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Start-up of SSTC semiconductor tesla coil - an example of an educational project

***Abstract**. The use of semiconductor elements open up new opportunities associated with construction of semiconductor tesla coils. In the semiconductor Tesla coil, the resonant circuit function and the spark gap functions is taken over by an electronic system. The most common way to power up the Tesla's transformer primary winding is the inverter bridge or half-bridge comprises a pair of MOSFET transistors.*

Streszczenie. Zastosowanie półprzewodnikowych elementów otwiera nowe możliwości związane z konstrukcją i sposobem działania cewki Tesli. W półprzewodnikowej cewce Tesli funkcję obwodu rezonansowego oraz iskiernik przejmuje układ elektroniczny. Najczęściej spotykanym sposobem zasilenia uzwojenie pierwotne transformatora Tesli jest falownik zwany dalej mostkiem lub pół-mostkiem złożonym z pary tranzystorów MOSFET. ***(Uruchomienie półprzewodnikowej cewki Tesli- przykład projektu edukacyjnego)****.*

Keywords: Tesla coil, educational project, semiconductor systems.
Słowa kluczowe: Cewka Tesli, projekt edukacyjny, układy półprzewodnikowy

Introduction

In the semiconductor Tesla coil resonant circuit function and the spark gap is taken over by an electronic system. The most common way to power up the Tesla transformer primary winding as bridge or half-bridge comprises a pair of MOSFET transistors. Transistor brigde is controlled by an electronic system that enables and disables from self-resonance frequency of the resonator Tesla. As a result, a spark gap and a capacitors in a high voltage become unnecessary[1,2]. The bridge is powered directly from the rectified mains voltage, which eliminates large, expensive and heavy power transformer[3,4]. Another advantage of this system is systemically is carried out feedback that adjusts the resonance frequency of the coil to the switching of frequency MOSFET gate[5].

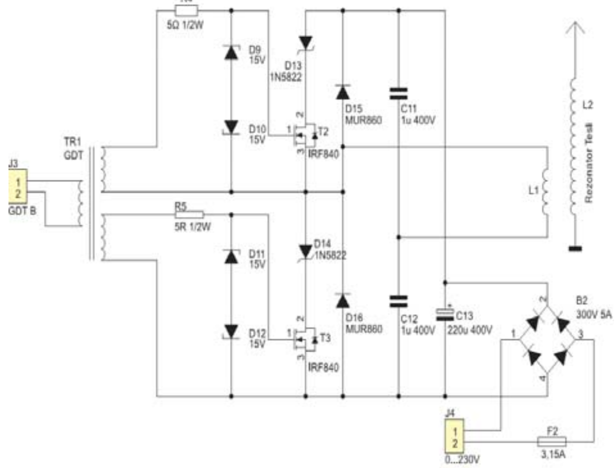

Fig. 1 bridge based on MOSFET's Schema

The bridge circuit

The schematic diagram of the two transistors is given in figure 1. This is the simplest structure that can be used, and is being very often used by young constructors of semiconductor coils. The second module is composed of a rectifier bridge and the electrolytic capacitor filtering input system voltage. Transistors T2 and T3 used in this devices contain in their structure a diode that during the operation at a high frequency may be too slow. In this unit the operating frequency is about several hundred kilo Hertz. In the central part of the system the primary winding of the Tesla coil, is located or L1. The bridge consists two branches. The first is a capacitive divider consisting a pair pulse capacitors C11 and C12. The second branch and constitute are transistors T2 and T3. The element providing a signal to the gates of the bridge is a transformer TR1. And a galvanic separation between the sternum and systems control system is located. Control transformer must be constructed of a core adapted for work at high frequencies. The most common material used to core is 3E25. It is also necessary to join the casings of transistors T2 and T3 heat radiating fins. In order to prevent a rapid heating, caused by high currents that happened during work[6,7].

Table 2 elements of the bridge and power circuit.

Elements	Name and discription
Resistors	R3, R4: 1 kΩ R5: 1 MΩ
Capacitors	R9, R10: 10 kΩ/A
	C1: 1μF 10 V, electrolyte C2, C3: 100 nF C4: 180 nF 400 V, impulse
Diode	D1, D2: 1N4148 D3, D4, D5, D6, D7, D8: 1N5819
Transistors	Q1: BC548
Semiconductor circuits	IC1: NE555 IC2A: 74HC14 IC2B: 74HC14 TCA: TC4422 TCB: TC4421
Additional elements	A1: antena

The control system

The control system is based on an chipset NE555, but it is not directly switching a half-bridge system. Its task is to generate a periodically blocking signal for half-bridge transistor. Figure number 2 shows the control circuit.

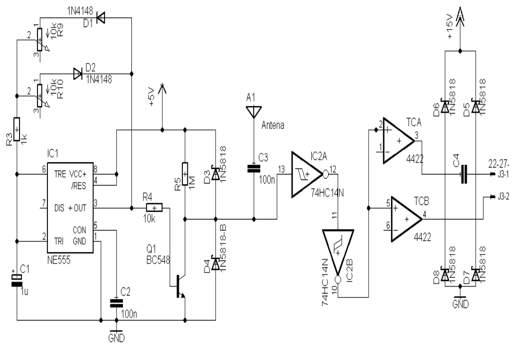

Fig. 2 Scheme of Control

Blocking of the signal is done by shorting the input negation circuits U4A to ground by a T1 transistor. Operating frequency of the generator does not exceed a few hundred Hz, and is adjusted in a wide range. Potentiometers R9 and R10 can adjust the duration of the state of the generated high and low mileage. The possibility of separately controlling the duration of both states of course not only allows setting different frequencies, but also a different duty cycle. You can thus reduce the heating of the elements, and also by changing modulation parameters one can obtained discharge with different appearanceand look.

The A1 antenna is the source of a control signal for setting operation point of the half-bridge transistor. The task of a Tesla coil is to produce not only a high voltage. Voltage accompanied by a strong electric field with a high intensity. It changes its value as well as the tension generated in the Tesla resonator. The antenna receives the signal from generated electric field, and the signal from the antenna after the formation of the IC2 and passing through the drivers and the transformer TR1, controls switching half-bridge power coil L1. And it is precisely the antenna that performs feedback. This solution makes the device becomes a generator LC, where LC circuit determining the frequency of the resonator Tesla alone. This eliminates the need any frequency tuning, complex calculations, and furthermore, the device is not sensitive to changes in resonant frequency of the winding. In addition, even small detuning between the control system and resonator Tesla would result in the creation of an large oscillation transistors in a half-bridge switching times, which would considerably would increase the risk of damage. Using feedback from the antenna means that these problems no longer have a significant role, because the control system operates with such frequency that determines the secondary winding of the transformer Tesla[8,9,10,11].

To get started you need a pulse excitation in the resonator slight vibrations that are received by the antenna and usher in a job. This pulse generator delivers described earlier NE555 modulating operation tesla coils. Switching on or off the transistor T1 results in a change of input status Negator IC2A. It will switch the status of drivers TCA and TCB, then FOR IN gets into the half-bridge short pulse for a while integrating one of the transistors. Such a pulse causes vibrations in the resonator sufficient to raise the system and began to generate high voltage[12].

An additional element connected with the control system is the power supply via circuits; 78L15 and U2; 78L05 voltage of 15 and 5 volts that are filtred by simple pair of capacitors. The list of elements that circiuts were made are discribed in table 1.

Table 1. Table of elements of core tesla system

Element	Name and discription
Resistors	R1, R2: 5 Ω 0,5 W, carbon
Capacitors	C11, C12: 1 μF, 400V, impulse
	C13: 220 μF, 400V, elektrolit
Diode	D9, D10, D11,D12: Zener 15 V
	D13, D14: 1N5822, Schottky's,
	D15, D16: MUR860
Transistors	T2, T3: IRF840, MOSFET
Semiconductor circuits	B2: Semicondactor bridge 3 A / 400 V
Additional elements	F2: safe fuze 3,15 A / 250 V TR1: controlling transformer

Assembling the electronic circuit

Control systems of the half-bridge and the supply circuit are being made on a single chip tray. All mergers are made to perform a jumper wire having a diameter of 0.6 millimeters. Due to the small value currents such a solution is fast and efficient and does not require a lot of work.

Potentiometers are positioned at the edges of the plates for the purpose of facilitating the fulfilment of control signals coming out of the NE555. During installation, one need pay attention to the connection of unused inputs of negatives outputs from the negatron's in the supply system to the masses, in order to correct their actions. Also, what is not clear from the diagram, connect the power supply to the power MOSFET drivers 15 volts. Scheme plate made of respective universal joints is shown in Figure 3.

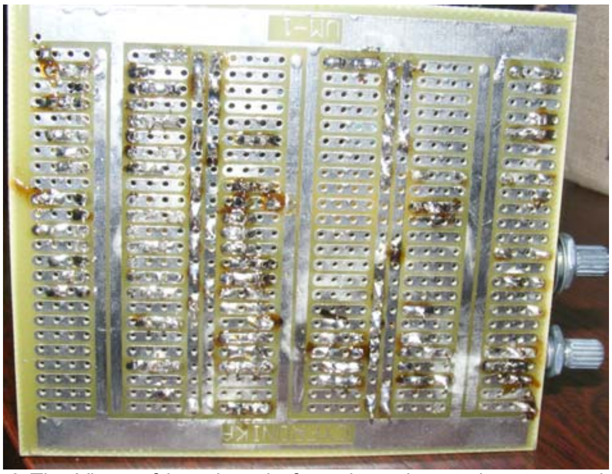

Fig. 3 The View of board made for universal control system and power supply

Then, a Tesla resonator in the form of PVC pipe wound with a winding wire, as it did in the standard coil. The most important parameter of the resonator is self-resonance frequency. This frequency is lower, greater more length of the winding, and the more turns, which has a low diameter of the winding wire. The higher resonant frequency, its opereting will be less stable.

The Tesla coil

The dimensions of the windings used in the described SSTC is 100 mm in diameter and 300 mm high. The coil is made with wire DNE 0.18 millimeters on cleaned and degreased with petrol pipe. For proper assembly there was a break between the beginning of a winding tube and the wire for easier installation. After winding it manually, coil was painted with a nitro lacquer. Its aim is to improve insulation and immobilization of coil while moving them, due to the wire the warm-up during its work. The entire coil was shown in Figure 4, the number is not essential counting frequency coil as the control and so generating a signal of the resonance frequency of the coil. A primary coil was wounded with copper wire 4 millimeters, directly on PVC pipe of thickness 110 millimeters. The whole was part was reinforced with silicone mounting. At the top of the resonator one can mount a metal, or the sharp element from which electrical discharges will go out, combined with the tip of the secondary winding. Without the metal end of the Tesla coil will work normally, but the lightning will come out with sticking a wire and cause its melting fast. Unlike the classic coil it is not necessary to mount the terminal, because the process of stabilizing the frequency is controlled by the feedback realized by mounted the antenna:

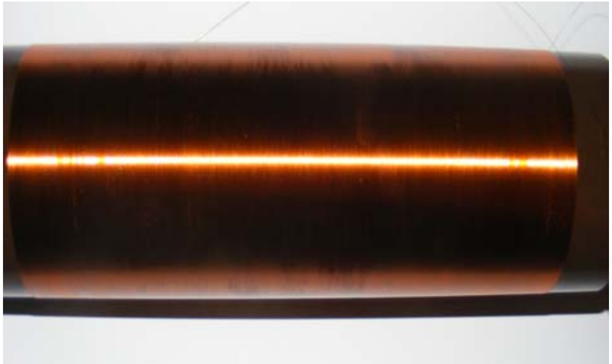

Fig. 4 Wired And painted coil

This antenna should situated 10 centimeters above the working resonator and reach about half the length of the coil. Too close installation may cause damage to the entrance negatrons and burnout the control system. Just as in the case of classical tesla lower end of the coil should be connected to a thick grounding wire cable or a homemade earth, with thick wire planted in the ground[13].

Start-up

Initial start-up of the coil is to connect to the power terminals AC voltage of no more than 50 VA. For proper operation it should have appearance of the square on the same level as fill parameter. Input signal was shown at figure 5.

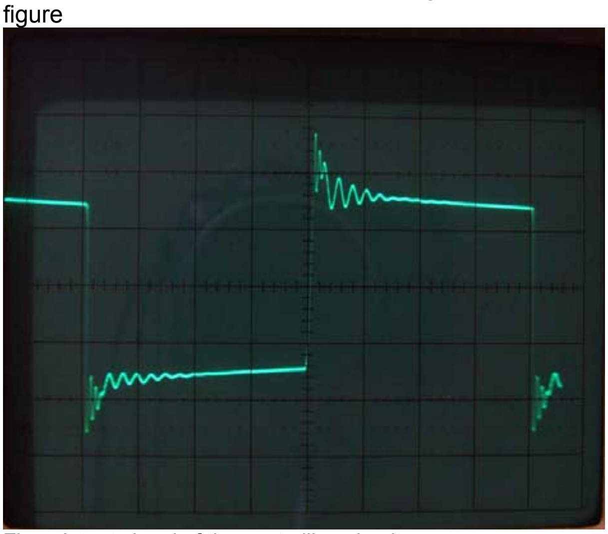

Fig. 5 Intput signal of the controlling circuit

Any irregularities should be actuated by means of potentiometer control system. Sequentially check the signal after passing both an isolation transformer system. On the output pulse signals the emerging that will involve alternating switching the MOSFET bridge.

Summary

After a series of calculations coil has been designed and manufactured as an educational project of Tesla transformer. The project involved the creation of the classic of the coil additionally, and was also made of a semiconductor circuit design corresponding to the form of work, of the standard coil. After assembly and construction elements was quite spectacular launch of this device. This was followed by a series of studies of both of the classic coil and semiconductor. So the issues of generating high voltages are useful in various spheres of life. Further work related to generating high voltages can be used to design, for example, ozone-producing devices or other.

REFERENCES

[1] Borowik, L., Ptak, P., Wzorcowanie przyrządów do pomiarów grubości warstw wierzchnich. Przegląd Elektrotechniczny, 2010 nr 04, 97-100.
[2] Horowitz P., Hill W., Sztuka elektroniki, Warszawa 2009. cz. 1 i 2.
[3] Janiczek R., Ptak, P., Przetworniki indukcyjnościowe w pomiarach grubości warstw wierzchnich. Przegląd Elektrotechniczny, 2007 nr 1, 86-90
[4] Pilawski M., Fizyczne podstawy elektrotechniki, Warszawa 2010, 118-130.
[5] Pilawski M., Pracownia Elektryczna, Wydawnictwo Szkolne i Pedagogiczne, Warszawa 1993, 114-131.
[6] Ptak, P., Borowik, L., Dokładność czujników indukcyjnych w defektoskopii warstw ochronnych urządzeń elektrycznych, Przegląd Elektrotechniczny, R. 90 NR 12/2014, 277-280.
[7] Prauzner, T., Ptak, P., Analiza parametrów pracy wybranych czujników pola magnetycznego, Przegląd Elektrotechniczny, R. 90 NR 12/2014, 273-276.
[8] Ptak, P., Prauzner, T., Badania czujników detekcji zagrożeń w systemach alarmowych. Przegląd Elektrotechniczny, 2013 nr 10, 274-276.
[9] Ptak, P., Borowik, L., Analiza wpływu częstotliwości sygnału na czułość czujnika indukcyjnego do pomiarów grubości powłok ochronnych. Przegląd Elektrotechniczny, 2013 nr 12, 269-271.
[10] Ptak, P., Borowik, L., Diagnostyka zabezpieczeń antykorozyjnych na potrzeby elektroenergetyki. Przegląd Elektrotechniczny, 2012 nr 09a, 142-145.
[11] Prauzner, T., Zakłócenia elektromagnetyczne w elektronicznych systemach alarmowych. Przegląd Elektrotechniczny, 2012, 205-208.
[12] Ptak, P., Borowik, L., Dobór częstotliwości i rodzaju sygnału czujnika indukcyjnego na potrzeby pomiaru grubości wielowarstwowych powłok ochronnych. Przegląd Elektrotechniczny, 2012 nr 12b, 245-247.
[13] Tilbury M., The ultimate Tesla Coil Design and construction guide, McGraw-Hill Companies, 2008, 29-32.

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