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Solenoid EV System using 555 IC Timer

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***Abstract*— Conventional electric vehicles (EVs) have complex rotary Permanent Magnet Synchronous Motors (PMSMs), which require sophisticated control algorithms due to their complex electro-mechanical coupling, posing challenges in system integration.Our investigation delves into the viability of a Solenoid Powered Engine (SPE) as a disruptive linear actuation technology for electric vehicles (EVs). Inspired by the reciprocating motion of internal combustion engines, the SPE strategically positions linear solenoids controlled by a low-cost 555 timer integrated circuit (IC) to generate propulsive thrust. This approach eliminates the need for brushes and commutators found in traditional rotary Permanent Magnet Synchronous Motors (PMSMs), potentially leading to a more robust and lower-maintenance system with reduced operational complexity. Furthermore, the inherent modularity of solenoids offers superior design flexibility compared to conventional EV drivetrains, with the potential to overcome packaging and scalability limitations that hinder current architectures. The SPE's inherent simplicity, achieved through the absence of intricate motor components, has the potential to reduce manufacturing costs and enhance manufacturability compared to Battery Electric Vehicles (BEVs) and Hybrid Electric Vehicles (HEVs).**

***Index Terms*— Linear actuator, Brushless design, Simplified drive train, Propulsion system, 555-timer integrated circuit**

I. INTRODUCTION

The transportation sector faces a crucial challenge: mitigating its significant contribution to global greenhouse gas emissions. In response, a paradigm shift is underway towards cleaner mobility solutions. Electric vehicles (EVs) have emerged as a frontrunner in this endeavor, offering a compelling alternative with zero tailpipe emissions and the potential to leverage renewable energy sources [2]. However, traditional EVs predominantly rely on electric motors as their primary propulsion system, which while advantageous in certain aspects, can present inherent complexities in design, maintenance, and cost. This project ventures into exploring a novel concept: the Solenoid Powered Engine (SPE) for EVs. Drawing inspiration from the reciprocating motion of internal combustion engines, the SPE utilizes strategically positioned linear actuators in the form of solenoids[7].

These solenoids are meticulously controlled by a 555-timer integrated circuit (IC), enabling efficient linear motion for propulsion. This innovative design eliminates the need for brushes and commutators, potentially leading to a simplified, more robust, and lower-maintenance system compared to conventional rotary Permanent Magnet Synchronous Motors (PMSMs) typically employed in EVs [5]. Additionally, the inherent modularity of solenoids offers greater design flexibility and configuration possibilities, potentially surpassing the constraints faced by current EV architectures in terms of packaging and scalability. This analysis examines the performance of a typical

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mid-range sedan EV equipped with a 60 kWh Lithium-ion battery pack and a 150 kW AC permanent magnet synchronous motor (PMSM) with a peak efficiency of 90% [8]. The car is assumed to have a drag coefficient (Cd) of 0.3, a frontal area (A) of 2.5 m², and a total mass (m) of 1500 kg including the battery weight [1][8]. While the SPE concept offers intriguing potential benefits in terms of design simplicity and potentially lower cost, further research and development are crucial to overcome the challenges and validate its performance compared to established EV technologies like PMSMs.

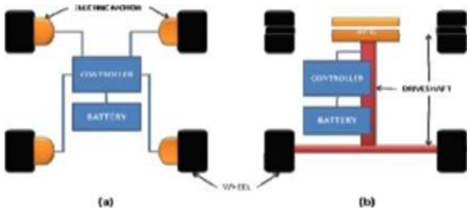

Fig 1. Conventional EV design using electric motor and SPE model.

II. WORKING MODEL

Solenoid EV: Exploring A Simpler Drive

This project delves into the "Solenoid EV", a concept using strategically placed linear solenoids. A 555 timer IC orchestrates their activation via relay circuits and dedicated driver ICs. Capacitors and diodes enhance circuit stability and protect components. This design aims to achieve propulsion through sequential solenoid activation, potentially offering a simpler and potentially lower-cost alternative to traditional electric vehicle motors. The main components of the System are:

1.Solenoid
2. 555 IC timer
3. Solenoid driver circuit
4. Relay driver circuit
5. Variable resistor
6. Battery
7. Adapter
8. Diode

A. 555 IC Timer

The 555 timer IC is a versatile and popular integrated circuit primarily known for generating precise timing signals and oscillations. This functionality makes it useful in various applications, including timers, delay circuits, pulse width modulation (PWM) generators, and even musical instruments. Its ease of use, low cost, and wide availability make it a popular choice for both hobbyists and engineers. Additionally, the ability to be configured in different modes like astable, monostable, and bistable offers flexibility for a diverse range of timing needs. The 555 timer IC presents a rudimentary approach for actuating solenoids within a conceptual Solenoid EV design. It assists in:

1. System Power and control
2. Pulse width modulation
3. Duty cycle & Solenoid activation
4. Amplification and Solenoid Driving
5. Sequential Solenoid Activation for Movement

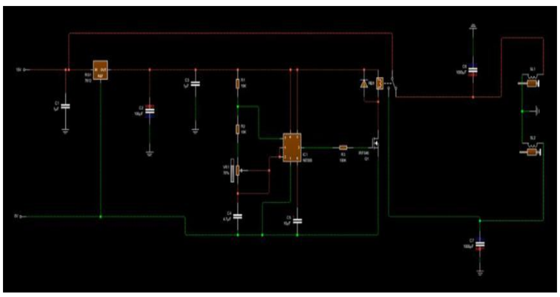

Fig 2. Circuit Diagram

Working of the Circuit

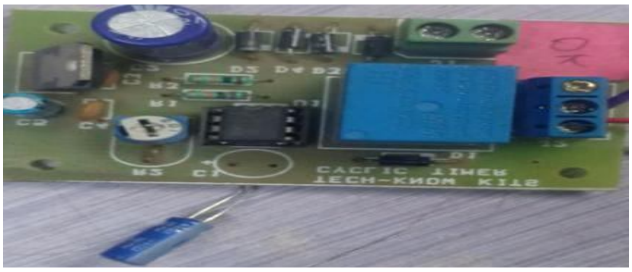

Fig 3. Real time Circuit

Here, a 555 timer integrated circuit (IC) is employed in an astable operating mode. Pin 3 provides a continuous square wave output that activates and deactivates the relay. The Relay should be powered once the battery is connected to the circuit. Recheck the connections if it doesn't work. Additionally, confirm that electricity is getting to the circuit's parts and that the battery is inserted into the breadboard correctly. Here, you can adjust the variable resistance using a different resistance to alter the relay's clicking speed. Use the appropriate resistors to connect additional solenoids in parallel with the first solenoid in this circuit if you wish to add more. This circuit modifies a standard 555 astable multivibrator for independent control of on and off times using diodes and a potentiometer connected to pins 7 and 2.

B. Solenoid Driver Circuit

An apparatus that transforms electrical energy into mechanical energy is a solenoid. Solenoids are frequently used in automation systems for various purposes. They consist of a coil wrapped around a metal core. When energized, the coil generates a magnetic field that moves the metal core. This movement is reversed by a spring when de-energized. Due to the high current draw, solenoids cannot be directly driven by logic circuits and require a driver circuit. to build a driver circuit to control a 12V solenoid valve using an MOSFET, voltage regulator, and other components is done in our project.

III. MATERIALS REQUIRED

1. Solenoid Valve
2. 12V Adapter
3. 7805 Regulator IC
4. IRF540N MOSFET
5. Diode IN4007
6. 0.1uf Capacious
7. 1k and 10k Resistors
8. Connecting wires
9. Breadboard

D. Circuit Diagram

The following are the parameters that you must check while selecting the MOSFET.
1. Gate Source Threshold Voltage VGS(th)
2. Continuous Drain current, Drain-Source
3. On-State Resistance

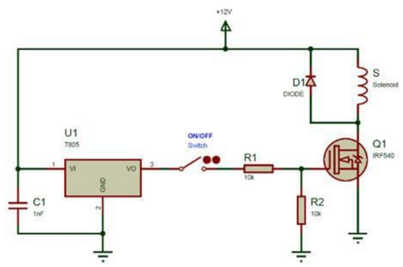

Fig 4. Solenoid Driver Circuit

Working of Solenoid Driver Circuit:

When the switch in between is pressed the +12V supply is provided to the MOSFET and it turns on the Solenoid. When the switch is pressed again it disconnects the +12V supply to MOSFET and the solenoid goes back to off state.

E. Relay driver Circuit

Relay clicking or chattering when the relay driver transistor is turned on or off is one of the major issues with relay-operated circuits. If a light or temperature sensor is the input circuit, then this issue is very serious. The relay clicks when the temperature or light changes, which could spark the connections. An easy way to prevent this issue is to use a tip. The relay driver circuit utilizing the NPN transistor BC 548 is shown below. The transistor's collector and positive rail are linked to the relay. The input signal conducts and pulls the relay when it goes through the 1K resistor and reaches the transistor's base. A brief delay can be created in the relay driver transistor by placing a 470 uF electrolytic capacitor at the base of the transistor, causing the transistor to turn on only when the input signal is present. Once more, the transistor continues to conduct until the capacitor fully drains, even if the input signal stops. This provides clean relay switching and prevents relay clicking.

F. Solenoid

In EVs, beyond motors, solenoids act as versatile muscles. These electromagnets translate electrical signals into controlled movements, enabling them to handle critical tasks like gear changes, clutch operation, even deploying emergency brakes. while offering a solution, their implementation requires expertise due to the high currents and forces involved. Consulting qualified engineers is crucial for ensuring a safe, efficient, and reliable EV experience. In our project we have used linear type of solenoid in order initiate the linear motion to give mechanical output.

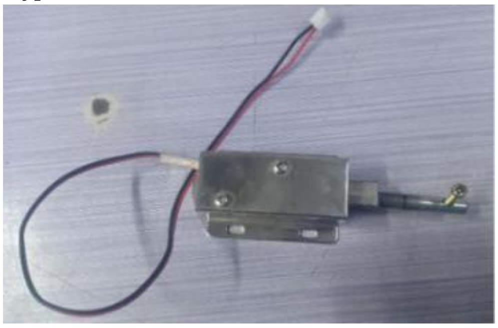

Fig 5. Solenoid

G. Gear System

While most modern electric vehicles (EVs) use single-speed transmissions due to the efficiency and simplicity of electric motors, older converted EVs or those with specific performance needs might still utilize gearboxes. In such cases, the role of the gears remains largely the same as in conventional combustion engine vehicles.

1. Optimizing Engine Performance
2. Matching Power Demand

Gear Ratio Selection

Lower Gears: Provide higher torque for better acceleration at the expense of lower top speed.
Higher Gears: Offer higher top speed but with less torque for slower acceleration.
We have used 50:25 gear ratio in our system

IV. Initial Design And Operations Manual For A Solenoid-Based System

The main layout of a SPE consists of solenoids, feedback mechanism, power transistor and microcontroller.
Fig. 1(b). Proposed SPE system layout. As a whole engine design, SPE is based on mechanical and electronic components. Solenoid, freewheel and output shaft are mechanical components that drive the whole engine motion. These interconnected mechanical components are shown in the remaining components are electronic components that are systematically integrated to develop an electronic controller.
The remaining electrical circuit layout is discussed under the block diagram given below. It depicts the exact working of solenoid systems using 555 IC timer which only included the electronic components in it.

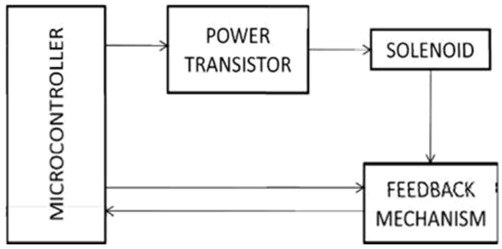

Fig 6. Block Diagram of Existing System

PWM Controller 555

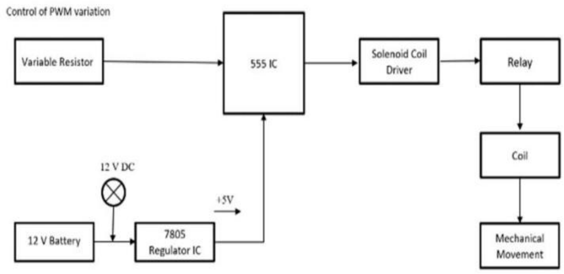

Fig 7. Block Diagram of Proposed System

Our project utilizes a control system mediated by a 555 timer IC to precisely manage the power delivered to a solenoid, ultimately affecting the force it exerts. This fine-tuned control allows for versatile actuation within the system. At the heart of this control system lies a variable resistor. By manually adjusting this resistor, the user sets the control voltage, which then serves as the input for the 555 timer IC. This versatile timer chip interprets this voltage and generates a special type of signal called a Pulse Width Modulation (PWM) signal. The key aspect of a PWM signal is its duty cycle, essentially the percentage of time the signal is "on" compared to its total period. Critically, this duty cycle directly corresponds to the average power delivered to the solenoid. In simpler terms, a higher duty cycle translates to more power reaching the solenoid. The generated PWM signal is then directed to a transistor driver circuit. This crucial component acts as an amplifier, boosting the signal's strength to a level that effectively controls the current flowing through the solenoid. To ensure proper operation, the circuit is powered by a 12V source. However, the 555 timer IC itself requires a stable 12V supply for optimal performance. This stable voltage is achieved through the inclusion of a 7805-voltage regulator. Finally, the solenoid itself is connected to the output of the driver circuit. The resulting movement of the solenoid plunger due to the controlled current can then be harnessed to perform various tasks within the overall system. It's important to remember that this simplified explanation provides a foundational understanding. A deeper dive into the intricacies of the circuit would necessitate expertise in electronics and electrical engineering. For safety reasons, specific circuit designs or instructions cannot be provided. If building this circuit is your goal, consulting with a qualified professional is paramount to ensure a safe and effective implementation.

V. SOLENOD CHARACTERISTICS

Mathematical formulae using in the project includes Time period formula:

$$T=0.693*(R1+2*R2)*C$$

Here,

T = Time period

R1 = is the resistance connected to pin 7(discharge pin)

R2 = the resistance connected between pin 6 and 7

C = the capacitance connected between pin 6 and 2(threshold and trigger)

which is the total time it takes for the output of the 555 timers to complete one cycle.
This is the ratio of the time the output of the 555 IC timer is high (on time) to the total time start to decrease drastically and the engine's torque will reach its maximum value before the value drops in a similar manner as the speed. The reason for this phenomenon is stroke length. As depicted in Fig. 9 and Fig. 10, the engine's torque and speed will decrease significantly at a certain stroke length which is generally known as maximum stroke length. The engine's torque and speed will no longer increase from this point onwards. Thus, it is not practical to operate the engine above the maximum stroke length due to inefficiency. The maximum stroke length is strongly related to the solenoid force – stroke characteristic. This SPE model has a force – stroke characteristic as illustrated in Fig. 11 for its four solenoids. The graph is not linear since the force decreases exponentially as the stroke length increases. The graph even shows that at a certain value of stroke length or higher, the force is too little to provide an adequate amount of acceleration and initial torque to the system. This explains the eventual drop of torque and speed values at that point.
The torque (τ) developed by a solenoid coil can be calculated***using* the formula:

$$\tau = N\ I\ A\ B \sin(\theta)$$

Here,
τ = the torque.
N = the number of turns in the solenoid coil.
I = the current flowing through the coil.
A = the area of the coil.
B = the intensity of the magnetic field.
θ = the angle formed by the magnetic field's direction and the normal to the coil's plane.
This formula considers the current, number of turns, cross-sectional area, magnetic field strength, and the coil's angle with respect to the magnetic field. Adjusting these parameters will affect the torque developed by the solenoid coil.

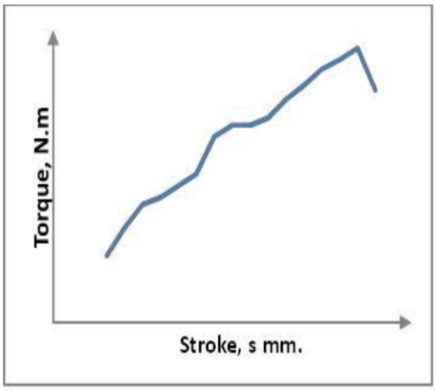

Fig 8. (a) Torque vs Stroke,

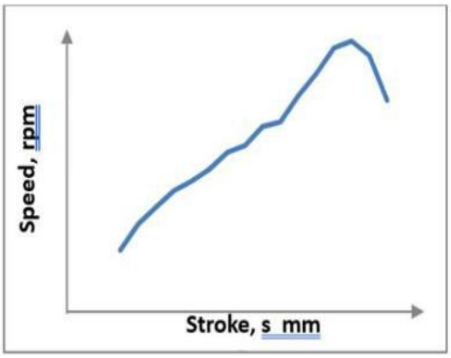

Fig 8.(b) Speed vs Stroke,

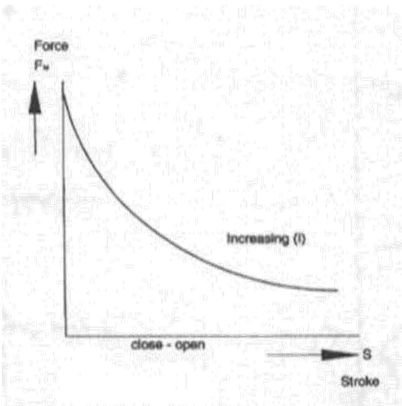

Fig 8. (c) Force vs Stroke.

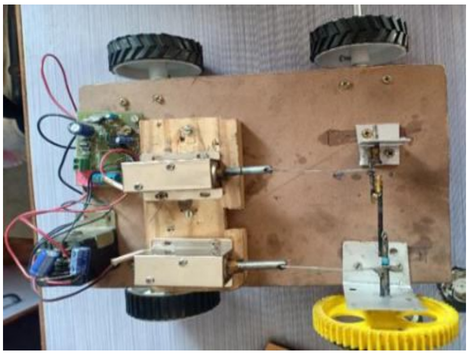

Fig 9. Prototype Solenoid EV

SPECIFICATION TABLE

S. NO	NAME OF THE COMPONENT	QUANTITY	SPECIFICATIONS
1	Solenoid	2	1 Amps
2	Relay	1	12V/5A
3	Variable Resistor	1	220 ohms
4	Battery	4	3.75 V
5	Charger	1	15 V

VI. CONCLUSION

Our investigation into the Solenoid Powered Engine (SPE) employing strategically positioned linear solenoids governed by a low-cost 555 timer IC demonstrates a potentially disruptive approach to EV propulsion. This design eliminates the complexity of brushes and commutators found in traditional PMSMs, paving the way for a more robust, lower-maintenance, and potentially scalable system. Further research efforts will focus on optimizing force generation characteristics, efficiency curves, and thermal management strategies specifically tailored to the SPE. Additionally, exploring advanced control algorithms optimized for the unique actuation behavior of solenoids will be crucial. We believe that successfully addressing these aspects could revolutionize EV design by offering a more robust and adaptable linear actuation technology compared to existing rotary motor architectures.

ACKNOWLEDGEMENTS

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