Audio Modulated Solid State Tesla Coil

Bos Mathew Jos¹ N.M. Naveen² Noble Jose³ Thomas Cherian⁴ K.R. Vishnu⁵

¹Professor, Dept. of EEE, Mar Athanasius College of Engineering, Kothamangalam.
²3 UG Student, Dept. of EEE, Mar Athanasius College of Engineering, Kothamangalam.

Abstract—This paper explores into the acoustic qualities of Tesla Coils and the physics of sound generation. It includes the construction of a solid state Tesla Coil capable of replicating the audio production properties of a conventional speaker, as well as a unique musical interface designed to transform the coil into a non-conventional musical instrument. This work removes some of the mystery surrounding this device and help to bridge the gap between musicians and engineers as music technology continues to grow.

Keywords—Audio Modulation, Microcontroller, Solid State Tesla Coil, Tesla Coil

I. INTRODUCTION

Tesla Coils can provide their own physical means of producing sound through the electrical arcs they generate. In effect, Tesla coils are creating music not only through electronic means, but are literally generating sound by passing electricity through the air. Tesla coils can be used in this respect as performance tools, one popular example of this being, the group Arc Attack who use a pair of large Tesla Coils combined with other automated instruments to perform live concerts.

Tesla coils can also be built to produce a high quality sound by increasing their resonant frequency. In these cases, the coil can be used to produce extremely clear sounds without any distortion, particularly in the higher frequency ranges. Thus, Tesla Coils can be built to act as very high quality tweeters that rival even the best sound systems.

This work explores into the acoustic qualities of this unique technology by constructing a coil capable of producing clear sound. The result of this work will be a fully functional Solid State Tesla Coil (SSTC) capable of modulating the sound of its corona discharge into music. The goal of this project is to create a musical instrument with a unique interesting interface that displays some of the physical aspects of how sound is created. The block schematic representation of the proposed system is given in Fig.1.

II. HARDWARE DESIGN

A. Power Inverter circuit design

The goal of the inverter (using MOSFET) is to produce a square AC wave across the primary coil. It include a rectifier for DC bus supply and the power electronic inverter[1]. The bus supply as it is named, supplies the power to the input of the inverter. This is usually rectified mains AC, which can simply be stored in a large electrolytic capacitor. During the switching, the inverter pulls power from this capacitor which is driven into the primary coil.

Figure 1: Block diagram of proposed system of audio modulation in Tesla Coil

Figure 2: Inverter – half bridge
There are two possible layouts for the inverter - a half bridge or a full bridge[2]. The main advantage of the half bridge inverter is simplicity and lower part count. However, the advantage of a full bridge inverter is twice as much voltage across the primary and hence most possible power. In this work, a half bridge has been chosen for ease and compactness.

B. Inverter Driver circuit

Inverter driver is used to switch Transistors on and off correctly. Its goal is to switch the inverter at the correct frequency so we achieve resonance. It also has to be powerful enough to charge the gates of our Transistors quickly. A gate driver is a powerful amplifier that accepts a low power input from a controller IC and produces a high current drive input for the gate of a high power MOSFET or transistor [3].

Gate drive transformer is used for the isolation between driver circuit and power circuit. It is simple to implement, produces good results and is significantly cheaper. Gate drive transformer is accurately wound on a suitable core.

C. Frequency Generator

The frequency generator drives the frequency of the primary coil and it should be able to be adjusted to run at the resonant frequency of the secondary coil. The most obvious way is to use an external frequency generator, such as a TL494 or 555 IC. A common method of use simply calls for a vertical wire being places a few centimeters from the coil, around 15cm in length[4]. This acts as an antenna, picking up a small sinusoidal current. Hence, the coil is self-tuned using feedback. This method represents the easiest and most convenient method to implement.

D. Interrupter Circuit

The interrupter can be any circuit which gives a 1-bit signal (on or off) to the driver. We used an Atmega32 Microcontroller to produce the interrupter signals. The use of a Microcontroller facilitates the implementation of PRF modulation and precise control over the inverter and driver. The inbuilt Analog to Digital Converter is used to a potentiometer and is used to control duty ratio of the pulse. It is limited to 10% for safe operation. Controller creates square pulses of required frequency according to the musical notes given. This square wave is connected to the enable pin of the MOSFET driver IC. The output of driver ICs are turned ON/OFF according to the enable input.

E. Power supply

Power supply circuit provides power to driver and interrupter circuits. DC supplies at voltage levels 12V and 5V. A 230/12V 1A step down transformer is connected to a bridge rectifier to get unregulated DC. The regulated 12V supply is obtained by using LM2576 switching regulator. The 5V supply is derived from 12V supply using LM7805 linear regulator.

F. Secondary coil

The secondary coil of the Tesla Coil is where the voltage is built up before being release through corona discharge. In simplest terms it can be modeled as a circuit formed by a capacitor in series with a resistor and inductor [5]. The resistance is created by the large amount of wire used, typically hundreds or thousand s of turns, while the inductance is that of a single layer of tightly wound coil. Resonant frequency of the coil is given by

\[ f_r = \frac{1}{(2\pi\sqrt{LC})} \]

The software called WinTesla was used to estimate the secondary coil requirements. Main design considerations include Diameter of the coil, length of coil and Wire gauge. A design with 4 inch PVC former (Dia. of 110mm), Length 15 inches and wire of gauge 32 SWG was found to be sufficient to meet our requirements. The secondary coil was hand wound on the PVC former with 32 SWG enameled copper wire. The finished coil measured a height of 14.7 inches. So the height to diameter ratio is 3.4, which is a typical value for SSTC secondary coil. A turn per inch is 90 and total turns are around 1300. The coil was given a...
generous 7 coats of varnish. This protect coil from unwinding due to thermal expansion and also provide protection. The resonant frequency was experimentally determined and value is close to 280 kHz.

G. Primary coil

The primary coil is made by simply winding a few turns of thick wire (>=14AWG) at the base of the secondary. For a normal SSTC, we generally want good coupling and many turns to reduce magnetizing current. Around 6 to 9 turns is common. We used 6 turns of insulated copper wire.

III. WORKING PRINCIPLE

Audio modulation is achieved by interrupting the gate drive signals to the inverter at audio frequency. The inverter driver with the aid of feedback maintains resonant frequency operation by tracking. The inverter provides the drive for primary of the tesla coil. Here is an overview of the schematic and how the coil operates. In the top of the schematic we see the low voltage power supply section for providing 12V and 5V for ICs. U1 is any typical 555 running at about 200 kHz. Its sole purpose is to trigger the oscillation. There is a 100K resistor on its output that makes the 555 look weak to the input of the 74hc14 the Schmitt inverter. In fact, it’s just strong enough to trigger the 74hc14. Now, also on the input of the 74hc14 we see an antenna with a series capacitor. When the coil starts to oscillate, this antenna picks up a signal from the Tesla Coil output and feeds it right back into the system. This signal looks strong so it overrides the 555 (U1). Now the coil is running from its own noise and will be perfectly in tune at all times. Also on the input are two 1N60 germanium diodes. Their function is to clamp the antenna's voltage to the 5V and GND rails so that we don’t fry our 5V logic chip. The output of the 74hc14 is fed to the inputs of an inverting and non-inverting gate driver chip (Texas instruments UCC37322 and UCC37321). They work in opposition creating an effective 24V peak to peak voltage across the primary of a transformer[6]. This transformer is just a small ferrite core wound by hand and is used to supply isolated gate driver signals to each of the MOSFETs. This transformer is known as a Gate Driver Transformer (GDT). Q1 and Q2 make up a half-bridge. One FET is on while the other is off. This creates a square wave across the primary of our Tesla Coil of about half of the voltage supply. The MUR860 diodes are fast diodes there to catch any reverse current that is back flowing from the tesla resonator[7]. D9 and C12 provide the DC for the half-bridge. The last piece of the puzzle is U5. It’s another 555, but running at a low pulse rate. This 555 controls the ON/OFF period of the tesla coil by enabling/disabling the gate drivers. This 555 oscillator was replaced by microcontroller later. The microcontroller facilitates multiple features. A 20x4 LCD display is interfaced to the microcontroller. It uses one port (8 pins) for data signals and 3 pins for control signals. This is used to display information like the musical note which is being played, octave, repetition, frequency, time period and the duty cycle of the modulating signal. A potentiometer is connected to the inbuilt ADC (port A) which is used to change the duty cycle of interrupt signal.

IV. CONCLUSION

In this paper we have created a unique tesla coil which is capable of replicating musical tones and shed some light on the technical and artistic nature of Tesla coils. The coil that was created was capable of producing audible music very clearly, and the musical interface was limited only by the lack of properly functioning equipment. The spark output was close to 7 inches. There are a number of improvements that could be made. The current design can be modified so as to interface a memory card. By this we can store number of lengthier coded music. Musical Instruments like guitar, piano can be connected to the device.
with proper interfacing circuitry. This will enable the coil to do live music performances. By altering the
driver and interrupter to a PLL based SSTC it is possible to make continuous wave SSTC opposed to our
interrupted mode SSTC. Upgrading MOSFETs to IGBTs can reduce overheating and increase power
handling capacity. Converting SSTC to a DRSSTC (Dual resonant SSTC) will improve streamer length
significantly. This increases loudness of the music and appeal of the arc display. Protective features like
overheating protection and current sensing can be incorporated.

Figure 5: Inverter Driver Circuit

Figure 6: Gate drive signals from the Inverter driver

REFERENCES

Teknikal Malaysia Melaka (UTeM), Ayer Keroh, Malaysia; Din, A.; Rahman, A.A.; Yahaya, M.S.
Published in Electrical and Control Engineering (ICECE), 2010 International Conference.
Gough, C.; Ivkovic, S. Published in Pulsed Power Conference, 2005 IEEE
Published in Pulsed Power '97 (Digest No: 1997/075), IEEE Colloquium on