Multi-Tube Piezoelectric Inverters

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Abstract

Piezoelectric inverters are often used in cold cathode tubes of LCD panels, etc. This is because of their superior performance over electromagnetic inverters and for their higher efficiency and their potential for inclusion in compact and slim devices. This paper introduces a newly designed inverter that is capable of supporting four cold-cathode tubes. This device features output controls and irregularity detection circuitry that have been developed with a view to exceeding the performance of competing products.

Keywords

piezoelectric, inverter, cold cathode tube, full-bridge, LCD, liquid crystal

1. Introduction

The applications of notebook PCs have recently been adopting two orientations. Mobile models using 14-inch or smaller LCDs are promoting portability and increasing the need for a reduction in size/weight and extended battery life. On the other hand, the models using 15-inch or larger LCDs otherwise known as “all-in-one models” are equipped as their name implies with DVD drives and TV capture functions as standard. Their positioning is thus shifting from the previous role of Internet terminal to movie/TV viewing terminals and their shipments are increasing. The increase in the LCD sizes and the expansion of widescreen sources are also increasing the requirement for an increase in brightness to support enhancement of the comfort of viewing. Actually, the LCDs used in large-screen notebook PCs have been shifting from single cold cathode type to double cold cathode type, and it is presently not at all unusual to find notebook PCs offering brightness of 500 Nits or greater.

At NEC TOKIN, we have already commercialized double tube piezoelectric inverters to meet the market needs for LCDs with high brightness [1], and we have recently succeeded in developing 4-tube piezoelectric inverters for use in large-screen monitors and LCD TVs with higher brightness requirements.

2. Piezoelectric Inverter

2.1 Features of Piezoelectric Inverter

The piezoelectric transformer utilizes the piezoelectric effect of piezoelectric ceramics for voltage transformation. The piezoelectric material generates an electrical energy when a mechanical energy is applied to it (piezoelectric effect) and generates a mechanical energy when an electrical energy is applied to it (inverse piezoelectric effect). Many products, such as piezoelectric vibrators, piezoelectric actuators and piezoelectric gyros have been commercialized using either of these properties. The piezoelectric transformer is a product that utilizes both of the two properties.

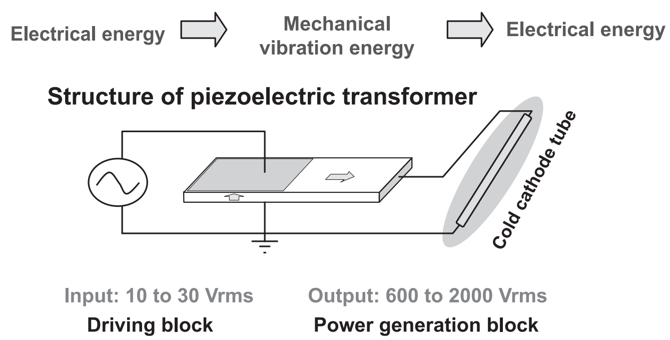

Fig. 1 Principles of the piezoelectric transformer.

With the piezoelectric transformer, the primary- and secondary-side electrodes are installed on a piezoelectric ceramic material. An AC voltage (at the resonance frequency of the transformer) is applied to the primary electrode to excite mechanical vibrations, these mechanical vibrations generate power on the secondary side and the power is output from the device (**Fig. 1**).

While a traditional power transformer converts energies via electricity → magnetism → electricity, the piezoelectric transformer is based on completely different principles, converting energy via electricity → mechanical vibrations →

electricity.

The following summarizes the main features and drive systems of the piezoelectric inverter.

2.2 High Efficiency

The fact that the piezoelectric transformer utilizes the mechanical resonance of a piezoelectric body is one of the key points supporting improvement of energy utilization efficiency. Other technical factors that improve efficiency include the type of piezoelectric material, its shape/dimensions, the electrode formation process, the method of mounting on a PWB and the drive circuit system. All of these need to be optimized.

The inverters commercialized by NEC TOKIN can be classified into two types: the inverters that adopt a push-pull system in the drive circuitry in order to meet the recent drop in prices (**Fig. 2**); and the high-efficiency type inverters adopting the full-bridge system in the drive circuitry (**Fig. 3**). The features of these drive systems are as follows.

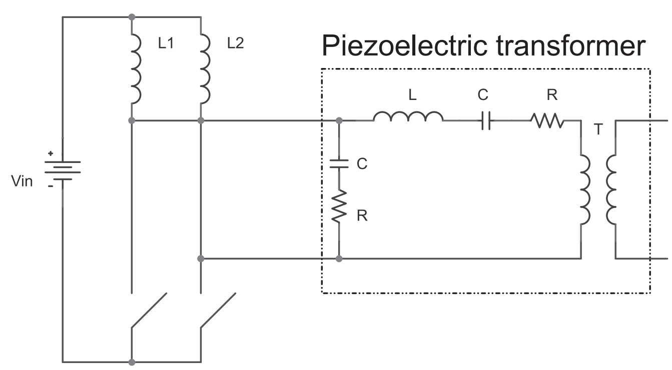

Fig. 2 Push-Pull system.

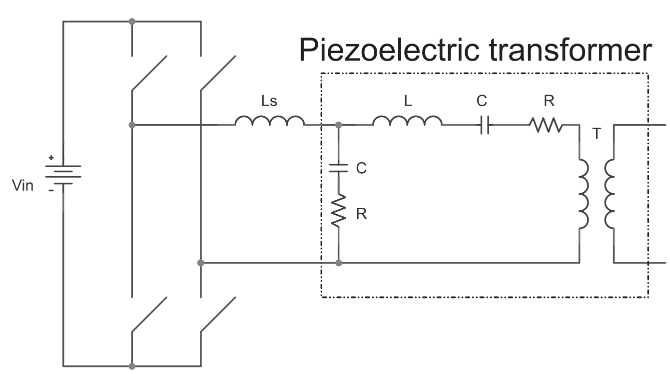

Fig. 3 Full-Bridge system.

(1) Push-Pull System

This system drives two switching devices alternately in order to supply AC power to the piezoelectric transformer. The simple switching circuit configuration makes this system helpful for reducing the number of power components and in controlling IC costs.

(2) Full-Bridge System

This system generates a sine wave based on the resonance of a circuit in which the inductance Ls and the piezoelectric transformer's primary capacity Cd_1 are connected in series as shown in Fig. 3. High efficiency is achieved by reducing the harmonics contained in the resonance voltage waveform. The inverter efficiency is increased based on the principle that the energy conversion efficiency increases as the electrical signal used to generate the mechanical vibrations (piezoelectric transformer input voltage waveform) approaches closer to the sine wave.

2.3 Compact and Slim

Whether piezoelectric or electromagnetic, the possibility of reducing the sizes of current inverters can be regarded as being dependent on the transformer. In general, the piezoelectric transformer has a higher power density (energy per unit volume) than the electromagnetic transformer and it is therefore advantageous as a means of reducing the size and thickness of the inverter.

2.4 Low Noise

While the electromagnetic inverter utilizes electromagnetic energy, the piezoelectric inverter functions by converting electricity into vibrations temporarily and reconverting it into electrical energy and it is therefore almost free of noise. The traditional method that reduces electromagnetic noise by absorbing it by using additional components can be changed to a radical measure that eliminates the noise at the source.

2.5 Non–Flammability

Another feature of the piezoelectric inverter is its safety. Thanks to the inclusion of a TV viewing function, the PC is tending to be transformed into an entity close to becoming a home appliance; considerations with regard to its safety performance have naturally become no longer distinguishable from those of home appliances. However, since the piezoelectric inverter uses a ceramic that is a non-flammable material in its transformer, it is free from the risk of smoking or fire ignition that could occur with an electromagnetic inverter due to a wire disconnection or wire degradation in the coil windings.

3. Development of the 4-Tube Inverter

At NEC TOKIN, we have already commercialized double tube piezoelectric inverters to meet the market needs for brightness improvement. Recently, we have developed 4-lamp piezoelectric inverters targeted at large-screen monitors and LCD TVs that need even higher brightness. **Photo** shows an example of a 4-tube piezoelectric inverter. The inverters can adopt various arrangements including square and long rectangles according to market needs.

The drive circuit uses the full-bridge system for high efficiency (**Fig. 4**).

Additionally, a step up coil that performs an auxiliary role in voltage boosting is provided and the piezoelectric transformer is then attached to it. This arrangement makes it possible to use a single-plate type piezoelectric transformer and thus reduce the cost.

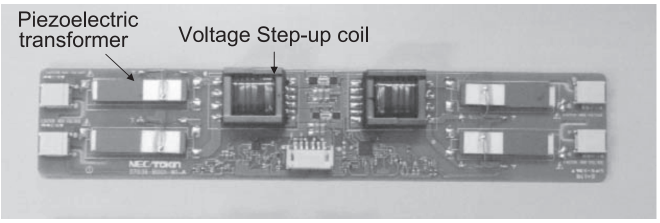

Photo 4-tube piezoelectric inverter.

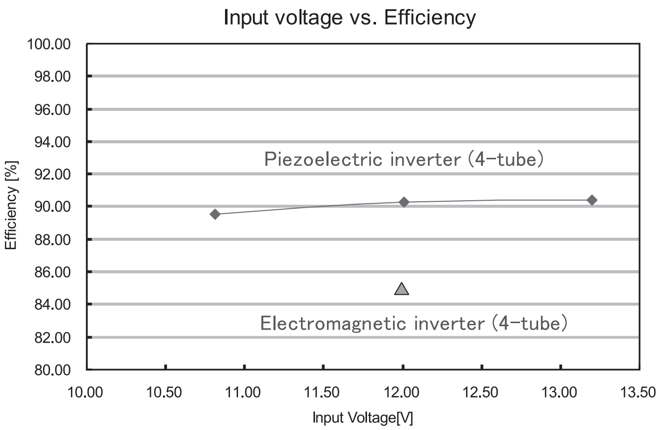

Fig. 4 Comparison of efficiency between our piezoelectric inverter and competitor's electromagnetic inverter.

4. Protection Circuitry for 4-Tube Piezoelectric Inverter

Multi-tube piezoelectric inverters have been developed despite the fact that they use more complicated designs in both the drive and protection circuits and the circuit design is more difficult compared to that for the single tube inverters.

4.1 LCP (Low Current Protection) Circuit

This circuit is used with an LCD unit in which multiple cold cathode tubes are used, in order to detect defective tube(s) when one or more tube(s) are not lit or the current flowing through them is lower than that set by the predetermined threshold.

In the case of a non-lighting irregularity due to an inverter output fault or a cracked cold cathode tube as shown in **Fig. 5** , the potential in the tube current feedback line drops. If this is detected by the LC monitoring signal line, a stop signal is sent to the drive circuit.

4.2 LVP (Low Voltage Protection) Circuit

This circuit stops the inverter safely if the inverter output voltage drops due to an abnormal decrease in the load impedance, etc. If the current flowing through any of the four LV detection signal lines in **Fig. 6** drops below the predetermined threshold, a stop signal is sent to the drive circuit.

Instances in which the protection circuit stops the inverter safely include short-circuiting between the high and low

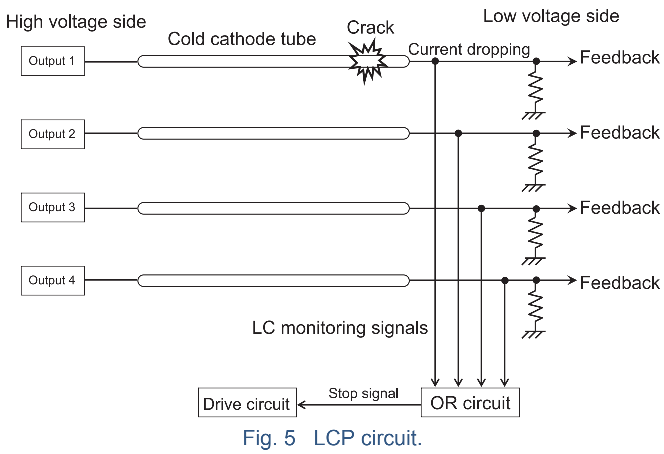

Fig. 5 LCP circuit.

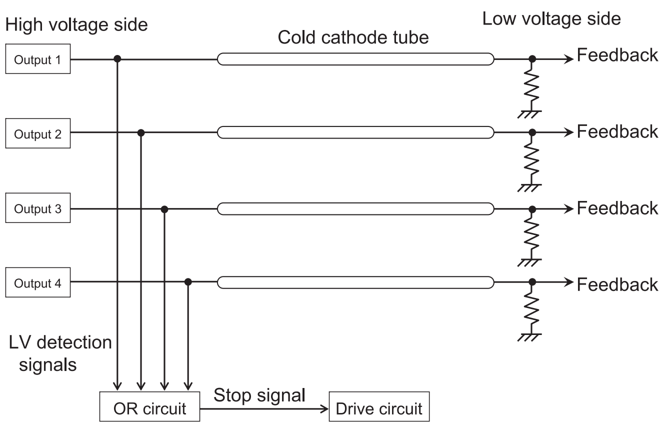

Fig. 6 LVP circuit.

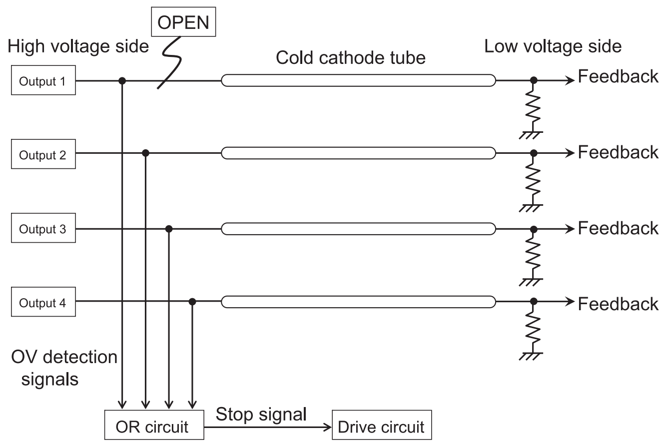

Fig. 7 OVP circuit.

voltage output connectors, short-circuiting between the high voltage side and GND and during measurements for current limiting testing (UL60950).

4.3 OVP (Over Voltage Protection) Circuit

This circuit stops the inverter safely when an excessive output voltage is generated (**Fig. 7**). It identifies the largest of the four output voltages from the inverter. When this value exceeds the predetermined threshold, this circuit controls the piezoelectric transformer drive frequency so that the threshold output voltage is maintained and, after a certain period of time, it sends a stop signal to the drive circuit to achieve a safe stoppage.

In addition to protection against over-voltage, the OVP circuit also performs the important role of determining the output voltage when the output connector is open. The impedance of the cold cathode tube varies depending on the ambient conditions and the current flowing through the tube. In particular, when the ambient temperature is low or the surroundings are dark, the impedance of the cold cathode tube increases so that the voltage required for lighting it (the kick-off voltage) also increases. Therefore, the threshold value for the OVP circuit should be determined in consideration of the kick-off voltage of the cold cathode tubes.

The brightness of the LCD backlight is adjusted by a time-division brightness control, which turns the inverter drive on and off repeatedly at a frequency of about 200Hz and adjusts the brightness by varying the on-duty time of the lighting. However, since a relatively high kick-off voltage must be applied for a certain period in order to start up the backlight, this circuit has the function of outputting voltage at the 100% on-duty status of the brightness control when the output is open.

4.4 Timer Circuit

Each of the three protection circuits described above has a timer circuit, which sets the time individually from the detection of a trouble until a stoppage of the drive circuit. The reason for individual setting is that the optimum stop time is variable depending on the expected irregularities. For example, in order to prevent excessive current flow into the piezoelectric transformers when a high-voltage output from the inverter is connected to GND, the drive circuit is stopped almost instantaneously, or in a few hundreds of microseconds. On the other hand, the timer operation of the OVP circuit is designed to be generally more than a second because a relatively high voltage needs to be applied for a certain period of time in order to light the cold cathode tube when the impedance is high.

5. Conclusion

As described above, in order to meet market trends in which the need to increase the size and brightness of the LCD panels of PCs is paramount, we have developed 4-tube piezoelectric inverters for use in PC monitors and LCD TVs.

In the future, inverters used in notebook PCs, LCD monitors and large-screen LCD TVs are expected to have to support increased power and efficiency as well as being capable of continuously reducing their sizes and weights. Piezoelectric inverters can meet these requirements with a higher efficiency, smaller size, lighter weight and a higher safety capability than can the electromagnetic inverters. We are planning to promote ongoing price reductions while continuing to maintain such advantages.

References

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