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Design and Evaluation of the Performance of an Electronic Accelerator for Electric Vehicles

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ABSTRACT: Accelerator pedals can be found in different devices from conventional electronic sewing machines to motorcycles and automobiles. Generally, they are used to control flow from valve or power from pneumatic, hydraulic or electrical systems. In this work, the electronic pedal is designed for use in electric vehicles. It is well understood that when pressure is applied to the throttle pedal in a vehicle, the engine gains acceleration and speed, the opposite occurs when the pressure is withdrawn. This paper discusses the design and evaluation of an electric throttle applicable in electric vehicles.

Keywords: *Signal processing, electronic throttle, electric vehicle.*

I. INTRODUCTION

Electronic accelerator are the latest trends and this is because of the obvious advantages over the gas pedal (mechanical accelerator). Gas pedaled systems due to moving parts are subjected to a lot of wear. Over the life of the car, the various components can wear out. By comparison, an electronic throttle control system has comparatively few moving parts as it sends its signal by electric impulse, not moving parts. Safety can also be improved by proving computer controlled intervention of vehicle controls with systems such as electronic stability control, adaptive cruise control and lane assist systems [1-3].

The electronic accelerator is a crucial component of electrically pedaled vehicles/machines, but their replacements are not available locally in Nigeria. The fact that they are not/ available locally and electric vehicles including cars, tricycles, as well as electrically driven sewing machines are increasingly gaining acceptance and becoming very popular in our society has necessitated the need for this project.

Some of the available pedals are not precise, the voltage output at their extremes (low and high ends) are indeterminate and for some others that have been put to test, it was observed that they were not able to achieve a minimum of zero (0) volts or a maximum of five (5) volts.

METHOD DESCRIPTION

A. Power Supply

A regular dual power supply is designed for the implemented circuits. This features a ±5Vdc designed off a 12V sealed lead-acid battery. This is used to bias the op-amps used in these electronic circuits.

B. Differential amplifier

We will be achieving this circuit using op-amps (UA741 op-amp). This type of amplifier circuit can be for as a subtractor. The output is a result of the difference between the two input signals that will be fed to the inverting and non-inverting pins of the op-amp [5,6,7,8].

The circuit is guided by the following formula:

$$V_o = \frac{-R_2}{R_1}V_1 + (1 + \frac{R_2}{R_1})(\frac{R_4}{R_3+R_4})V_2 \qquad (1)$$

When $R_3 = R_4$ and $R_1 = R_2$, the equation becomes:

$$V_o = V_2 - V_1 \qquad (2)$$

By making the resistors of uniform value, we will be able to simply subtract two voltage inputs V_1 and V_2.

By connecting a hall effect sensor to the +5V and -5V terminals (10V), the output from the sensor becomes half (5 volts) of its input and the presence of a positive or negative magnetic field deflects the output value upward or downward respectively [8-11]. Also, a variable resistor is connected to the 10V (+5V and -5V) power supply and its output varied to same output value as that from the hall effect sensor. The two outputs are sent into the operational amplifier as illustrated in Fig. 1 and the network of resistors together form the differential (subtractor) circuit.

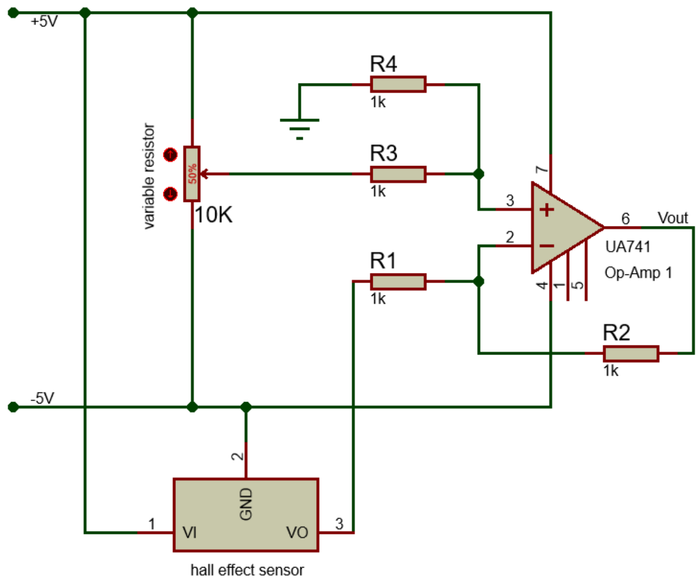

Fig. 1: Differential amplifier circuit of the accelerator pedal module

C. Inverting Amplifier

Under normal operation, an amplified but inverted (i.e., 180° phase shifted) version of the input signal (V_{in}) appears at the output (V_{out}). If the input signal is too large or the amplifier's gain is too high, then the output signal will be clipped at the positive and negative saturation levels ($\pm V_{sat}$). This type of amplifier can be used as a phase shifter as the output generated is of the 180-degree phase shift [5-8].

The output from the differential circuit is a negative value (-4.08). Therefore, there is need for inversion and amplification. This circuit is implemented as shown in Fig. 2.

$$Gain = \frac{V_o}{V_{in}} = \frac{-R_f}{R_{in}} \quad (3)$$

Our main concern in this section is to invert and improve the output voltage to 5V.

$V_o = 5V$

$V_{in} = -4.08V$

$$\frac{R_f}{R_{in}} = -(\frac{V_o}{V_{in}}) \quad (4)$$

$$\frac{R_f}{R_{in}} = -(\frac{5}{-4.08})$$

$$\frac{R_f}{R_{in}} = 1.2$$

We can therefore say that $\frac{R_f}{R_{in}} = \frac{1200}{1000}$

$\therefore R_f = 1200\ ohms$ and $R_{in} = 1000\ ohms.$

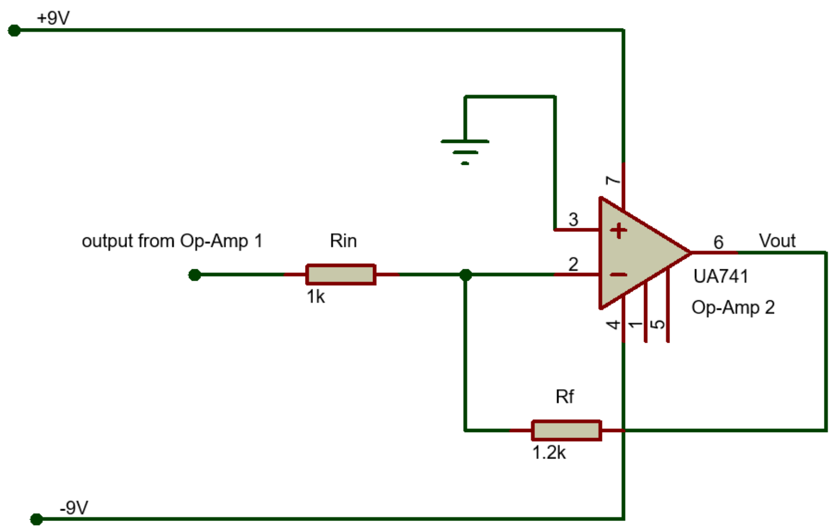

Fig. 2: Inverting amplifier circuit of the accelerator pedal module

III. RESULTS AND DISCUSSION

The voltage from the batteries is passed through LM7805 and LM7905 voltage regulators to reduce noise and to equally regulate it to constant voltages of +5V and -5V respectively. The hall effect sensor is connected across the +5 and -5 volts and due to its mode of operation, it divides the voltage into equal halves and then tends towards the positive or negative direction at the application of a positive or negative magnetic field respectively (this is illustrated in Fig. 2.2). For this reason, the output from the hall effect sensor is in turn passed through the differential op-amp circuit to be able set a difference thereby making it start from 0V and increasing due to an increase in the magnetic field strength. The output from the differential op-amp is passed through the inverting amplifier with a voltage gain of 1.2 to amplify the voltage as explained in Chapter Three, Section 3.2.3 and to equally invert it as the initial output from Section 3.2.2 was a negative value.

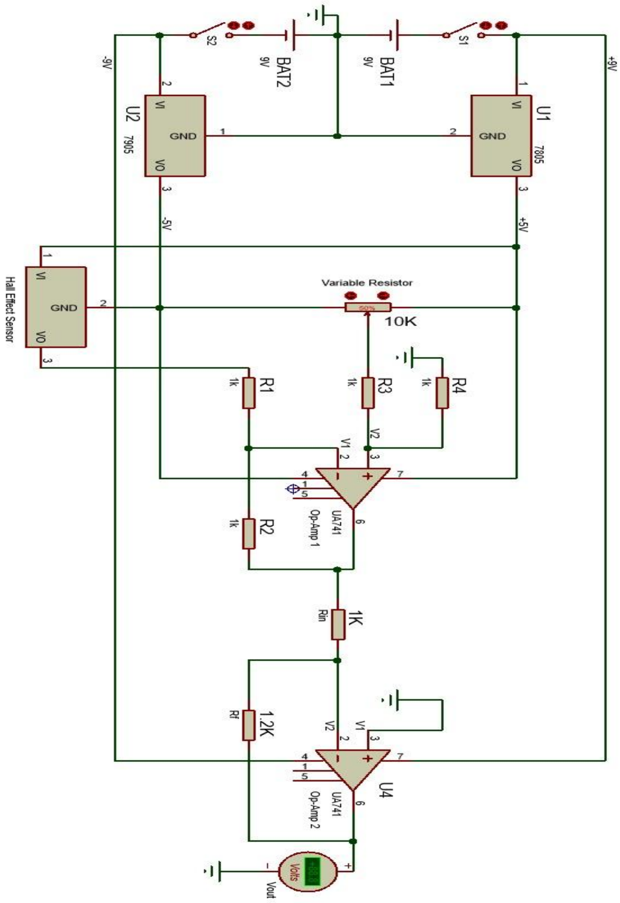

Fig. 3: Compound circuitry of the accelerator pedal module

Table 1: results from laboratory test

Pedal displacement (cm)	Output voltage (V) without the signal processing circuit	Resized output voltage (V) without the signal processing circuit	Output voltage (V) with the signal processing circuit
0	3.89	0	0.15
1	3.92	0.03	0.26
2	3.94	0.05	0.36
3	3.99	0.1	0.75
4	4.12	0.23	1.16
5	4.28	0.39	2.09
6	4.63	0.74	3.46
7	5.10	1.21	4.75
8	6.66	2.77	5.01

The following readings were obtained from laboratory tests. The values for the output voltage without the signal processing circuit is the raw output from the hall effect sensor. The sensor was connected to a 9V battery source but the voltage of the battery has dropped to 7.87V. The drop in the battery voltage is the reason why the readings started from 3.89V and saturated at 6.66V.

Fig. 4a shows the behavior of the Hall effect sensor when biased with 10V and an attached magnet. Fig. 4b is exactly same graph only readjusted to start from zero. Total displacement of accelerator from ground is about 8cm, and it requires a displacement of 7cm to achieve a step change of 1V and a step change of more than 1V between 7cm and 8cm displacement.

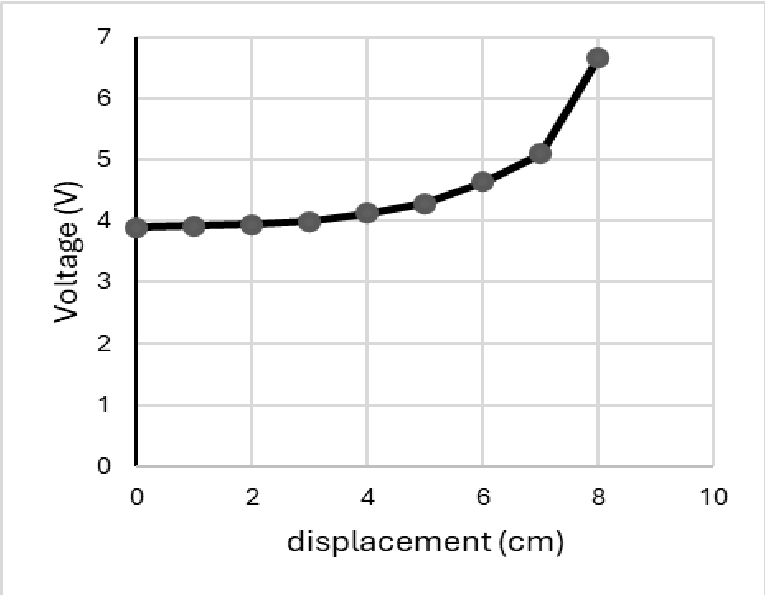

Fig. 4a: Voltage/vertical displacement characteristics of the accelerator pedal module without the signal processing circuit

Fig. 5 shows the behavior of the sensor with supporting signal processing circuitry. It's an exponential curve with the equation of the curve shown in the graph. With this, a suitable logic control circuit can be designed to control the voltage or frequency of an AC motor drivetrain for electric vehicles. Between displacements of 4cm and 7cm, it is almost linear but it is generally exponential and can suit the desired application in electric vehicles.

By using the signal processing circuit, we were able to solve the first issue (output from the hall effect sensor not starting from 0V). This we achieved by using a differential configuration of an op-amp circuit, thereby letting the output to be a difference starting from 0V. The negative output voltage was inverted using the inverting op-amp circuit configuration with a voltage gain of 1.2 to multiply the output with a factor of 1.2 so as to enable it get to 5V.

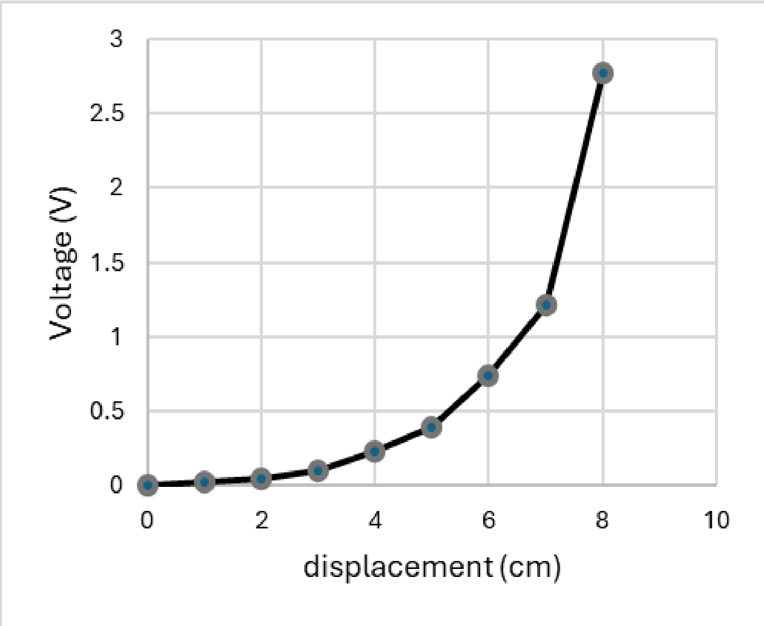

Fig. 4b: Resized voltage/vertical displacement characteristics of the accelerator pedal module without the signal processing circuit.

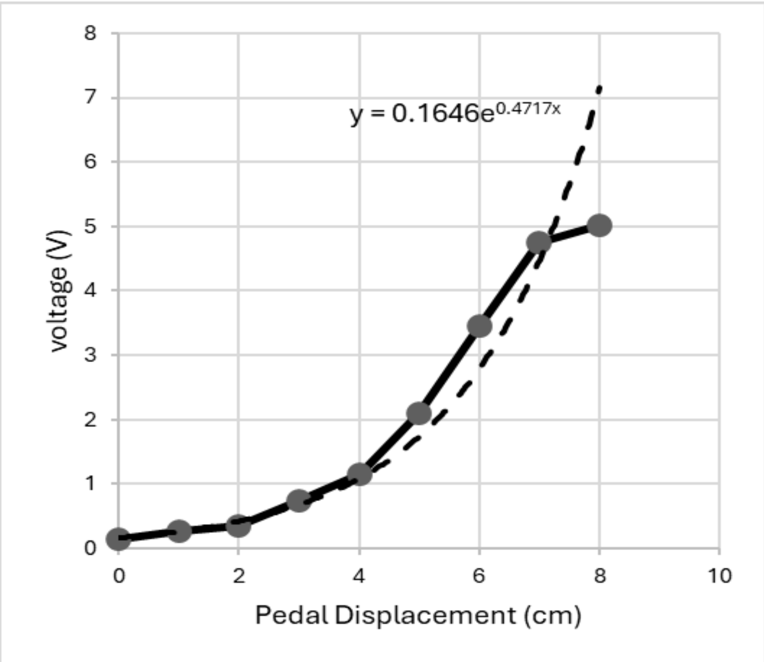

Fig. 5: Voltage/vertical displacement characteristics of the accelerator pedal module with signal processing circuit

IV. CONCLUSION

Fig. 6 and Fig. 7 shows the designed signal processing circuit and the accelerator module. The performance of the system has been evaluated and can be suitably applied in electric vehicles (EVs). The output voltage from the accelerator pedal module increases exponentially from 0V to 5V with respect to the displacement of the pedal. This design is meant for use in EVs. This module was put to test under a maximum input voltage of ±12V. It has a minimum output voltage of 0V and maximum output voltage of 5V with measured currents of up to 4.15mA.

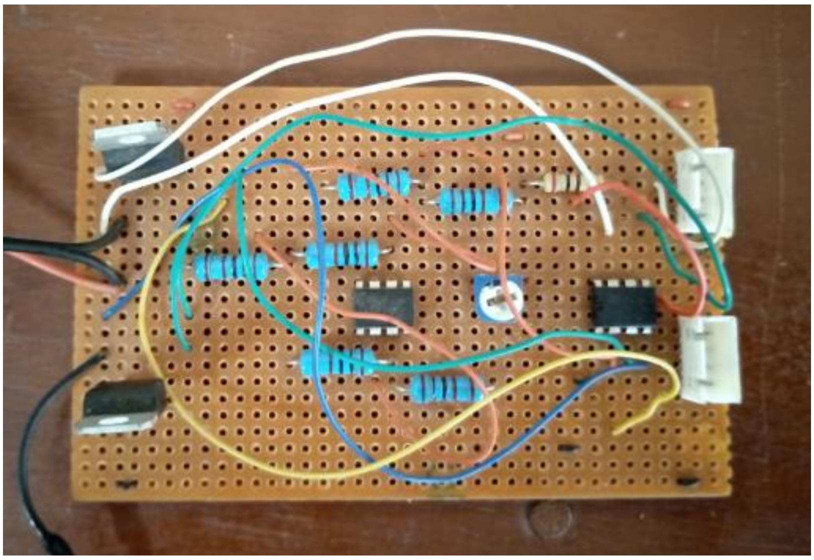

Fig. 6: The implemented circuit of the accelerator pedal module

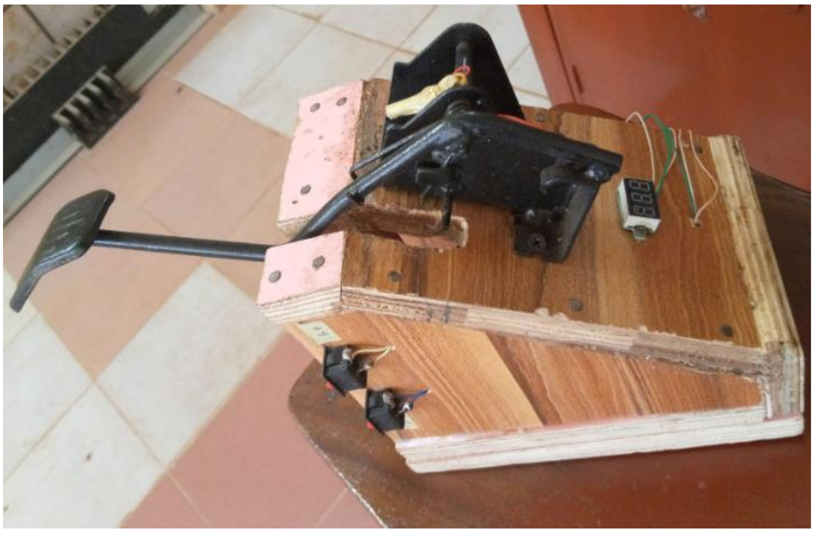

Fig.7: Side view of the accelerator pedal module

V. ACKNOWLEDGEMENT

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