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Low Voltage Power Supply Incorporating Ceramic Transformer

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A low voltage power supply provides the regulated output voltage of a few volts from the supply voltage around 48 V. The low voltage power supply incorporates a ceramic transformer which utilizes piezoelectric effect to convert voltage. The ceramic transformer isolates the secondary from the primary, thus providing the ground isolation between the supply and the output voltages. The ceramic transformer takes the place of the conventional magnetic transformer. The ceramic transformer is constructed from a ceramic bar and does not include any magnetic material. So the low voltage power supply can operate under a magnetic field.

The output voltage is stabilized by feedback. A feedback loop includes an error amplifier, a voltage controlled oscillator and a driver circuit. The amplitude ratio of the transformer has dependence on the frequency, which is utilized to stabilize the output voltage.

The low voltage power supply is investigated on the analogy of the high voltage power supply similarly incorporating the ceramic transformer. Stability of the power supplies is studied from the theoretical viewpoint of stability. It is shown that the compensation, which has been applied to the high voltage ceramic transformer, could work similarly for the low voltage power supply.

Summary

The article describes a low voltage power supply incorporating a ceramic transformer. The low voltage power supply provides the regulated output voltage of a few volts from the supply voltage around 48 V. The ceramic transformer utilizes piezoelectric effect to convert voltage. The ceramic transformer isolates the secondary from the primary, thus providing the ground isolation between the supply and the output voltages. The ceramic transformer takes the place of the conventional magnetic transformer. As the ceramic transformer is constructed from a ceramic bar and does not include any magnetic material, there is no leakage of magnetic flux such that it can be operated under a magnetic field. An inductance element is needed to obtain efficient voltage conversion, being implemented by an air-core coil that can also be operated under a magnetic field.

When energy is stored in inductance L loaded with resistance R, the time constant is L/R. To maintain voltage across the resistance, energy is injected into the inductor at switching time intervals roughly equal to the time constant. Accordingly, a large resistance increases the switching frequency. Since the load resistance of power supply tends to be large, the inductance is a good energy reservoir for the low voltage power supply. It might be difficult to implement the ground isolation between the supply and the output voltage without the magnetic transformer. Yet the magnetic transformer can not work in a magnetic field.

When energy is stored in capacitance C, the time constant is RC such that the switching time required maintaining voltage becomes longer as the resistance increases. The capacitance is therefore a good energy reservoir for the high voltage power supply. The piezoelectric ceramic transformer stores energy as mechanical vibration, with energy dissipation at the load decaying the vibration. The transformer is similar to capacitance in that the time constant of the decay is proportional to load resistance. In this sense, the low voltage power supply incorporating the ceramic transformer is similar to the charge-pump power supply. But it is difficult for the charge pump power supply to implement the ground isolation.

Many Japanese manufactures compete in development of the low voltage power supply employing the ceramic transformers. Main objective is miniaturization of power supplies. The competition is keen due to a large market of power supplies miniaturized in size. The power supply of a laptop computer is so far a small box placed outside the computer. The box is to be replaced with the card that can be inserted into the slot of the laptop computer. Yet such the card-size power supply is not yet available so far.

The ceramic transformer reduces the power supply in size mainly for the following two reasons. Firstly power density of the ceramic transformer is more than five times larger than that of the conventional magnetic transformer. Secondly the ceramic transformer can be operated efficiently at high frequencies where the conventional magnetic transformer increases in loss.

From the viewpoint of the ceramic transformers for the power supply operating in a strong magnetic field, it is not so important to reduce the size. To moderate the requirement for size brings large freedom to the design of the ceramic transformer. Following the view of an expert in the ceramic transformer, further studies

are unnecessary to manufacture the low voltage ceramic transformer operating in the magnetic field. A manufacturer is ready to supply such the ceramic transformers if there is enough demand.

Such the ceramic transformer is not yet commercially available. So we have no chance to learn the low voltage ceramic transformer by experience. Yet manufacturers have already accumulated a lot of experience and knowledge about the low voltage power supply employing the ceramic transformer. No manufacturer has put such the power supply to market. Price might be a problem or there may be difficulties which we have not yet understood.

The output voltage of the power supply is stabilized by feedback. A feedback loop includes an error amplifier, a voltage controlled oscillator and a driver circuit. The feedback mainly utilizes the frequency dependence of the amplitude ratio of the ceramic transformer which depends on the driving frequency whose range is designed to be higher than the resonance frequency of the ceramic transformer. The feedback increases the driving frequency when the output voltage is higher than a reference voltage at the input of the error amplifier. Similarly, the driving frequency decreases when output voltage is lower than the voltage specified by the reference voltage.

The stability of the low voltage power supply is studied by analogy with the high voltage power supply similarly incorporating the ceramic transformer. The compensation, which has been applied to the high voltage ceramic transformer, could work similarly for the low voltage power supply. Simulations based on a lumped-constant equivalent circuit for the ceramic transformer are extensively utilized to understand the compensation. Responses of the power supply are simulated into details. Hopefully we could compare the simulations with the responses of a practical circuit and report its efficiency and performance.

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