Modeling and solution for quality control in the production of ignition coils

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Abstract. The article discusses a device based on a microcontroller, developed to control the quality of ignition coils manufactured by NPO Sever for cars with a gasoline internal combustion engine. The results are recorded in the report on a flash drive in the form of an excel file. This device can be applied to other lines of ignition coils thanks to variable control settings.

1. Introduction
According to the terms of reference, the stand has semiconductor switches that alternately switch the windings of the ignition coil to a stabilized voltage source (14V) for a certain measurable time interval until the primary current reaches the specified value (9A). After the current reaches the set value, the switch opens, and the energy accumulated in the coil creates an arc discharge on the candles connected to the secondary winding [1]. The process of voltage change from the moment of start-up to the end of the transient process is recorded on an external storage device [2, 7, 8, 9].

2. Description of a model
Figure 1 and Figure 2 show a complex developed by the authors for testing ignition coils. Block diagram of device 4 in Figure 1 is shown in Figure 3. Here, the power switch (K1, K2) commutes the ignition coil to the source when the control signal is supplied from the microcontroller (CPU). The microcontroller receives the analog value of the primary current and the scaled voltage across the coil winding as initial information for control. The test progress is set from the keyboard (KB). Intermediate and final results are displayed on a liquid crystal display (LCD) [3], which is also powered from the source. The received and processed information is written to an external flash drive, the role of which is played by an SD card. The next step is to develop an electrical schematic diagram [4].

The schematic diagram is shown in Figure 4. On the DD1 chip of the UC3843 brand, a pulse voltage converter is made from 9V to 60V and then lowered to 14 volts. This is used to supply power to a coil with a high current in a pulsed mode, because the low-voltage source is weak, and the capacitor C5 200μF 63V plays the role of the source. The voltage stabilization of 14V is performed by a parametric stabilizer on a field-effect transistor, the input voltage of which is 60V.
The analog signal input/output interface is made by a resistor voltage divider with a midpoint bias resistor R21.

The primary winding of the ignition coil is switched to a stabilized voltage source by powerful field-effect transistors controlled by the IR4427 charge driver. The 9A current is set by the LM 393 comparator.

The liquid crystal display is controlled in parallel with the slave port and connected to the digital RC port of the microcontroller. The flash drive and keyboard are connected to port B.

**Figure 1.** Testing complex for quality control of ignition coils: 1) sections for limiting the voltage of the secondary circuit of the tested coil; 2) ignition coil; 3) keyboard with PS/2 connector; 4) microprocessor-based device for quality control of ignition coils; 5) connector for installing a flash drive.

**Figure 2.** Microprocessor-based ignition coil quality control device
The work is supposed to use the method of structural synthesis, which considers the geometric configuration of electrical circuits of an alternating current rectifier with a frequency formed from transformer windings and power semiconductor devices (PSD) in the form of topological graphs [2].

**Figure 3.** Block diagram of the test complex

**Figure 4.** Schematic electrical diagram of a device for testing ignition coils.
Figure 5 shows the oscillogram of two channels of the primary voltage of the ignition module.

![Oscillogram of voltages of two channels of the ignition module](image)

**Figure 5.** Oscillogram of voltages of two channels of the ignition module

### 3. Mathematical model

The following areas can be distinguished on the resulting oscillogram:

- 0 – 5 ms - charge of the ignition module coil;
- 5 – 5 ms - voltage pulse (jump) before the arc discharge;
- 5 – 6.3 ms - arc discharge in the spark gap;
- 6.3 – 8.5 ms - damped free oscillations;
- 8.5 – 10 ms - steady state.

In the charging area, the coil is connected to a stabilized 14 V voltage source until the current value reaches 9 A. According to Faraday's law:

\[
E = -\frac{d\Psi}{dt},
\]

or replacing differentiation with an increment and given that

\[
\Psi = L \cdot I,
\]

We can get it:

\[
U_L = \frac{L \cdot I_m}{t_1},
\]

where \(U_L\) - the source voltage equal to 14 V;

\(L\) - inductance of the coil of the ignition module;

\(I_m\) - current limit value equal to 9 A by the end of the charging period;

\(t_1\) - coil charging time.

Thus, at constant voltage and current values in (3), the inductance turns out to be proportional to the charging time.
The presence of a voltage pulse in the next area characterizes the absence of short-circuited turns of the coil and a sufficient quality factor. A small value of the pulse voltage may not be enough to ignite the arc in the spark gap. Therefore, the rejection of ignition modules is also carried out according to this criterion [5].

The duration of the arc discharge in the range of 5...6.3 ms in Figure 5 characterizes the energy reserve of the coil of the ignition module. As a rule, the duration of the arc burning is 1...2 ms. After this time, the arc extinguishes due to a decrease in the rate of ionization of particles by the energy of the discharging coil in relation to the rate of recombination [6, 11].

The presence of damped free oscillations in the next region indicates a sufficient quality factor of the circuit formed by the inductance of the coil, the turn-to-turn capacitance of the winding and the active resistance of the winding wire. This is another criterion for the health of the ignition module coil.

After the damping of free oscillations, the region corresponding to the steady-state regime follows.

4. Conclusion

According to the obtained oscillograms in various modes of the ignition system, it can be noted that the Q-factor of the coil in the system depends on the number of free oscillations in the fourth section, since it determines the rate of decay of relaxation oscillations, while the Q-factor is not reflected in the charge time.

A sufficient amount of stored energy can be confirmed by a sufficient arc duration.

The absence of short-circuited turns is possible in the presence of free oscillations in the fourth section of the oscillogram, and can also be indirectly estimated by the duration of the charge and arc burning.

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