount of torque (turning force). A gasoline engine works best turning over quickly (making lots of revolutions per minute), no matter what speed you're actually doing on the road. You use a gearbox to convert the engine's high revs into high torque (and low speed) or high speed (and low torque) depending on whether you're starting off from a standstill, racing along the freeway, driving slowly uphill, or whatever. Hub motors have to be able to produce any combination of speed and torque without a gearbox; they usually work by "direct drive."

To get enough torque, you need quite a powerful motor but not so powerful that it accelerates you too quickly. Hub motors typically achieve more torque by increasing the hub size quite significantly (a bigger stator and rotor make more torque than smaller ones).

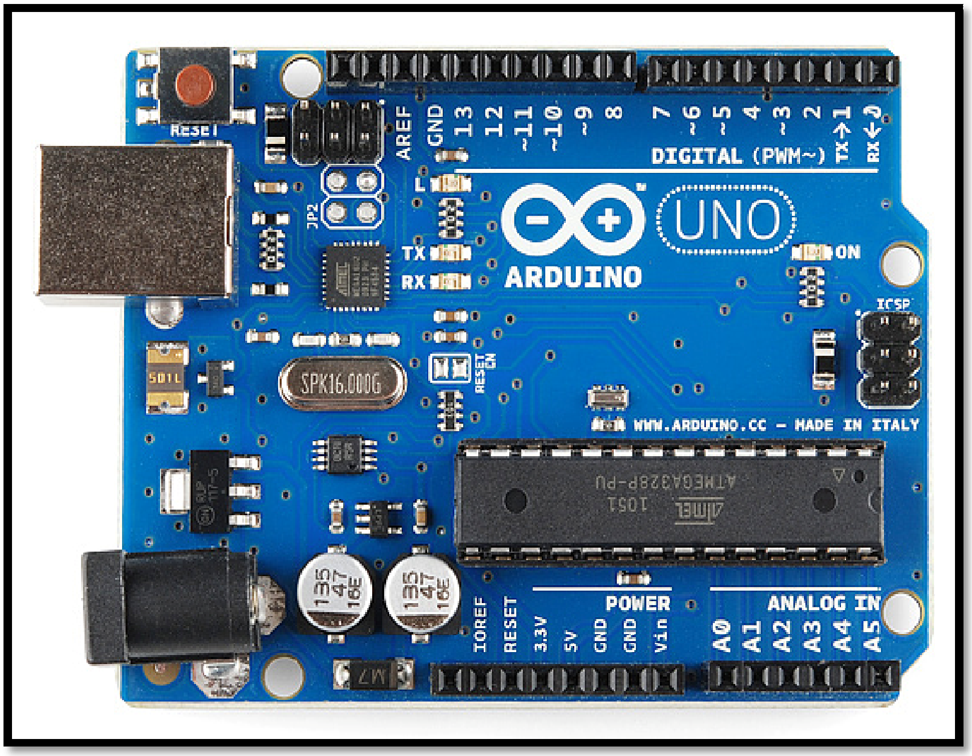
3.0 CONTROLLER

3.1 Arduino Uno atmega328p

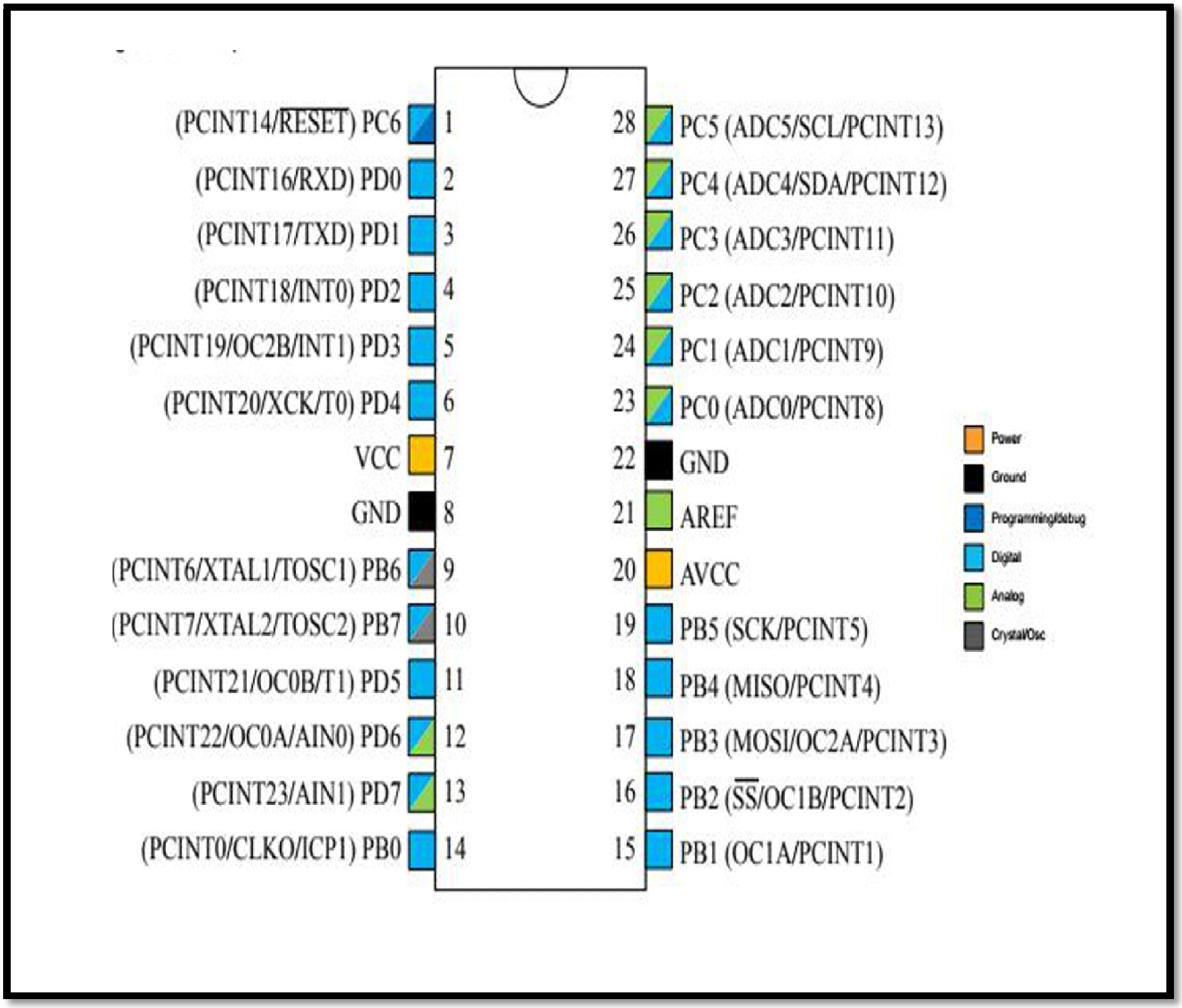
Arduino is an open source computer hardware and software company, project, and user community that designs and manufactures single-board microcontrollers and microcontroller kits for building digital devices and interactive objects that can sense and control objects in the physical world.

Arduino board designs use a variety of microprocessors and controllers. The boards are equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The boards feature serial communications interfaces, including Universal Serial Bus (USB) on some models, which are also used for loading programs from personal computers. The microcontrollers are typically programmed using a dialect of features from the programming languages C and C++. In addition to using traditional compiler tool chains, the Arduino project provides an integrated development environment (IDE) based on the Processing language project.

Here we are using arduino atmega328p.



3.1.1 Pin configuration



3.1.2 Features

- **High Performance, Low Power 8-Bit Microcontroller**
- **Advanced RISC Architecture:**

– 131 Powerful Instructions

– Most Single Clock Cycle Execution

– 32 x 8 General Purpose Working Registers

– Fully Static Operation

- **High Endurance Non-volatile Memory Segments:**

– 32K Bytes of In-System Self-Programmable Flash program memory (ATmega328P)

– 1K Bytes EEPROM (ATmega328P)

– 2K Bytes Internal SRAM (ATmega328P)

- **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

– On-chip Analog Comparator

– Interrupt and Wake-up on Pin Change

- **Special Microcontroller Features:**

– Power-on Reset and Programmable Brown-out Detection

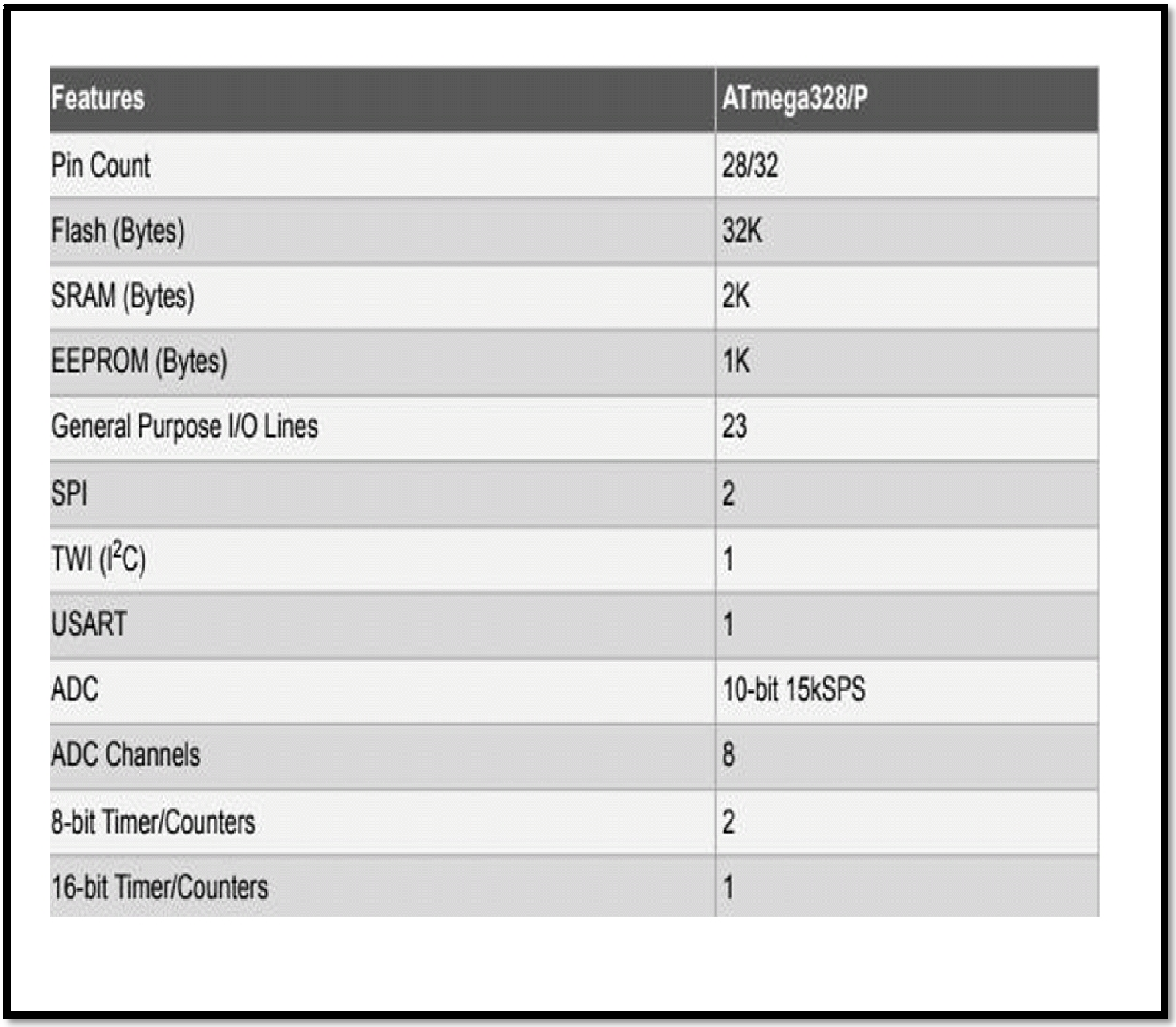
– External and Internal Interrupt Sources

- **I/O and Package:**

– 23 Programmable I/O Lines

- **Operating Voltage:** – 1.8 - 5.5V for ATmega328P
- **Temperature Range:** – -40°C to 85°C

3.1.3 Specification table



Features	ATmega328/P
Pin Count	28/32
Flash (Bytes)	32K
SRAM (Bytes)	2K
EEPROM (Bytes)	1K
General Purpose I/O Lines	23
SPI	2
TWI (I^2C)	1
USART	1
ADC	10-bit 15kSPS
ADC Channels	8
8-bit Timer/Counters	2
16-bit Timer/Counters	1

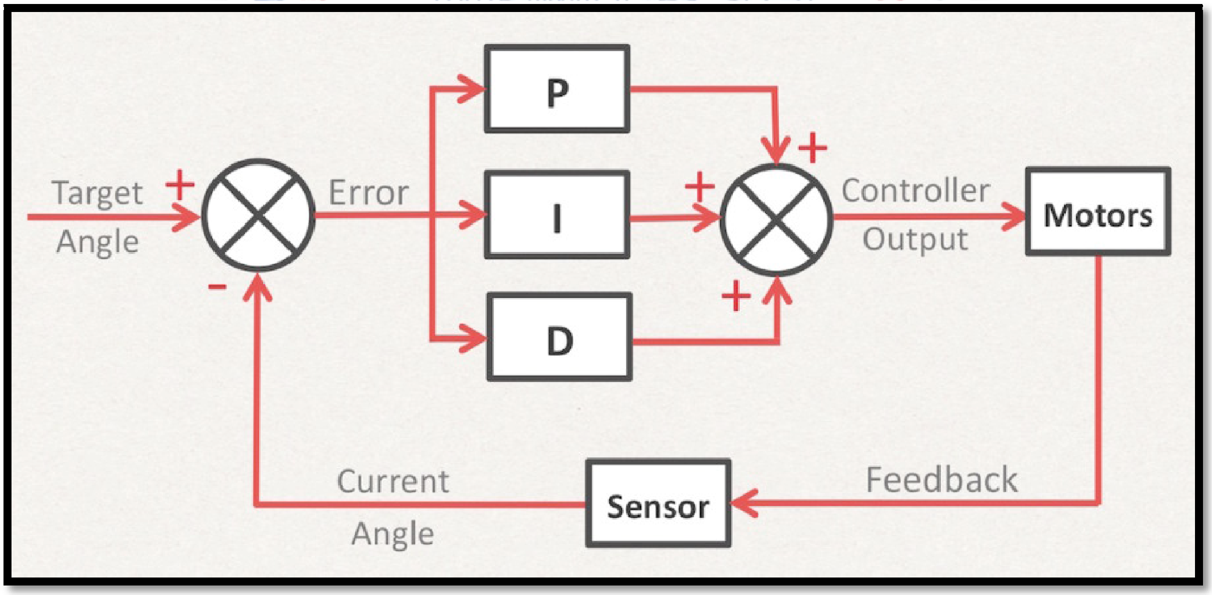
3.2 The PID Controller

PID stands for proportional, integral and derivative, referring to the mathematical equations used to calculate the output.

The P-component simply takes in the current angle of the robot and makes the motors move in the same direction as the robot is falling. Therefore the further the robot falls off target, the faster the motors move. If the P-component is used on its own, the robot might stabilise for a while, but the system will tend to overshoot, oscillate and ultimately fall over.

The component is used to accumulate any errors. For example if the robot tends to fall over to one side, it knows that it needs to move in the opposite direction in order to keep the on target and to prevent drifting left or right. Finally,

The D-component is responsible for dampening any oscillations and ensures that the robot does not vibrate too much. It simply acts against any movement.



3.2.1 PID controller

The IMU sensor mounted on top of the vehicle measured the acceleration and angular acceleration in three axes namely x, y and z. These values were processed by Digital Motion Processor (DMP) which transformed these values in to a more convenient set of variables i.e. yaw, pitch and roll. Here only pitch was necessary as it produced the value for tilt in the axis under consideration. This value was fed to the controller; which acted as feedback to the microcontroller.

The micro controller processed the values obtained from DMP according to program specified algorithms. The controller compared the pitch value obtained from feedback with the pre-set value, if there was a deviation then the error value was sent to the PID controller which via its algorithm produced a proportional force to be applied on the motors in order to bring it to back to the original vertical position. The control signal was produced and sent to the motor controller L298N.
The motor controller derived the motor at the specified speed, torque and direction

3.2.2 PID algorithm

The control algorithm that was used to maintain balance on the autonomous self balancing two wheel robot was the PID controller. The proportional, integral, and derivative (PID) controller is well known as a three term controller. The input to the controller was the error from the system. The Kp, Ki, and Kd were referred as the proportional, integral, and derivative constants (the three terms get multiplied by these constants, respectively). The closed loop control system is also referred to as a negative feedback system. The basic idea of an negative feedback system was that it measured the process output ‘y’ from a sensor. The measured process output gets subtracted from the reference set-point value to produce an error. The error was then fed into the PID controller, where the error got managed in three ways. The error was used on the PID controller to execute the proportional term, integral term for reduction of steady state errors, and the derivative term to handle over shoots. After the PID algorithm processed the error, the controller produced the control signal ‘u’. The PID control system then fed into the process under control. The process under PID control was the two wheeled robot. The PID control signal was try to drive the process to the desired reference set point value.

In case of the two wheel robot, the desired set-point value was the zero degree vertical position. The PID control algorithm can be modelled in a mathematical representation. PID was used to calculate the “correction factor” as shown below:

-

= *+ *∫ () + * [()/] (4.1)

Kp, Ki, and Kd which are specific error constants, are set experimentally E is the error signal constant The integral term was simply the summation of all previous deviations and called this Integral as–“total error”. The derivative was the difference between the current deviation and the previous deviation Following was the code for evaluating the correction. These lines were runin each iteration: Correction=Kp*D + Ki*[(DT)*dt] + Kd[(D-D0)*dt] (4.2)

D0=D

DT=D+DT

Where ‘D’ is the deviation, ‘D0’ is the previous deviation, ‘DT’ is the total deviation or accumulated deviation and ‘dt’ is the sampling time. It was assumed that if only the first term had been used to calculate the correction, the robot would have reacted in the same way as in the classical line following algorithm. These cond term forced the robot to move towards the mean position faster. The third term resisted sudden change in deviation

4.0 SENSORS

4.1 IMU sensor

The IMU sensor contains a Micro Electro Mechanical System (MEMS) accelerometer and a MEMS gyro in a single chip. It is very accurate. It contains 16-bits analog to digital conversion hardware for each channel, therefore, it captures the x, y, and z channel at the same time. The sensor used the I2C-bus to interface with the microcontroller.

The sensor sleep mode was disabled, and then the registers for the accelerometer and gyro were read. The sensor also contained a 1024 byte FIFO buffer. The sensor values are stored in the FIFO buffer and the buffer was read by the microcontroller.

The FIFO buffer was used together with the interrupt signal. If the IMU places data in the FIFO buffer, it signals the microcontroller with the interrupt signal to apprise the microcontroller about the data in the FIFO buffer waiting to be read.

4.1.1 Sensor Fusion

The IMU had two sensors, an accelerometer and a gyroscope. The tri-axial accelerometer gave the components of acceleration (g) along its three axes. It was sensitive to noisy data. The gyroscope provided the angular velocity along its three axes. It was less sensitive than the accelerometer but its Output drifts from the reference value along with time. This was the reason sensor fusion becomes necessary as the values obtained from either of the senor is not completely reliable. The sensor had a ‘Digital Motion Processor’ (DMP), also called a "Digital Motion Processing Unit".

This DMP can be programmed with firm ware and is able to do complex calculations with the sensor values. The DMP can do fast calculations directly on the chip. This reduced the load for the microcontroller (like the Arduino). The values obtained from accelerometer and gyroscope was processed by DMP. It gave the yaw, pitch and roll of the vehicle. Here only value of the pitch is necessary as it gives the tilt value in the axis under consideration.

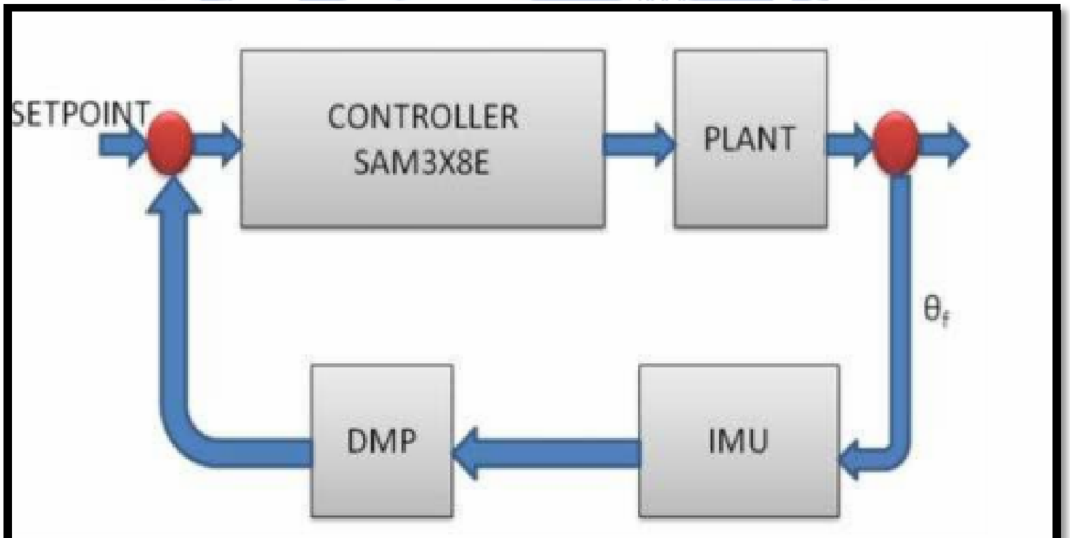


Figure 4: System Schematics

4.2 BATTERY

Power: High charge and discharge rates

Better performance and efficiency are achieved through high charge and discharge rates. Nanophosphate is a positive electrode material of remarkable rate capability, critical to high power systems. Our high power products are able to pulse at discharge rates as high as 100C and deliver superior power by weight or volume in a cost effective solution.

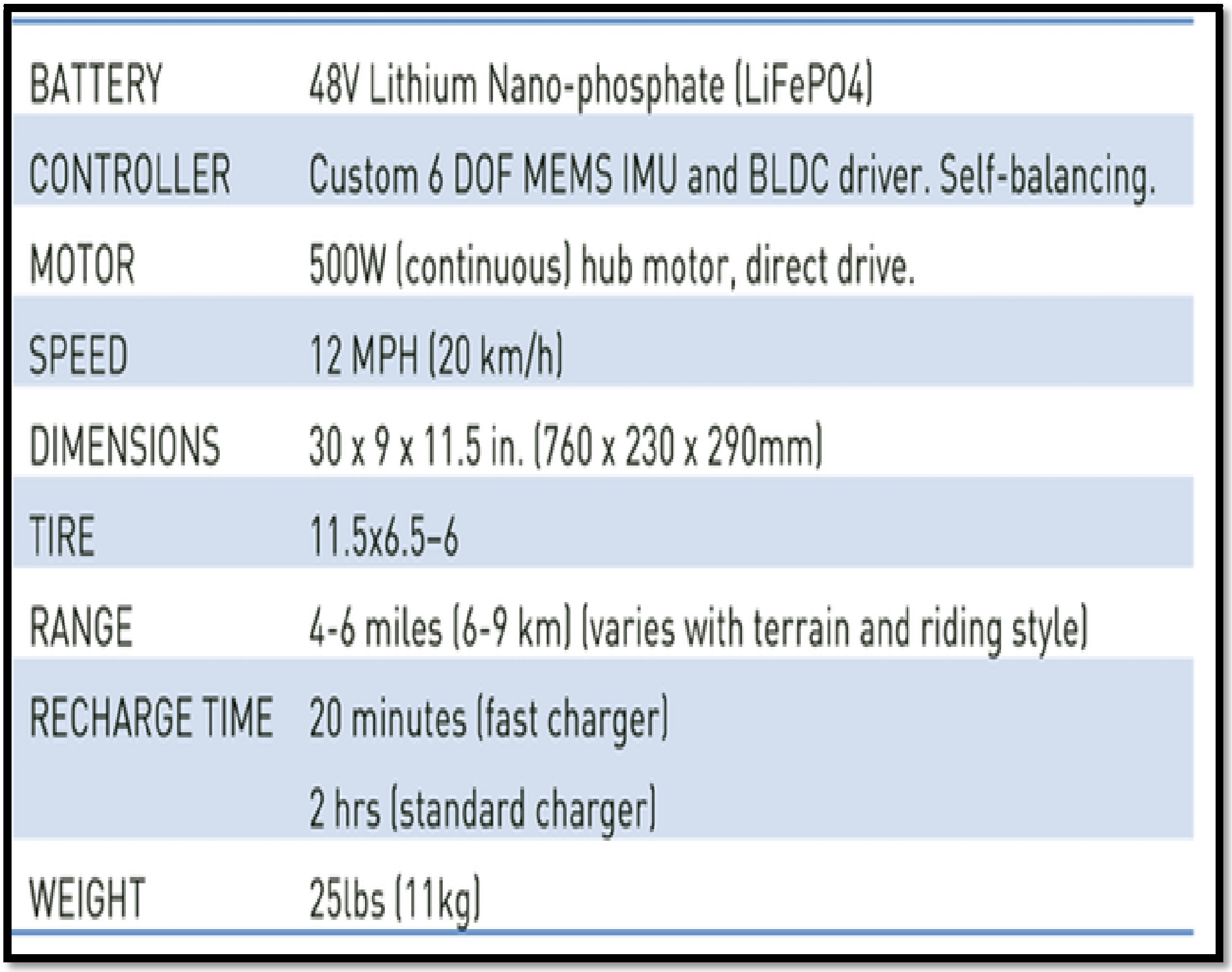
Safety: Superior abuse tolerance

Safety begins with chemistry. A123’s Nanophosphate is stable chemically, which provides the foundation for safe systems while meeting the most demanding customer requirements.

Life: Long battery life for both deep & shallow cycling

A123’s lithium iron phosphate technology delivers exceptional calendar and cycle life

4.3 SPECIFICATIONS



BATTERY	48V Lithium Nano-phosphate (LiFePO4)
CONTROLLER	Custom 6 DOF MEMS IMU and BLDC driver. Self-balancing.
MOTOR	500W (continuous) hub motor, direct drive.
SPEED	12 MPH (20 km/h)
DIMENSIONS	30 x 9 x 11.5 in. (760 x 230 x 290mm)
TIRE	11.5x6.5-6
RANGE	4-6 miles (6-9 km) (varies with terrain and riding style)
RECHARGE TIME	20 minutes (fast charger) 2 hrs (standard charger)
WEIGHT	25lbs (11kg)

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