Vol. 20 · March 2015
Print ISSN 2012-3981 • Online ISSN 2244-0445
doi: http://dx.doi.org/10.7719/jpair.v20i1.320
Journal Impact: H Index = 2 from Publish or Perish

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Effectiveness of the Two-in-One Device; Ignition Coil and Spark Plug Testing Instrument

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ABSTRACT

Technological modernization and invention have brought convenience that life has become fulfilling, and they give amusement to our lives. This study aimed to evaluate the effectiveness of the Ignition Coil and Spark Plug Instrument that can be used to determine the condition of an Ignition coil through high voltage output and also spark plug through visible spark. It made use of project and experimental method of research. This was accomplished in three phases namely: the making of the design for the device, constructing the device and testing the device functionality through actual observation. Group of experts coming from the automotive and electronic sectors evaluated the effectiveness of the automotive testing instrument. A five-point Likert scale was used to find the mean product and the descriptive rating in terms of usefulness, effectives, functionality, reliability and safety. The results of the study revealed that the output voltage and frequency are directly proportional to the resistance of network Ra, but inversely proportional to resistance network Rb in the circuit. The output frequency is directly proportional to the output voltage. The evaluation of the group of experts in terms of usefulness, effectiveness, functionality, reliability and safety was rated excellent respectively. The device is an instrument for automotive technicians in testing ignition coil and spark plugs. The researchers recommended further study about the device for its safety because based on the result it has the least rating among the different standards although it was evaluated as "Excellent."

Keywords – Engineering, development, ignition, spark plug, testing instrument, R and D, Vigan City, Philippines

INTRODUCTION

Technological modernization and invention have brought convenience and satisfaction for the family. With the influence of these inventions, life has become fulfilling. Man-made appliances have considerably lessened the burden of everyday household chores. Appliances are electrical and mechanical "household help". They, too, give amusement to our lives.

However, these breakthroughs could not have been possible if not for the miracles brought about by the different electronic components used in these appliances or equipment. Yes, without these little wonders, this advancement in technology is not possible. Thus, life in this wonderful world could have been different. If we look around, it is not difficult to identify the usefulness of the different inventions.

Hafizin (2013), conducted a study entitled "design and development of a portable spark plug tester for motorcycle". The main purpose of his study is to design and develop a spark plug tester for motorcycle user to test the spark plug and ignition wire connectivity to minimized the risk of high voltage shock that the mechanic my receive in testing. He considered ignition system as one of the most important parts of the motorcycle. And, if trouble occurs in the system, the engine will not start due to failure in the combustion process. Improper use of tool by the motorcycle users in diagnosing the condition of spark plugs was observed and that made him think of developing the aforementioned testing instrument.

Arredondo (2009) stated in his article that using a multimeter in ohms mode does not guarantee accuracy in diagnosing an ignition coil either bad or in good condition. He further emphasized that using the said method of testing is useless. However, he suggested the dynamic spark test as one of the best methods in determining the condition of an ignition coil.

In automotive technology, electricity finds its use in several applications such as starting the engine, creating the sparks that ignites the compressed gasoline air mixture, supplying current or charging the battery, operating the lights, horn, airconditioner, radio, electric gauges, among others.

An automotive ignition coil boosts up the amount of voltage sufficient for it to create a spark that jumps across the spark plug gap that ignites the fuel-air mixture. Ignition coil and spark plugs like any other component parts are prone to failure. One way of determining the condition of an ignition coil is to use an ohmmeter to measure the internal winding resistance. However, there are times that the internal resistance may fall within an acceptable range. The technician may get confused due to this situation and might conclude that the problem is not due to the coil, and therefore, spends a great deal of time in the diagnostic process. It is also possible replacing other functional parts until it becomes exhausted and would need replacing the ignition coil.

To eliminate this kind of situation, it is important to have an accurate method and instrument in testing. Also, because ignition coil deteriorate in a progressive manner in which they become weaker and weaker, it is not only desirable to determine whether or not a coil remains to its acceptable amount of internal resistance but also its capability of boosting a high amount of voltage sufficient to cause a spark to occur and how strong the spark is. The trouble of the ignition system may not only be due to defective ignition coil but also may be due to fouled spark plugs it is also desirable to ascertain the accuracy of testing the condition of spark plugs.

The normal way of determining the condition of the spark plug according to William and Donald (1993) is to conduct a spark test by removing the spark plug and connecting it to the ground part of the engine and notice the intensity of spark. The high amount of voltage is created during this method of testing and the technician might receive electrical shock if some safety precautions were not observed. Accordingly there exists today a need for an ignition coil testing device that would promote safety and can verify with certainty whether or not a coil is defective.

OBJECTIVE OF THE STUDY

The researchers aimed to develop and evaluate the effectiveness of the ignition coil and spark plug testing instrument designed to test the condition of the ignition coil and spark plugs. This project may help automotive mechanics to determine the condition of the ignition coil and spark plug with ease and satisfaction. This state-of-the-art technology further eliminates probability that automotive technicians be harmed with the high amount of voltage created by the ignition coil and spark plugs during testing.

FRAMEWORK

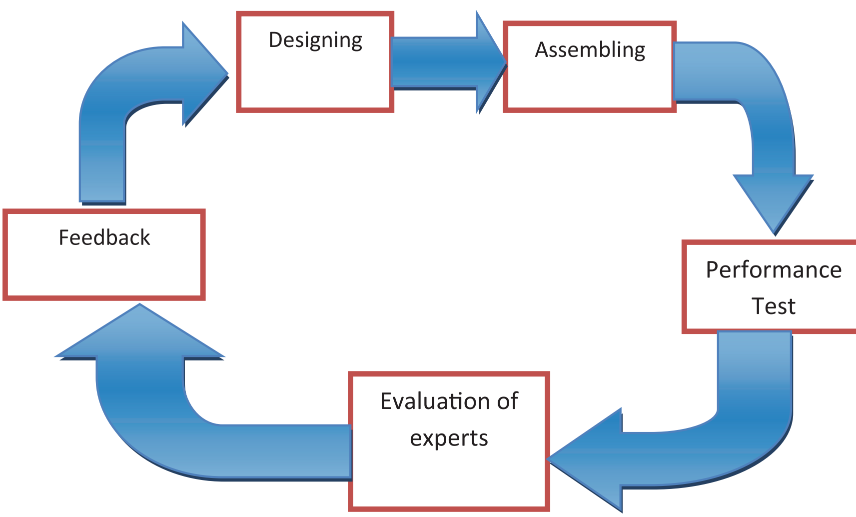

Figure 1. The Experimental Paradigm

As illustrated in the experimental paradigm, the construction of the two in one device Ignition Coil and Spark Plug Testing Device is based on the design, assembling of the instruments. The proper operation of the said device was also observed through series of experimentation. The relationship in the amount resistance, voltage and frequency that governs the proper operation of the device was recorded and analyzed. Evaluation of the assembled instrument was done by electronics and automotive experts in the College of Technology and the College of Teacher Education University of Northern Philippines. Feedback experts were incorporated to improve its usefulness, effectiveness, functionality, reliability and safety.

Alternating current is a type of current that reverses the direction a number of times per second. In the 60 cycle current, the direction of current flow is reversed 120 times per second. Pulsating current is also a type of current that flows intermittently, that is at the first instant the current flows from zero to maximum and back to zero value. At the second instant, no current flow (zero value). At the third instant, there is current flow again with the same value of the first instant. This process is repeated. A transformer cannot be used in a direct current because direct current flows continuously through the coils producing a constant amount of field flux embraced by the circuit. So, there will be no cutting of magnetic lines of force by the coils. Hence, alternating current is used in the transformer to produce electromagnetic induction (Storr, 1999-2014).

According to Fluke (1997), voltmeters or multimeters with other input impedances need to be connected with external shunt or a correction factor to have an accurate measurement. Higher impedance voltmeters or multimeters are provided with a shunt, and lower impedance voltmeters or multimeters should have correction factors.

Applicable formulas follow:

a. The given formula below is used to determine the value of an external shunt resistor (meter impedance >10 MΩ):

$$Rs = \frac{Rm \times 10}{Rm - 10}$$

Where: Rs = Shunt resistance in MΩ

Rm = Voltmeter input impedance in MΩ (>10 MΩ)

Example: If RM = 20 MΩ,

$$Rs = \frac{20 \times 10}{20 - 10} = \frac{200}{10}$$

= 2.0 MΩ

b. The next formula is applicable calculating a correction factor (meter impedance <10 MΩ):

$$Cf = \frac{1.11 + Rm}{1.11 \times Rm}$$

Where: Cf=Correction factor (actual multiplier for meter reading)
Rm = Voltmeter input impedance in MΩ

Example: If Rm = 1 MΩ,

$$Cf = \frac{1.11 + 1}{1.11 \times 1}$$

$$= \frac{2.11}{1.11}$$

$$=1.901$$

Therefore: Meter readings of 0.526 volts correspond to an input of: 0.526 x 1.901 = 1 or 1 kV.

Dvoracek (2006) designed an ignition coil driver which is a combination of suitable charging circuit that charges a 4uF capacitor to 380V. Based on figure 1, when fire switch is short of, small current run through the gate of the SCR to turn it on, by way of a 1k current limiting resistor and a small capacitor for debouching purposes. If the small capacitor becomes fully charged, enough current flow to the gate stops, thus, limiting the SCR from residual in the "on" state if the switch is held down. A ten mega ohms resistor is connected across the capacitor to discharge it once the switch is open. This prepares it for the next switching process. While the SCR is energized, it activates the main capacitor to the primary of the Ignition coil. The voltage across the primary increases to 380V, thus, storing the energy from the capacitor as a sufficient magnetic field. Once the capacitor is discharged, the voltage falls back to zero, and this magnetic field begins collapsing. At that moment, reverse polarity to the initial charging current is created, known as a "flyback". This pulse goes back to the capacitor and charges it back up via a 400V Fast diode connected backward across the SCR. This flyback pulse is anticipated to be around 700V. While the SCR is in the on state, this process continues until the energy is transferred from primary to secondary of the transformer. The pulsed nature of the charging circuit guaranteed that there is always time when no electricity is flowing, thus, allowing the SCR to switch off.

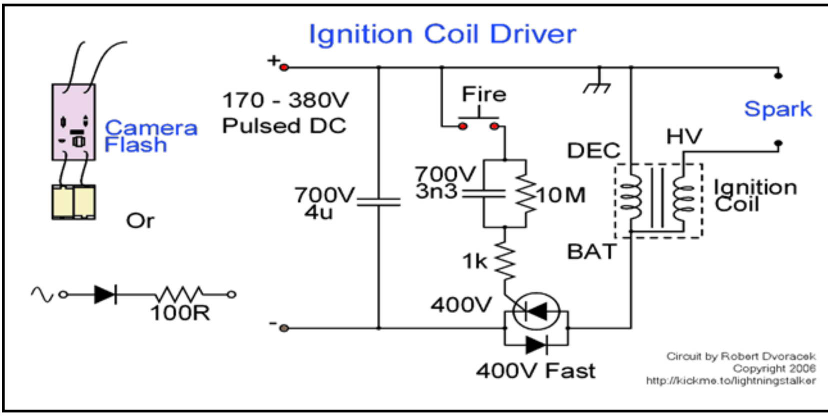

Figure 2. Ignition Coil Driver by Robert Dvoracek

A similar device was designed by Seltzman (2005) based on figure 2. He used 555 timer and three 2n3055 switching transistors to provide a variable frequency, variable voltage inputs to an automotive ignition coil. When supplied with 12V input, it normally creates up to 25KV at the coil's resonant frequency (8 kHz). If the input voltage is increased up to 24 volts, the output voltage will also increase for up to 50KV. However, the switching transistors will be burned out due to excessive input. At utmost output, the coil will create 3-5cm plasma arcs. Capacitors are rated at 50v and resistors also rated 1/2W, 5% tolerance. The output frequency to the coil is controlled by VR1; output voltage is controlled by VR2. V+ is connected to pin 3 on the 5V regulator.

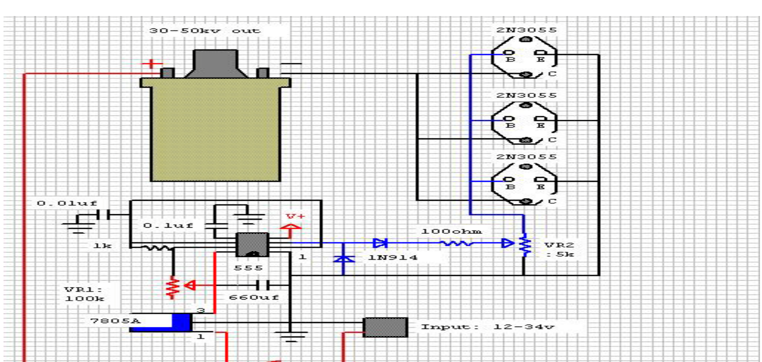

Figure 3. Ignition Coil Driver by Seltzman

Momename (2008) posted the mini power inverter and he used SCR to be the major part electronics, referring to the schematic diagram (Figure 4). The device performs as an Oscillator Generator 400Hz that generates up to 300V with an input of 12V and current 0.8A. The only problem in his circuit is that, it might latch in the switching state if the load excessive or if there is a short at the output, wherein protection must be provided at the input line in the form of a fuse. It would generate for up to 400Hz with an input of 6V inverted to 300 volts using ten watts transformer.

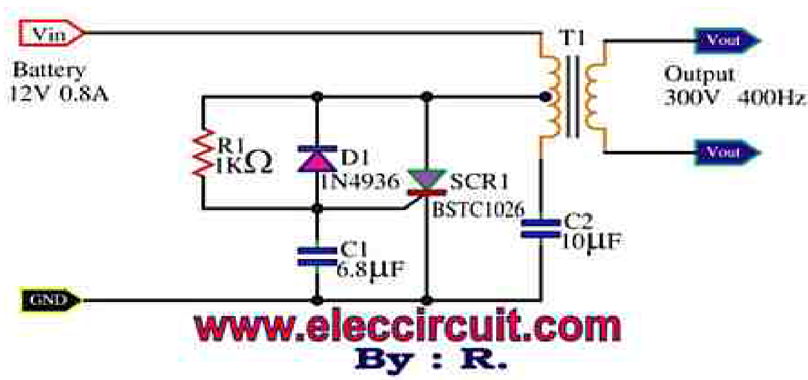

Figure 4. Mini Power Inverter by Momename

Another device was also designed by Roon (2011) (see Figure 5). He invented basic AC inverter Circuit which is more complicated circuit than of the device made by Momename. The IC 555 was utilized to produce the frequency, and then, enlarge with transistor NPN and PNP number TIP41 and TIP42 that drives the coil transformer. It generates an output of about 120V to 230V at frequency 50Hz. By having R4 that controls the circuit during operation. Voltage supply of about 5V to 15V is sufficient enough for the device to operate.

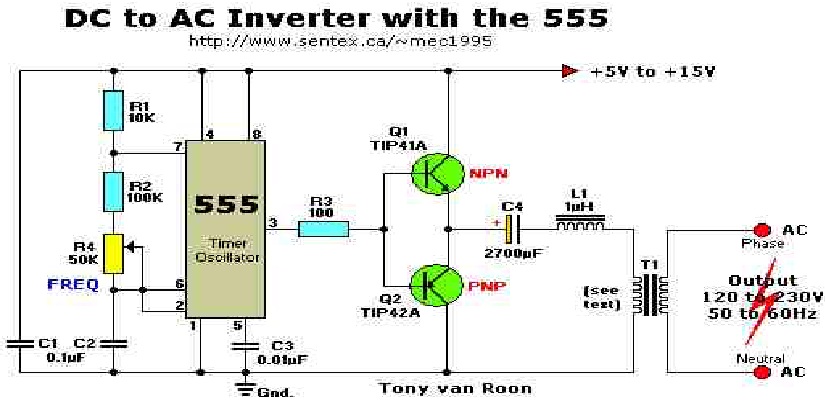

Figure 5. DC to AC Inverter by Roon

According to Storr (1999), one simple and easy way to control the speed of a motor is to regulate the amount of voltage across its terminals and this could be possible using "Pulse Width Modulation" or PWM. The circuit controls the motor with a series of "ON-OFF" pulses and varying the duty cycle, the fraction of time that the output voltage is "ON" compared to when it is "OFF" of the pulses while keeping the frequency constant.

The applied power is controlled by varying the pulses, thus, varying the average DC voltage applied to the motor terminals. By altering/modulating the timing of the pulses the speed of the motor is controlled, i.e. the longer the pulse is "ON", the faster the motor will rotate and likewise, the shorter the pulse is "ON" the slower the motor will rotate.

Therefore, the wider the pulse width, the more average voltage applied to the motor terminals and the stronger the magnetic flux inside the armature windings and the faster the motor will rotate (see Figure 6).

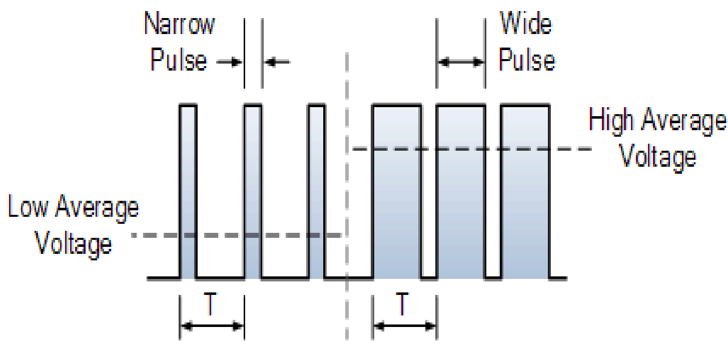

Figure 6. Pulse Width Modulated Waveform

The use of pulse width modulation to control a small motor has the advantage since the power loss in the switching transistor is small because the transistor is either fully "ON" or fully "OFF". As a result, the switching transistor has a much reduced power dissipation giving it a linear type of control which results in better speed stability.

Meanwhile, Bajet and Garcia (2013) designed and developed an Energy Saver Multi-Fed Cooking Stove, made up of scrap iron bars sheet, and a pipe welded together. The multi-fuel cooking stove can be fuelled with firewood, charcoal, farm wastes like corncobs, tobacco stalks, and others, which were usually burned off when the farmers lack knowledge in making use into fertilizer. Further, the researcher found out that in cooking different food, it is significantly different among fuel materials used. This implies that all the fuel materials are significantly different in terms of cooking different food. Furthermore, cooking different food is significantly different in all cooking stoves like LPG, kerosene, clay and electric stove.

Bajet and Bajet (2013) in their study entitled, "Design and Development of Domestic Refrigeration Trainer", disclosed an advancement in the teaching and learning process and the principle operations. It is easy to understand the different connection of electric circuitry in the mechanical components. The trainer can also present the four phases of refrigerant cycle.Its design focuses on skills training approach to aid the beginner student in an easy and comprehensive way of learning the trade in a very limited time that servicing and repair are in his hands.

On the study of Bajet (2013) in Design and Development of Fish Natural Convection Drying Facility, its performance and characterization as a natural convection dryer for stunted tilapia were tested. Parameters in the study were air temperature, relative humidity, drying chamber, moisture content, drying time, capacity and rate. Findings disclosed that drying rate was noted at the highest during first two hours interval with an average drying rate of 7.20 grams per minute. Average drying rate after the tree trials was 2.63 grams per minute. The moisture content of the samples was reduced from 92.86%- 75.23% during the 20 hours of drying and weights of fish samples were also reduced from 20 to 15 kilograms. Further, results on relative humidity were higher at the upper trays compared with the lower trays. The return of investment was 72% and has a payback period of 0.05 year.

MATERIALS AND METHODS

The study used the experimental method of research. It was accomplished through identifying the needed materials type of circuit, designing a desirable circuit for the assembling of the oscillator circuit and the voltage divider circuit, device, testing and evaluation of experts in terms of usefulness, effectiveness, functionality, reliability and safety. The researcher conducted observation and analysis on the amount of resistance, voltage and frequency. A rating scale was used to evaluate the Ignition coil and Spark plug Testing Device usefulness, effectiveness, functionality, reliability, and safety. The designed testing instrument was validated by the experts along Electronics and Automotive Technology through validation form.

In evaluating the acceptability of the device along usefulness, effectiveness, functionality, reliability and safety, the researcher with the assistance of the research committee, devise the rating scale which is used to rate the designed tester based from the given standards as given below:

Numerical Rating	Descriptive Rating
4.20 – 5.00	Excellent
3.40 – 4.19	Very Good
2.60 – 3.39	Good
1.80 – 2.59	Fair
1.00 – 1.79	Poor

The data were treated statistically with the use the mean to describe the evaluation scores of the respondents.

RESULTS AND DISCUSSION

Description of the Device

The device constructed in this study consists of two independent circuits that will perform as an oscillator and voltage divider. The oscillator circuit contains different electronic components that will affect each other as an oscillator/ circuit that will convert the direction of current flow from a direct current into a pulsating current using direct current source which is the 12V DC battery. The frequency of the oscillator circuit output can be adjusted to its desired frequency through the use of the variable resistor. As the name implies, the device can be used to test or determine the condition of an ignition coil and spark plug using the correct setting.

Resistor R_1 combined to the "top" part of the potentiometer, VR_1 represent the resistive network of R_A. While the "bottom" part of the potentiometer added to R_2 represent the resistive network of R_B above. The two IN4005 diodes were used to protect the electronic circuit from the inductive loading of the ignition coil.

The ignition coil to be tested using the device creates large amount of output voltage and this cannot be read by an ordinary voltmeter. The researcher developed a voltage divider circuit used to minimize the high amount of voltage in the secondary output of the ignition coil to be tested for the digital voltmeter to read its actual output voltage (See Figure 7).

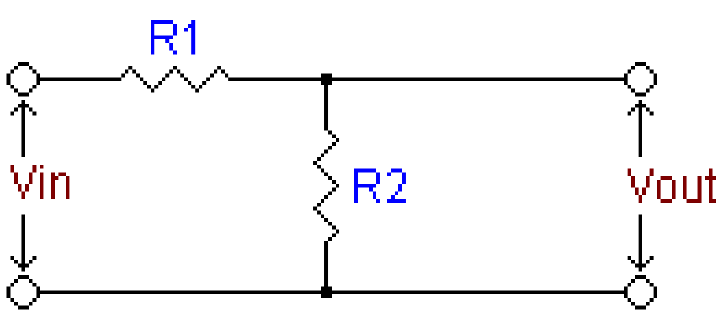

Figure 7. Voltage divider network of the Spark Plug and Ignition Coil Testing Instrument

The circuit is just a combination of two resistors in shunt connection. The Vin is connected to the High voltage output of the ignition coil to be tested and Vout is connected to a suitable digital voltmeter. Based on the designed circuit for the voltage divider, Vin is unknown because we cannot determine the voltage output of the ignition coil by just using an ordinary VOM alone.

The circuit resistance is computed using the following formula:

$$Vin = \frac{R1+R2}{R2} X Vout$$

The resistor values on the voltage divider circuit is computed as follows

Vin = ?

R1 = 33KΩ

R2 = 33Ω

$$Vin = \frac{33{,}000 + 33}{33} X Vout$$

= 1,001 Ω X Vout

If the reading of the specified VOM is 20V it should be multiplied into approximately 1000V and therefore, the actual reading or the voltage coming from the high voltage output of the ignition coil being tested is about 20 kilovolts.

Notes on Safety and Operation of the Two in One Ignition Coil and Spark Plug Testing Instrument

1. DO NOT use the device around explosive gas, vapor, or dust.
2. DO NOT use the device if it operates abnormally. Protection may impair. When in doubt have the device serviced.
3. DO NOT use this device to measure high voltage on power distribution systems.
4. DO NOT attempt touch the spark plug and ignition coil while testing it.
5. Make sure that the connections are firmly attached.
6. Make sure that the battery source is disconnected before putting the spark plug on the socket.
7. Follow the instructions in the user's manual on how to use the device properly.
8. DO NOT drop the device.

The condition of the spark plug can be determined through the following color indicators:

1. Straight bluish white spark – indicates that the spark plug is in good condition.
2. Reddish orange and intermittent spark – indicates that the spark plug is weak.
3. No spark – indicates that the spark plug is open.

Device Setting in Testing Spark Plug and Ignition Coil
Minimum to Mid – ideal for testing Ignition Coil and Spark Plug
Minimum to Maximum – ideal for testing Ignition Coil

Spark Plug Gap Distance
.025 inch - for two-stroke engine.
.035 inch- for four-stroke engine.

The ignition coil must able to produce a voltage from 20 and above to conclude that it is in good condition and must vary its voltage output when the frequency adjuster is adjusted from minimum to maximum. If unconvinced, prove it by disconnecting the high tension wire connection from the port and place it near the port of about ¾ of an inch using insulated long nose pliers to see the visible spark. The device must be turned OFF before attempting to do this method of testing.

Table 1. The cost of the different supplies and materials needed in fabricating the two in one device, Ignition Coil and Spark plug Testing Device

Quantity	Unit Description	Unit/ Price	Amount
2pcs.	Perforated Board	$0.91	$1.82
1 pc.	NE555 IC	$1.93	$1.93
1 pc.	Variable resistor	$1.47	$1.47
6 pcs.	¼ Watt Carbon composition resistor	$0.41	$0.41
1 pc.	2 Watts Carbon composition resistor	$0.23	$0.23
4pcs.	Diodes	$0.68	$0.68
2pcs	Ceramic Capacitor	$0.45	$0.45
1pc.	Electrolytic Cpacitor	$0.34	$0.34
2pcs	N-Channel MOSFET	$9.53	$9.53
1pc.	Push Button Switch	$0.79	$0.79

1pc	Selector Switch	$0.91	$0.91
1pc.	Ignition Coil	$13.61	$13.61
2 M	Aluminium angle bar	$3.40	$3.40
3 Box	Bolt and nut	$2.04	$2.04
1pc.	DC Indicator lamp	$0.68	$0.68
2 sq.ft.	Plastic Fiber	$7.71	$7.71
1 pc.	DT830 Digital tester	$5.67	$5.67
3 pairs	Port and connector	$2.72	$2.72
3 M	Automotive wires	$1.36	$1.36
2pcs.	Sticker paper	$0.23	$0.23
1pc.	Variable resistor handle	$0.34	$0.34
1pc	Circular bolt washer	$0.23	$0.23
2 M	Soldering lead	$0.91	$0.91
1pc.	IC Socket	$0.79	$0.79
TOTAL $**54.98.00**			

The total expenditure in construction is more efficient and practical as compared with having the two testing instruments individually, the ignition coil testing instrument and spark plug testing instrument.

Steps and procedures in assembling the Ignition Coil and Spark Plug Testing Device

1. Prepare all needed materials in assembling the testing device.
2. Assembling the oscillator circuit.
3. Assembling the voltage divider circuit.
4. Fabricating the container box of the testing device.
5. Fastened the oscillator circuit to its proper position inside the container box through the use of bolts and screws.
6. Fastened the built-in ignition coil inside the container box near below the spark plug socket
7. Fastened the voltage divider circuit inside the container box.
8. Fastened switches, ports, and other control components of the circuit.
9. Fastened the digital voltmeter inside the facing the hole provided for its monitor.
10. Connect one of the oscillator output terminals to the common terminal lead of the selector switch.
11. Connect the positive primary terminal of the built-in ignition coil to the selector switch.

12. Connect the positive primary terminal port to the other terminal lead of the selector switch.
13. Connect the output terminal of the voltage divider circuit to the digital voltmeter.
14. Connect the input terminal of the voltage divider to the high voltage port of the device.
15. Connect all ground connections of the circuit.
16. Secure all wire connections with electrical tape/insulator.
17. Label the parts and controls of the testing device.
18. Testing the device.

Table 2. Relationships on the amount of Resistance, frequency and voltage in three different settings.

Knob Setting	Resistance (Ω)		Frequency (Hz)	Voltage (V)
	Ra	Rb		
Minimum	652Ω	170.3KΩ	570 Hz	2.4
Mid	44.9KΩ	123.2 KΩ	1,530 Hz	14.6
Maximum	89.9KΩ	81.0 KΩ	2,560 Hz	20.2

The amount of voltage is directly proportional to the amount of frequency output and inversely proportional to the resistance. Furthermore, when frequency and voltage changes in value, there is also variation in the amount resistance applied to the oscillator circuit. This implies that the electromagnetic induction of the ignition coil either the built-in or the ignition coil to be tested vary. Therefore, the high output voltage of an ignition coil and as well as the spark of the spark plug must vary according to the desired setting of the user. The measured resistance of 170KΩ at minimum and voltage output of 2.4V are inversely proportional, but voltage is directly proportional to the amount of frequency of 570Hz. The measured resistance of 81KΩ in minimum setting has an output voltage of 20.2V.

Table 3. The evaluation of experts in terms of usefulness, effectiveness, functionality reliability, and safety.

A. Usefulness	Mean	Descriptive Rating
1. The device can be used in ignition system troubleshooting.	4.6	Excellent
2. It is useful in teaching automotive students in determining the trouble of an ignition coil and spark plug.	4.5	Excellent
3. It is easy to transfer to another place.	4.3	Excellent
4. It saves time and effort on the part of any automotive technicians.	4.6	Excellent
5. It is useful in the field of automotive electricity.	4.7	Excellent
Sub-mean	4.54	Excellent
B. Effectiveness		
1. It can operate in each of the selected settings.	4.6	Excellent
2. When it is used to test the ignition coil, It can show its actual output voltage digitally.	4.6	Excellent
3. Unopened spark plug creates spark when it is being tested depending on frequency setting.	4.6	Excellent
4. It is interesting and accurate in testing the condition of spark plug and ignition coil.	4.6	Excellent
Sub-mean	4.6	Excellent
C. Functionality		
1. It is easy to operate.	4.7	Excellent
2. It can perform to test spark plug accurately.	4.7	Excellent
3. It can perform to test ignition coil accurately.	4.7	Excellent
4. The labels of its parts are simple and easy to understand	4.4	Excellent
5. Controllable in different frequencies.	4.6	Excellent
Sub- mean	4.62	Excellent
D. Reliability		
1. It can able operate for a long period.	4.2	Excellent
2. There is no failure/s observed in the proper operation of the device.	4.3	Excellent
3. It contains the standard on auto electrical wiring system components/parts.	4.3	Excellent
4. The different parts of the device are arranged logically.	4.2	Excellent
Sub-mean	4.25	Excellent

E. Safety		
1. The device is properly made.	4.2	Excellent
2. There is a user's manual in using the device.	4.2	Excellent
3. There are safety precautions in using the device.	4.3	Excellent
4. The device promotes safety through its design and construction.	4.3	Excellent
5. The components and controls of the device are properly labeled.	4.3	Excellent
6. It provides comfort and convenience.	4.4	Excellent
7. The device wire connections are properly insulated, and it prevents electrical hazard.	4.4	Excellent
Sub-mean	4.3	Excellent
Grand Mean	4.46	Excellent

Based on the data, the device is very useful according to the group of respondents. This implies that the automotive and electronics experts noticed the device as useful in testing the condition of ignition coil and spark plug based on characteristics and features. Due to the unique characteristics and feature of the device, experts also find the device useful in teaching automotive students about the principles of operation of ignition coil and spark plug. Therefore, the device was rated excellent but with a rating reflected in the table tends to imply further that there is a need to improve the device in terms of its portability.

On the other hand, the device was also excellent in terms of its effectiveness. It would also imply that the group of respondents finds the device effective in determining the trouble of an ignition coil and spark plug. However, a constant thread of the figure shown in the table tends to imply further that there is more to improve for it to be completely effective because it does not meet a perfect rating.

Along functionality, the device was also rated excellent and this would also mean that the group of evaluators found the device functional as it can be operated simply and it can perform according to its desired function. However, based on its rating, it tends to imply that there is a need to improve the label of parts and control and the frequency stability of the device while operating.

The device was also rated excellent along reliability which means that it is reliable to use as a device instrument in testing the condition of an ignition coil and spark plug. Hence, based on the rating given, it would imply that there is more to improve in its operation though there is no failure during the test of the device. Besides, the researchers might have to strive more to observe the weaknesses of the device and turn them to a possible effective solution for it to be completely reliable.

Moreover, the device was also rated excellent along safety. It would also imply that the device can be used safely to test ignition coil and spark plug. Though it is rated excellent, there's more to improve on construction or the way it is made and a more precise user manual might be provided for the user. However, the researchers did not find any risk of using the device as long as the user is familiar with all the safety precautions and the user's manual is provided. However, with the rating given as the mean, it further implies that there is a need of improvement regarding safety.

In general, the findings entail that the device is very much acceptable to use as an instrument to test the condition of an ignition coil and spark plug though there is more to improve about the device as described in each of the standard that evaluates the researchers' output.

CONCLUSIONS

The results of the study revealed that the output voltage and frequency are directly proportional to the resistance of network Ra, but inversely proportional to resistance network Rb in the circuit. The output frequency is directly proportional to the output voltage.

On the other hand, the results show that it is a valid and acceptable instrument in determining the troubles of Ignition Coil and Spark Plugs. However, there is more to improve about the device from the given standards.

TRANSLATIONAL RESEARCH

The constructed testing device promoted safer and more accurate method of testing condition of an Ignition coil and spark plugs to automotive technicians. This study serves as a form of encouragement for instructors to design testing instruments as well as teaching devices featuring their field of specialization. They also utilize this as an instructional device in teaching the principle operation of an Ignition Coil and Spark Plug. Moreover, the findings of this study did not only provide information but also inspired other instructors who are trying to produce state-of-the-art technologies which are needed in the industry and upgrade the quality of teaching and learning. Lastly, the output of the study reinforced and developed the skills of students in determining the condition of an Ignition Coil and Spark Plugs.

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