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AI-Based Hybrid EV Assistive System for Fuel and Electric Switching

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ABSTRACT

This project presents an innovative energy management system for hybrid electric vehicles (HEVs) that optimizes fuel efficiency and reduces emissions. The system integrates advanced slope detection techniques to automatically switch between electric and fuel modes based on the vehicle's terrain and driving requirements. Additionally, an RF-based speed control mechanism is implemented to adjust vehicle speed according to designated zones, such as hospitals, schools, and accident-prone areas. The system utilizes sensors and machine learning algorithms to detect and respond to various driving conditions, ensuring improved fuel efficiency, reduced emissions, and enhanced safety. By seamlessly integrating energy management and automated speed control, this project offers a comprehensive solution for next-generation HEVs, promoting sustainable transportation and intelligent mobility.

Keywords: Sensor Integration and Data Collection, Slope Detection and Mode Switching, RF-Based Speed Control, Machine Learning for Predictive Energy Management, Centralized Control Unit.

Introduction

The increasing prevalence of hybrid electric vehicles (HEVs) is a response to the pressing need for sustainable transportation solutions that address environmental concerns while ensuring efficient energy use. With rising fuel prices and stringent emission regulations, the development of advanced energy management systems is critical for maximizing fuel efficiency and minimizing harmful emissions. This project aims to introduce an innovative energy management system specifically designed for HEVs, focusing on optimizing the transition between electric and fuel modes based on real-time driving conditions and terrain.

To achieve this, the proposed system employs advanced slope detection techniques that enable the vehicle to automatically switch between modes, ensuring optimal performance across various terrains. For instance, when driving uphill, the system can seamlessly engage the fuel mode to provide additional power, while transitioning to electric mode during downhill driving to maximize energy recovery and efficiency. styles over time, further enhancing its performance and effectiveness.

In summary, this project seeks to develop a comprehensive energy management system for hybrid electric vehicles that not only improves fuel efficiency and reduces emissions but also prioritizes safety in varying driving conditions. By integrating advanced slope detection techniques, RF-based speed control, and intelligent data analysis, the proposed system offers a multifaceted approach to enhancing HEV performance.

Related Work

1. Title: Enhancing the Energy Efficiency of Fully Electric Vehicles via the Minimization of Motor Power Losses

Authors: A. Pennycott,P. Gruber,A. Sorniotti,T. Goggia,

Publication: 2013 IEEE International Conference on Systems Man and Cybernetics

Individually-controlled power trains of fully electric vehicles present an opportunity to enhance the steady-state and transient cornering response of a car via continuously-acting controllers and enable various "driving modes" to be available. This study investigates the associated potential for energy savings through the minimization of power losses from the motor units via wheel torque allocation. Power losses in straight-ahead driving and a ramp steer maneuver for different motor types and under different wheel torque allocation schemes are analyzed in an offline simulation approach. Significant reductions in motor power losses are achieved for two motor types using an optimization scheme based on look-up tables of motor loss data. Energy loss minimization cannot be achieved through a direct quadratic approximation of the power losses."

2. Title: Efficiency enhancement of wireless charging for Electric vehicles through reduction of coil misalignment

Authors:Vatsala,Aqueel Ahmad,Mohammad Saad Alam,Rakan C Chaban,

Publication: 2017 IEEE Transportation Electrification Conference and Expo (ITEC)

In response to the ever increasing pollution levels and depleting fossil fuels, Plug-in Electric vehicle, hybrid electric vehicle and Electric vehicle (xEVs) technologies are emerging successfully in the automotive industry. The range anxiety issue of the xEVs customers are being addressed through various charging methods. The major hurdle in adoption of xEV is deployment of charging infrastructure. The wireless charging technology is being mechanized as a preferred option in the evolving xEV market. A substantive issue in the commercialization of wireless charging is the misalignment of the vehicle and the charging pad. This paper proposes and discusses a scheme which can significantly adjust the alignment between the coils by the deliberate movement of the receiver coil in response to the magnetic field of the transmitter coil. This will reduce the additional technique required for misalignment."

3. Title: Enhancement of Charging Efficiency of Batteries for Electric Vehicles: Review

Authors: Srinath M S,R Gunabalan,

Publication: 2022 Fourth International Conference on Emerging Research in Electronics Computer Science and Technology (ICERECT)

Computer Science and Technology (ICERECT)","abstract.

4. Title: Energy Efficiency Improvement for an Electric Vehicle PM BLDC Propulsion System Using Phase Advance and Dwell Control

Authors:LiviuPopescu,Leonard Melcescu,Ovidiu Craiu,

Publication: 2022 International Conference on Electrical Computer Communications and Mechatronics Engineering (ICECCME)

- Improving the propulsion system used in mobility applications remains a challenge for performant electric motors such as PM BLDC (Permanent Magnets Brushless DC motors). Their traction characteristic recommends them for EVs (Electric Vehicles), providing high power density and starting torque. The application of flux weakening techniques is not possible for such motors and other techniques are necessary. The actual paper presents the usage of PA (Phase Advance) and DC (Dwell Control) in a new perspective, not only for operational area extension but especially for efficiency improvement and the reduction of the electric energy consumption on EVs. With PA, the opening of commutation transistors sooner, before the trapezoidal back EMF (Electromotive Force) attempts the maximum value, increases the voltage applied on the phase terminals of the motor phase. In parallel, the blocking of the transistors is delayed using the DC technique. The phase current increases faster and the electromagnetic torque increases. Under MATLAB-Simulink, a speed-controlled motor allows for determining the pairs of PA and DC angles maximizing the energetic efficiency of the EV powertrain using two motors. By submitting the EV to a normalized testing cycle the application of the method confirms the powertrain capabilities to cover the request reducing the electric energy consumption."

Existing System:

Current energy management systems for hybrid electric vehicles (HEVs) primarily rely on basic algorithms that switch between electric and internal combustion engine (ICE) modes based on predetermined conditions, such as battery state of charge or vehicle speed. While these systems have improved fuel efficiency and reduced emissions to some extent, they often lack the adaptability to respond to dynamic driving conditions effectively. Existing systems typically do not account for external factors such as terrain variations, road gradients, or real-time traffic conditions. As a result, vehicles may operate inefficiently, wasting fuel during uphill climbs or failing to utilize regenerative braking effectively during descents. Additionally, many current systems do not integrate safety features that regulate speed in sensitive areas, leading to potential risks in urban environments where pedestrians and cyclists are present. Consequently, there is a pressing need for more sophisticated energy management solutions that can optimize energy usage in real time and enhance overall vehicle performance while prioritizing safety.

Drawbacks:

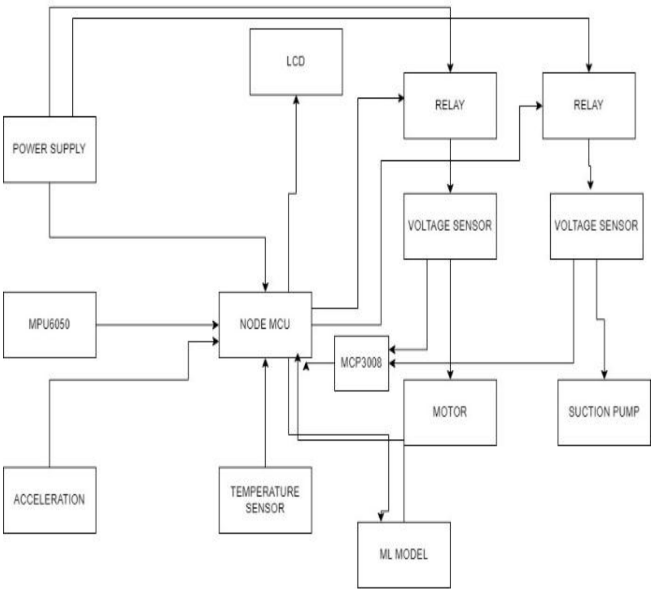
✓ **Limitations of Current HEV Energy Management Systems:**
- Depend on fixed thresholds or driver input for energy switching.
- Lack adaptability to real-time terrain and driving style changes.

✓ **Efficiency and Emission Challenges:**
- Focus primarily on fuel efficiency, neglecting optimal emissions reduction.
- Struggle with inefficiencies during rapid acceleration and steep climbs.

✓ **Need for Intelligent Adaptation:**
- Conventional systems fail to maximize hybrid propulsion benefits.
- A smarter system is required for real-time dynamic energy optimization.

Proposed Solution:

The proposed energy management system for HEVs addresses the limitations of existing technologies by integrating advanced slope detection techniques, RF-based speed control mechanisms, and machine learning algorithms. This innovative system continuously analyzes the vehicle's terrain, allowing for automatic switching between electric and fuel modes based on real-time conditions. For instance, during steep ascents, the system will engage the ICE for optimal power, while during declines, it will activate regenerative braking to recover energy. Furthermore, the RF-based speed control feature will ensure compliance with speed limits in sensitive zones, enhancing safety by alerting drivers to adjust their speed accordingly. The system's use of machine learning allows it to adapt to changing driving patterns and predict future conditions, ensuring optimal energy management tailored to individual driving styles. By seamlessly integrating these features, the proposed system aims to enhance fuel efficiency, reduce emissions, and significantly improve safety, making HEVs a more sustainable and reliable choice for modern transportation.



MERITS:

- **Slope Detection:** Sensors analyze road slope in real time to decide energy mode.
- **Automated Switching**: Dynamically shifts between electric (flat/downhill) and fuel (uphill/load).
- **Regenerative Braking:** Recharges battery during downhill driving for maximum efficiency.
- **Smart Algorithms:** Optimizes energy use using real-time sensor data (speed, slope, load).
- **Fuel & Emission Reduction:** Enhances fuel economy while cutting greenhouse gas emissions.
- **Seamless Driving Experience:** Ensures smooth transitions for optimal performance.

MODULE DESCRIPTION:

A module is a Hardware and software component or part of a program that contains one or more routines.

HARDWARE:

✓ **NODEMCU (ESP8266)**

The Atmel AVR® core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in a single instruction executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers. The ESP8266/P provides the following features: 32Kbytes of In-System Programmable Flash with Read-While-Write capabilities, 1Kbytes EEPROM, 2Kbytes SRAM, 23 general purpose I/O lines, 32 general purpose working registers, Real Time Counter (RTC), three flexible Timer/Counters with compare modes and PWM, 1 serial programmable USARTs , 1 byte-oriented 2-wire Serial Interface (I2C), a 6- channel 10- bit ADC (8 channels in TQFP and QFN/MLF packages) , a programmable Watchdog Timer with internal Oscillator, an SPI serial port, and six software selectable power saving modes.This allows very fast start-up combined with low power consumption. In Extended Standby mode, both the main oscillator and the asynchronous timer continue to run. Atmel offers the QTouch® library for embedding capacitive touch buttons, sliders and wheels functionality into AVR microcontrollers. The patented charge-transfer signal acquisition offers robust sensing and includes fully debounced reporting of touch keys and includes Adjacent Key Suppression® (AKS™) technology for unambiguous detection of key events. The easy-to-use Q Touch Suite toolchain allows you to explore, develop and debug your own touch applications. The device is manufactured using Atmel's high density non-volatile memory technology. The On-chip ISP

Flash allows the program memory to be reprogrammed In-System through an SPI serial interface, by a conventional non-volatile memory programmer, or by an On-chip Boot program running on the AVR core.

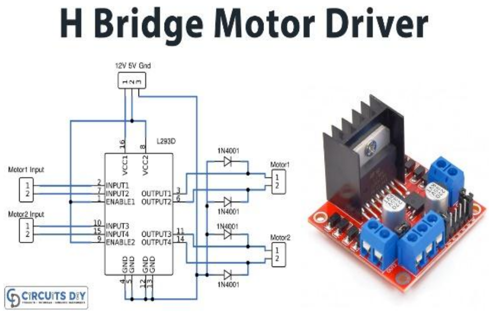
✓ **LIQUID CRYSTAL DISPLAY (LCD)**

A Liquid Crystal Display (LCD) is an electronically-modulated optical device shaped into a thin, flat panel made up of any number of colour or monochrome pixels filled with liquid crystals and arrayed in front of a light source (backlight) or reflector. It is often utilized in battery-powered electronic devices because it uses very small amounts of electric power. LCD has material, which continues the properties of both liquids and crystals. Rather than having a melting point, they have a temperature range within which the molecules are almost as mobile as they would be in a liquid, but are grouped together in an ordered from similar to a crystal. They are used in similar applications where LEDs are used. These applications are display of display of numeric and alphanumeric characters in dot matrix and segmental displays.

LCD consists of two glass panels, with the liquid crystal materials sandwiched in between them. The inner surface of the glass plates is coated with transparent electrodes which define in between the electrodes and the crystal, which makes the liquid crystal molecules to maintain a defined orientation angle. When a potential is applied across the cell, charge carriers flowing through the liquid will disrupt the molecular alignment and produce turbulence.

When the liquid is not activated, it is transparent. When the liquid is activated the molecular turbulence causes light to be scattered in all directions and the cell appears to be bright. Thus the required message is displayed. When the LCD is in the off state, the two polarizer's and the liquid crystal rotate the light rays, such that they come out of the LCD without any orientation, and hence the LCD appears transparent.

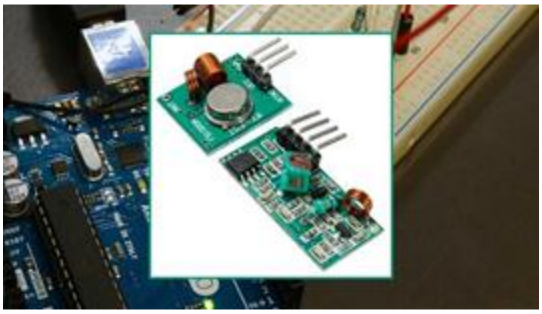
✓ **H-BRIDGE:**



The Device is a monolithic integrated high voltage, high current four channel driver designed to accept standard DTL or TTL logic levels and drive inductive loads (such as relays solenoides, DC and stepping motors) and switching power transistors. To simplify use as two bridges each pair of channels is equipped with an enable input. A separate supply input is provided for the logic, allowing operation at a lower voltage and internal clamp diodes are included. This device is suitable for use in switching applications at frequencies up to 5 kHz. The L293D is assembled in a 16 lead plastic packaage which has 4 center pins connected together and used for heatsinking The L293DD is assembled in a 20 lead surface mount which has 8 center pins connected together and used for heatsinking.The L293 and L293D are quadruple high-current half-H drivers. These devices are designed to drive a wide array of inductive loads such as relays, solenoids, DC and bipolar stepping motors, as well as other high-current and high-voltage loads. All inputs are TTL compatible and tolerant up to 7 V. Each output is a complete totem-pole drive circuit, with a Darlington transistor sink and a pseudo-Darlington source. Drivers are enabled in pairs, with drivers 1 and 2 enabled by 1,2EN and drivers 3 and 4 enabled by 3,4EN. When an enable input is high, the associated drivers are enabled, and their outputs are active and in phase with their inputs. When the enable input is low, those drivers are disabled, and their outputs are off and in the high-impedance state.

With the proper data inputs, each pair of drivers forms a full-H (or bridge) reversible drive suitable for solenoid or motor applications. On the L293, external high-speed output clamp diodes should be used for inductive transient suppression. On the L293D, these diodes are integrated to reduce system complexity and overall system size. A VCC1 terminal, separate from VCC2, is provided for the logic inputs to minimize device power dissipation. The L293 and L293D are characterized for operation from 0°C to 70°C.

- ✓ **RF433MHz Transmitter/Receiver:**



Throughout this tutorial we'll be using the FS1000A transmitter and corresponding receiver, but the instructions provided also work with other 433MHz transmitter/receiver modules that work in a similar fashion. These RF modules are very popular among the Arduino tinkerers and are used on a wide variety of applications that require wireless control.

These modules are very cheap and you can use them with any microcontroller (MCU), whether it's an Arduino, ESP8266, or ESP32.

Specifications RF 433MHz Receiver

Frequency Range: 433.92 MHz

Modulation: ASK

Input Voltage: 5V

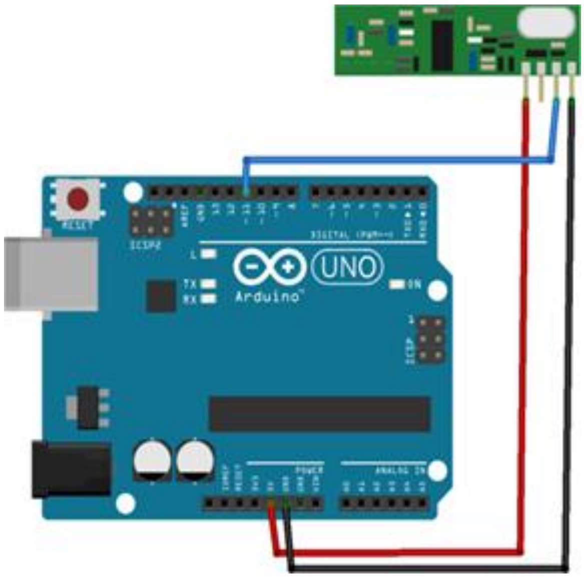
Specifications RF 433MHz Transmitter

Frequency Range: 433.92MHz

Input Voltage: 3-12V

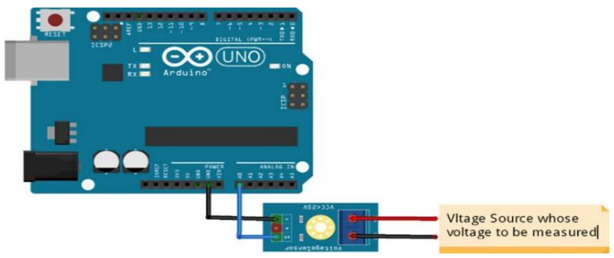
In this we build a simple example that sends a message from an Arduino to another using 433 MHz. An Arduino board will be connected to a 433 MHz transmitter and will send the "Hello World!" message. The other Arduino board will be connected to a 433 MHz receiver to receive the messages.

- ✓ **Transmitter Circuit:**



In project the transmitter is sending a message "Hello World!" to the receiver via RF. Those messages are being displayed in receiver's serial monitor. The following figure shows what you should see in your Arduino IDE serial monitor.some realistic expectations when using this module. They work very well when the receiver and transmitter are close to each other. If you separate them too far you'll lose the communication. The communication range will vary. It depends on how much voltage you're supplying to your transmitter module, RF noise in your environment, and if you're using an external antenna.Decode and Send 433 MHz RF Signals with ArduinoThis guide shows how to use an Arduino to decode 433 MHz signals from RF remotes, and send them with an Arduino and a 433 MHz transmitter to remotely control mains switches outlets.It's difficult to come up with a solution that is safe and works for everyone. One of the easiest and safest ways to remotely control appliances connected to mains voltage is using radio frequency (RF) controlled outlets.

✓ **VOLATGE SENSOR:**



Voltage Detection Sensor Module Features & Specifications

Input Voltage: 0 to 25V

Voltage Detection Range: 0.02445 to 25

Analog Voltage Resolution: 0.00489V

Needs no external components

Easy to use with Microcontrollers

Small, cheap and easily available

Dimensions: 4 × 3 × 2 cm

Brief about Voltage Sensor Module:

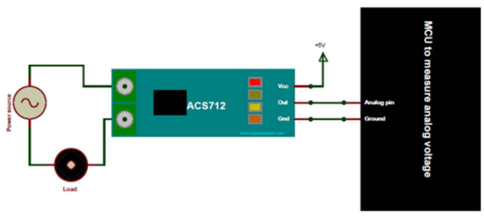
Voltage Detection Sensor Module is a simple and very useful module that uses a potential divider to reduce any input voltage by a factor of 5. This allows us to use the Analog input pin of a microcontroller to monitor voltages higher than it capable of sensing. For example, with a 0V - 5V Analog input range, you are able to measure a voltage up to 25V. This module also includes convenient screw terminals for easy and secure connections of a wire. Input and output voltage can be calculated using:

Vin = Vout * (R2/(R1+R2))

Here R1 = 30K ohm and R2 = 7.5K ohm

Vout = (analogvalue * 5 / 1024).

✓ **Current sensor:**



The **ACS712 Module** uses the famous **ACS712 IC** to **measure current** using the Hall Effect principle. The module gets its name from the IC (ACS712) used in the module, so for you final products use the IC directly instead of the module.These ACS712 module can measure current AC or DC current ranging from +5A to -5A, +20A to -20A and +30A to -30A. You have to select the right range for your project since you have to trade off accuracy for higher range modules. This modules outputs Analog voltage (0-5V) based on the current flowing through the wire; hence it is very easy to interface this module with any microcontroller. So if you are looking for a module to measure current using a microcontroller for you project, then this module might be the right choice for you.As told earlier it is very simple to **interface the ACS712 Module with Microcontrollers**. The below diagram would be more illustrative.The ACS712 module has two phoenix terminal connectors (green colour ones) with mounting screws as shown above. These are the terminals through which the wire has to be passed. In our case I am measuring the current drawn by the motor so the wires that is going to the load (motor) is passed through the ACS 712 Module. Make sure the module is connected in series with the load and be extra cautious to avoid shorts.

On the other side we have three pins. The Vcc is connected to +5V to power the module and the ground is connected to the ground of the MCU (system). Then the analog voltage given out by the ACS712 module is read using any analog pin on the Microcontroller.

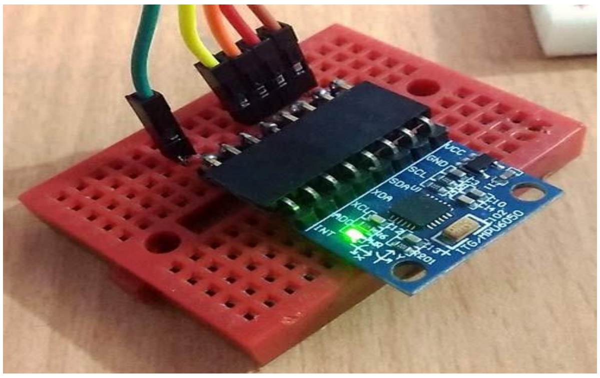
✓ **TRANSFORMER:**

This document presents the solution for a 12V 1A flyback converter based on the Infineon OPTIREG™ TLE8386-2EL controller and IPD50N08S4-13 OptiMOS™-T2. The user is guided through the component selections, the circuit design and, finally, an overview of the experimental results are presented. The TLE8386-2EL is part of the Automotive OPTIREG™ family and it implements a low-side-sense current mode controller with built in protection features. The device is AECQ-100 qualified. The IPD50N08S4-13 is an AEC-Q101 qualified 80V N-channel enhanced mode MOSFET, it is part of the OptiMOS™-T2 family. Intended audience This document is intended for power supply design engineers, application engineers, students, etc., who need to design a Flyback converter for automotive power applications where a galvanic isolation between two voltage domains is required. In particular the focus is on a battery connected flyback that delivers up to 12W at 12V output voltage; the intention is to provide the user with all of the needed information to fully design and characterize the SMPS bringing it from an engineering concept to its production. Specific features and applications are: - 48V to 12V Automotive applications - Isolated current mode SMPS - Flyback regulators with auxiliary sensing.

✓ **RECTIFER CIRCUIT:**

We have learnt in rectifier circuits about converting a sinusoidal ac voltage into its corresponding pulsating dc. Apart from the dc component, this pulsating dc voltage will have unwanted ac components like the components of its supply frequency along with its harmonics (together called ripples). These ripples will be the highest for a single-phase half wave rectifier and will reduce further for a single-phase full wave rectifier. The ripples will be minimum for 3-phase rectifier circuits. Such supply is not useful for driving complex electronic circuits. For most supply purposes constant dc voltage is required than the pulsating output of the rectifier. For most applications the supply from a rectifier will make the operation of the circuit poor. If the rectifier output is smoothened and steady and then passed on as the supply voltage, then the overall operation of the circuit becomes better. Thus, the output of the rectifier has to be passed though a filter circuit to filter the ac components. The filter is a device that allows passing the dc component of the load and blocks the ac component of the rectifier output. Thus the output of the filter circuit will be a steady dc voltage. The filter circuit can be constructed by the combination of components like capacitors, resistors, and inductors. Inductor is used for its property that it allows only dc components to pass and blocks ac signals. Capacitor is used so as to block the dc and allows ac to pass. All the combinations and their working are explained in detail below. As the name of the filter circuit suggests, the Inductor L is connected in series between the rectifier circuit and the load.

✓ **MPU6050 Gyro Sensor:**



MPU-6050 is an 8 pin 6 axis gyro and accelerometer in a single chip. This module works on I2C serial communication by default but it can be configured for SPI interface by configuring it register. For I2C this has SDA and SCL lines. Almost all the pins are multifunctioning but here we are proceeding only with I2C mode pins.

✓ **SOFTWARE:**

Python ,ThonnyIDE ,Matlab software

➢ **PYTHON:**

Python is an interpreter, high-level, general-purpose programming language. Created by Guido van Rossum and first released in 1991, Python's design philosophy emphasizes code readability with its notable use of significant whitespace.Python is an easy to learn, powerful programming language. It has efficient high-level data structures and a simple but effective approach to object- oriented programming. Python's elegant syntax and dynamic typing, together with its interpreted nature, make it an ideal language for scripting and rapid application development in manya reason most platforms andmay be freely distributed. The same site also contains distributions of and pointers to many free third party Python modules, programs and tools, and additional documentation. The Python interpreter is easily extended with new functions and data types implemented in C or C++ (or other languages callable from C). Python is also suitable as an extension language for customizable applications. This tutorial introduces the reader informally to the basic concepts and features of the Python language and system. It helps to have a Python interpreter handy for hands-on experience, but all examples are self-contained, so the tutorial can be read off- line as well. For a description of standard objects and modules, see library-index. Reference-index gives a more formal definition of the language. To write extensions in C or C++, read extending-index and c-api-index. There are also several books covering Python in depth. This tutorial does not attempt to be comprehensive and cover every single feature, or even every commonly used feature. Instead, it introduces many of Python's most notes worthy features, and will give you a good idea of the language's flavor and style. After reading it, you will be able to read and write Python modules and programs, and you will be ready to learn more about the various Python library modules described in library-index. If you do much work on computers, eventually you find that there's some task you'd like to automate.

- **THONNY IDE:**

Thonny is as mall and light weight Integrated Development Environment. It was developed to provide a small and fast IDE, which has only a few dependencies from other packages. Another goal was to be as independent as possible from a special Desktop Environment like KDE or GNOME, so Thonny only requires the GTK2 toolkit and therefore you only need the GTK2 runtime libraries installd to run it.

For compiling Thonny yourself, you will need the GTK (>= 2.6.0) libraries and header files. You will also need the Pango, Gliband ATK libraries and header files. All these files are available at http://www.gtk.org. Furthermore you need, of course, a C compiler and the Make tool; a C++ compiler is also required for the included Scintilla library. The GNU versions of these tools are recommended. At startup, Thonny loads all files from the last time Thonny was launched. You can disable this feature in the preferences dialog (see Figure 3-4). If you specify some files on the command line, only these files will be opened, but you can find the files from the last session in the file menu under the "Recent files" item. By default this contains the last 10 recently opened files. You can change the amount of recently opened files in the preferences dialog. You can start several instances of Thonny , but only the first will load files from the last session. To run a second instance of Thonny , do not specify any file names on the command-line, or disable opening files in a running instance using the appropriate command line option.

- **MATLAB:**

MATLAB, software is a technical matrix manipulating based computation software manipulating matrices leads to big data analysis. The things to learn in MATLAB are entering matrices, usage of the: (colon) operator, invoking functions. At the heart of MATLAB is a new high level language due to its multilanguage inheritance fully exploits its power. Matrix manipulation and function working will be the basics of MATLAB and. Users will be rewarded with high productivity, high- creativity, and strong computing power that will change the way us work. Introduction - describes the basic and commands and components of the MATLAB system. Development Environment - introduces the MATLAB development environment which is based script making based on our needs, including information about toolboxes and the MATLAB desktop window environment.

Manipulating Matrices - introduces how to use MATLAB to generate matrices and perform mathematical operations on matrices such addition and various mathematical operations. Graphics - introduces MATLAB graphic capabilities, including information about plotting data, annotating graphs, working with large data base and working with images. Programming with MATLAB - describes how to use the MATLAB language to create scripts and functions based on external calculations, and manipulate data structures, such as cell arrays and multidimensional arrays

Conclusion and Future Work:

This project presents a comprehensive and innovative energy management system for hybrid electric vehicles (HEVs), addressing key challenges such as fuel efficiency, emissions reduction, and road safety. By integrating advanced sensor technologies, slope detection, RF-based speed control, and machine learning algorithms, the system offers real-time adaptability to changing driving conditions. The automatic switching between electric and fuel modes based on terrain, coupled with predictive analytics that optimize energy consumption, ensures a significant improvement in fuel efficiency and a reduction in emissions. The addition of RF-based speed control enhances safety by automatically adjusting vehicle speed in sensitive zones like schools and hospitals.

Overall, this solution provides a forward-thinking approach to sustainable transportation by seamlessly combining energy management with intelligent speed regulation and personalized driving adjustments. As hybrid and electric vehicles become more integral to reducing global carbon footprints, this project sets a new standard for enhancing vehicle performance, safety, and environmental impact. The proposed system not only improves current HEV technology but also lays the groundwork for smarter, more efficient, and safer transportation solutions in the future.

Future advancements in the AI-Based Hybrid EV Assistive System For Fuel and Electric Switching are:

- **Adaptive Driving Behavior Integration** – AI-based learning from driver habits for optimized performance.
- **Vehicle-to-Infrastructure (V2I) Communication** – Smart road data integration for real-time adjustments.
- **Enhanced Battery Management System** – Intelligent algorithms for battery health optimization.

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