

# Artificial pumping of heart using transcutaneous transformer essay sample



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**Abstract:**

A power supply system using a transcutaneous transformer to power an artificial heart through intact skin is presented in this paper. With the number of cardiac patients increasing dramatically each year, the potential for development of implantable circulatory assist devices is remarkable. Such circulatory assist devices consist of totally artificial hearts and ventricular assist devices. In order to realize both high-voltage gain and minimum circulating current, compensation of leakage inductances on both sides of a transcutaneous transformer is proposed. A frequency region which realizes the robustness against coupling coefficient and load variation is identified. In this region, the converter has inherent advantages such as zero voltage switching (ZVS) or zero-current switching (ZCS) of the switches, high-voltage gain, minimum circulating current and high efficiency.

**Keywords:** Artificial heart—Transcutaneous energy transmission—Magnetic field immunity of the system. **Introduction:**

With the rapid development of life science and bio-engineering, the research of implanted medical device, especially the totally artificial heart (TAH), has made great progress, and the TAH with the character of miniaturization, durability and low-resistance, might be used as widely as the artificial pacemaker. With the development and improvement of this technology, non-invasion and low-risk treatment in medical field will be further promoted, thus it has great research value and application prospect.

In this paper the TETS, which consists of the transcutaneous energy transmission through intact skin to power a TAH, has been designed and built. Here a transcutaneous transformer transmits driving energy to an

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artificial heart implanted inside the body by using electromagnetic induction between two coils inside and outside the body. IH cookers generate a magnetic flux, and if a cooker is operated near a transcutaneous transformer, the magnetic flux generated will link with the transformer's external and internal coils. This can affect the performance of the TET system and the artificial heart system. Hence, it is necessary to investigate the magnetic-field immunity of the TET system. TET System:

The TET system allows the non invasive transmission of energy to the inside of the body. Figure 1 displays a block diagram of the TET system. Outside the body, DC electric power that is supplied by a stabilized DC power supply or an external rechargeable battery is converted into high-frequency (300 kHz) AC electric power by a push-pull-type inverter circuit. The AC electric power is transmitted to the inside of the body through the transcutaneous transformer, as shown in Figure 1. The transcutaneous transformer consists of an external coil and an internal coil, of nine turns each, using Litz wire. Two primary coils outside the body are closely wound in the toroidal-type ferrite. To detach a coil outside the body easily, the ferritic core combined two ferrites of the character type C. The half of the annulus ring of the coil that is inside the body (nine turns) was buried under the hypodermis, and the remaining half was wrapped with the skin and thrust out like an arch (Figure2). Figure2 shows an installation of the passing skin transformer on a goat.

Figure 1: Block diagram of TET system.

Figure 2: Transcutaneous transformer.

Inside the body, AC electric power is converted into DC power in order to drive the artificial heart actuator and charge the rechargeable internal backup battery. Working of the system:

The original electric artificial heart is connected with the battery by the wires which penetrate the skin, leading to high ratio of cross-infection. With the use of transcutaneous energy transmission system (TETS) which does not have any physical connection with the outer battery to drive the TAH, it has greatly prevented infection complications and improved the life quality of the patients. Main tasks are as follows: 1. The factors affecting the contactless transformer of TETS coupling efficiency ( $k$ ) are analyzed. With the help of the finite element analysis software, the coupling performance and stability of the transformer are analyzed. And then core material, air gap, geometrical parameters, and coils axial displacement are selected to study their effects on coupling coefficient. By simulating with various values, the transformer is designed. Then a type of high coupling and small size coil is proposed in this paper, which solve the design contradiction between transcutaneous transformer and transmission efficiency.

2. The working frequency 100 kHz of the TETS is determined according to the primary and secondary current ratio of the transcutaneous transformer.

Compared of various compensation methods, it can be obtained theoretically that two capacitors added in series on both sides to compensate the leakage inductances is more suitable for the TETS. 3. The coupling and energy transmission characteristics mainly including three aspects of the TETS are studied experimentally. Firstly, the coupling for the pot and PM (Pot Module Cores) core transformer with frequency, load, air gap and horizontal

displacement is investigated. Secondly, the power transmission characteristic of the TETS with frequency, load, air gap and horizontal displacement is studied with the experimental pot core transformer. Lastly, the applicability of various compensation methods is studied experimentally. The most efficient compensation method of the TETS for TAH, of which two capacitors are added in series on both sides, is obtained experimentally.

4. The temperature field of transcutaneous transformer is established.

Furthermore, an information transmission system is proposed. Through monitoring the temperature of secondary core which reflects the value of load power, the change of temperature can adjust the input power of the primary coil to achieve high system reliability. And a transcutaneous data communication system based on JASK2000 development board is built.

5. The hardware platform of charging and discharging experiments is built. On the basis of that, the expected life-span of the TETS using the energy conservation theory is deduced, and accordingly its validity is approved.

Actuarial 3-period charging and discharging experiments is operated.

Principle:

The pump in an artificial heart system generally requires a power of 12-35 W to operate. Electrical energy can be transmitted transcutaneously by means of the inductive coupling between the primary coil and secondary coil of the transcutaneous transformer. The primary part of the transcutaneous transformer is located on the skin and the secondary is implanted inside the body. However, the energy transmission efficiency is low because of the large gap (generally 5~15 mm) between the coils. In this case, the design of

the transcutaneous transformer has been one of the key challenges in developing an efficient power supply system. Three types of transcutaneous transformers have been investigated. The first type is ferrite pot core transcutaneous transformer.

The second type use amorphous fibres as the cores. The third type is a transcutaneous transformer with a combination core which has a ferrite primary core and an amorphous secondary core. A high frequency series resonant DC-DC converter is presented for a transcutaneous energy transmission system. By simulating with various values of coil geometry, the shape of each type of transcutaneous transformer has been studied with the aim of obtaining maximum output power. For each type of transformer, a power rating of more than 20 W can be delivered from a 12 V power source. This is sufficient for driving the heart pump. Circuit analysis on the transfer gain has also been presented, the simulation results can be well explained by theoretical calculation. Besides all this, these three types are also compared with each other with a view of the potential for clinical application.

The magnetic field immunity of the TET system:

The magnetic-field immunity of the TET system was examined using a prototype solenoid coil with five turns. The TET system was set up for the examination in the centre part of the coil, and a current of 3.5 A flowed into the coil. The induced voltage in the external and internal coils of the TET system was measured with an oscilloscope (Yokogawa, DL-1640, and Tokyo, Japan). The generated magnetic field was 140 dB $\mu$ A/m. This value was 12 dB stronger than the maximum magnetic-field strength of 128 dB $\mu$ A/m 35 cm above the IH cooker with the water-filled pan. Figures 3 and 4 shows the

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voltage induced in the external and internal coils of the TET system when the test frequency was assumed to be 30 kHz, which was the exciting frequency of the IH cooker. The voltages induced in the external and internal coils were 0.007 V and 0.079 V, respectively. It can be said that these voltage values are very smaller than the voltage rating of the artificial heart system (24 V); therefore, the TET system has sufficient magnetic immunity.

Figure 3: Induced voltage in external coil (measured).

Figure 4: Induced voltage in internal coil (measured).

Conclusion:

In this paper, we have reported on the development of a coil for the magnetic immunity system. This system is an important factor in guaranteeing the safety of TET systems for totally implantable artificial hearts or other medical devices. In addition, we detailed our investigation of the immunity of a transcutaneous transformer. The high-frequency magnetic-field immunity examination proposed and discussed in this paper is important for the evaluation of equipment for home medical care, as there is a risk of exposure to a magnetic field while using such equipment. Therefore, the examination presented here is applicable not only for the TET system but also for evaluating the reliability of many other medical devices. In future work, we will investigate the magnetic-field immunity of the TET system in other situations involving large magnetic fields and near power stations.

References:

1. T. Yamamoto, K. Koshiji, K. Tsukahara, et al., " An externally-coupled transcutaneous energy transmission system for totally implantable artificial <https://assignbuster.com/artificial-pumping-of-heart-using-transcutaneous-transformer-essay-sample/>

hearts-detection of abnormal coupling caused by misalignment and air gap in the ferrite core junction of the transcutaneous transformer, " Transaction of Japanese Society for Medical and Biological Engineering, vol. 43, no. 2, pp. 261-267, 2005. 2. T. Yamamoto, K. Koshiji, Y. Nawa, et al., " Transcutaneous energy transmission system for a totally-implantable artificial heart in case using external battery," in Proceedings of the World Congress on Medical Physics and Biomedical Engineering, pp. 3026-3029, 2006.