

TITLE OF THE INVENTIONELECTRONIC BALLAST FOR
FLUORESCENT LAMPBACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an electronic ballast for a fluorescent lamp.

2. Description of the Related Art

A fundamental circuit shown in Figure 6 has been conventionally used as an electronic ballast for a fluorescent lamp. Two power switches 31, 32 are arranged in a half bridge form, and a circuit of a fluorescent lamp 33 comprises a lamp at a reactance of one side and a L-C series resonance circuit.

In Figure 6, a metal-oxide semiconductor field-effect transistor (which is hereinafter described as a 'MOSFET' in the present invention) is used as each of the power switches 31, 32 and is driven by output of a transformer 34.

A primary coil of the transformer 34 is driven by electric current of a lamp circuit and is operated by a resonance frequency of a coil L and a capacitor C.

The circuit is not arranged to be self-starting, and it is necessary to send a pulse from a diode 35 and an AC switch which are connected to a gate of a low side MOSFET (the power switch 32).

The power switch 32 of low side (the low side MOSFET) is firstly turned off and oscillation starts, and a high frequency rectangular wave (30 to 80 KHz) produces electric current in the L-C resonance circuit. Sine wave voltage which is placed on the capacitor C increases owing to Q of resonance, and this value is sufficient to light a lamp. The lamp thereby provides light without blinks.

However, the conventional electronic ballast for a fluorescent lamp explained in Figure 6 has fundamental defects as follows.

The ballast is not arranged to be self-starting, it requires a long time until the lamp lights, considerable man-hour is required for manufacturing the ballast, dimmer is difficult, production of the ballast on a large scale costs a great deal, and a great amount of higher harmonic current occurs.

It is therefore an object of the present invention to provide an electronic ballast for a fluorescent lamp wherein self-starting is available, only a short time is required until the lamp lights, man-hour on manufacture is decreased, dimmer is easy, and manufacturing cost can be lowered owing to mass production.

It is another object of the present invention to provide an electronic ballast wherein a restraining level of higher harmonic

current of an electric power system for selling is further decreased.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be described with reference to the accompanying drawings, in which:

Figure 1 is a fundamental circuit diagram of an electronic ballast for a fluorescent lamp according to the present invention;

Figure 2 is a fundamental circuit diagram of power supply side of the electronic ballast;

Figure 3 is a circuit diagram in part illustrating in further detail;

Figure 4 is an explanatory view showing a principal portion of the circuit;

Figure 5 is a graphical representation of test results of actually measuring strength of each higher harmonic against each higher harmonic degree; and

Figure 6 is a circuit diagram showing a conventional electronic ballast for a fluorescent lamp.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will now be

described with reference to the accompanying drawings.

Figure 1 illustrates a fundamental circuit diagram of an electronic ballast for a fluorescent lamp according to the present invention. 1 is an oscillation circuit, and 2 is a gate driving circuit. The oscillation circuit 1 generates self oscillation at R_T and C_T , and a self-oscillation frequency f_0 is expressed by the following equation.

$$f_0 = \frac{1}{1.4 \cdot R_T \cdot C_T}$$

In this case, it is preferable to select R_T and C_T so that the self-oscillation frequency f_0 is arranged to be 40 to 60 KHz. 5 is a fluorescent lamp, and a coil L and a capacitor C are placed in a conventional arrangement. It is preferable to arrange the self-oscillation frequency f_0 within the foregoing range because the fluorescent lamp 5 lights only within this range.

High frequency signals I_1 , I_2 of the foregoing frequency f_0 are inputted from the oscillation circuit 1 into the gate driving circuit 2, and driver signals I_3 , I_4 are separately inputted from the gate driving circuit 2 into gates of a low side MOSFET 3 and a high side MOSFET 4 respectively.

In constructing the circuit shown in Figure 1, an IC which drives the low side MOSFET 3, the high side MOSFET 4, and IGBT on a logic level based on the ground is used. Unlike a conventional driver transformer 34 shown in Figure 6, the oscillation circuit 1 generates

self-oscillation at R_T and C_T , and the respective gates of the MOSFET 3 and the MOSFET 4 are driven at a duty cycle of 0 to 99 %. A dead time is arranged between the driver signal I_3 of the low side MOSFET 3 and the driver signal I_4 of the high side MOSFET 4.

This has an advantage of avoiding overheating of a power switch and trouble because overheating of the power switch of approximately 1 hs and the MOSFET 3 and the MOSFET 4 are turned on when either the MOSFET 3 or the MOSFET 4 is turned off.

Next, a power-supply fundamental circuit as shown in Figure 2 is used to provide rectified current from an AC input power supply into the IC shown in Figure 1. This circuit is provided with a shunt regulator of 15 V through dropper resistance.

In a conventional power-supply circuit, electricity is stored at a filter capacitor after bridge rectification and conducted only in the vicinity of a peak of AC input voltage due to the character of a fluorescent lamp, therefore an input power factor becomes approximately 0.6 delaying in a current waveform of a non-sine wave curve. In the viewpoint of rigorously decreasing higher harmonic current in a power distribution system obeying power quality regulations (guidelines on suppressing higher harmonic), the foregoing conventional circuit is defective.

Accordingly, a fundamental circuit with a power supply as shown in Figure 2 is used in the present invention. As shown in the drawing,

6

step-up is conducted by switching a step-up circuit CH_1 with an element Q_2 . This switching is controlled by a triangular wave A of an oscillation signal and the gate driver signal I_3 for the low side MOSFET 3 in Figure 1.

In concrete explanation, a switch means 6 comprises an element (i.e. a transistor) Q_1 , the element (i.e. a MOSFET) Q_2 , and a comparator U_1 . The switch means 6 is controlled by the gate driver signal I_3 consisting of a rectangular wave for the low side MOSFET 3 and the triangular wave A of the oscillation signal of the oscillation circuit 1. The step-up circuit CH_1 is switched by controlling the switch means 6 owing to a frequency for lighting a fluorescent lamp.

The driver signal I_3 is a rectangular wave of duty 50 %, and is connected and impressed to the element (MOSFET) Q_2 through a collector of the element (transistor) Q_1 . On the other hand, the triangular wave A of the oscillation signal is impressed to an input of the comparator U_1 , the comparator U_1 compares the direct current voltage and the triangular wave A, and its output signal is inputted to a gate of the element Q_1 and controls the element Q_1 .

Change in the direct current voltage is compared with the triangular wave inside duty 50 % waveform input I_3 , and a pulse width for switching the step-up circuit (booster) CH_1 is controlled.

That is to say, when the direct current voltage rises, the pulse width becomes narrow and the direct current voltage falls. On the

contrary, when the direct current voltage falls, the pulse width becomes wide and the direct current voltage rises. A closed loop like this is formed, and consequently, the direct current voltage is kept constant.

Therefore, in case the lamp (fluorescent lamp) is removed or broken and the circuit becomes opened, it is possible to prevent troubles such as a DC bus voltage reaching the upper limit of power MOSFET 3, 4 or overvoltage caused by the filter capacitor being heated.

The driver signal I_3 as an input waveform switches the step-up circuit CH_1 through the elements Q_1 , Q_2 , therefore input voltage and current are transmitted while the fluorescent lamp 5 is switched on and lights, and the current delays only within the waveform. A waveform of a sine wave (for example, 50 Hz or 60 Hz) which indicates electric current of electric power for selling is divided by an oscillation frequency (for example, 45 KHz) and electric power is obtained, therefore overall delay of electric current extremely decreases and a high factor can be secured.

Next, Figure 3 shows a further embodied circuit of the foregoing Figure 1 and Figure 2. U_2 is an integrated circuit IC for a gate driver of the low side MOSFET 3 and the high side MOSFET 4. A power supply is inputted from an AC power supply CN_1 , passes through a filter 7, and is impressed to a full-wave rectification diode BD_1 .

The integrated circuit for gate driver U_2 for sending driver

signals I_3 and I_4 to the gates of the low side MOSFET 3 and the high side MOSFET 4 respectively is cut by a DC bus through dropping resistances R_1 , R_2 and impresses direct current voltage smoothed by a smoothing capacitor EC_1 , and oscillates within a range of frequency $40 \text{ KHz} \leq f_0 \leq 60 \text{ KHz}$ according to the following equation.

$$f_0 = \frac{1}{1.4 \cdot R_T \cdot C_T}$$

Driving electric power of the high side MOSFET (switch) 4 is provided from a capacitor C_3 of a bootstrap, and approximately 14 V is charged on the capacitor C_3 while the low side MOSFET (switch) 3 is conducted.

When the high side MOSFET (switch) 4 is conducted, a bootstrap diode D_4 blocks DC bus voltage. It is necessary that the bootstrap capacitor C_3 does not discharge a part of the voltage when a fast-recovery diode (at least 100 ns) D_4 is under diode reverse recovery or blocks high-voltage bus.

Output from a half bridge comprising the MOSFET 3 and the MOSFET 4 is a rectangular wave (high frequency) of an extremely short transient period (approximately 50 ns). In order to prevent noise transiently emitted from an end of the fast waveform, snubbers R_7 , C_8 are arranged to decrease a switching time to approximately $0.5 \mu\text{s}$.

In order to prevent a vertical short circuit of the half bridge comprising the MOSFET 3 and the MOSFET 4, the integrated circuit U_2 is

constructed to produce a dead time of approximately $1\mu s$ between the driver output I_3 and the driver output I_4 .

A fluorescent lamp 5 operates in parallel in its own L-C resonance circuit. A reactance value of a lamp circuit is calculated from the following equation of series resonance.

$$f = \frac{1}{2\pi\sqrt{LC}}$$

It is necessary that the frequency is stable, therefore Q of the lamp circuit is low and differs owing to a common difference between R_T and C_T . The fluorescent lamp 5 normally does not require high lighting voltage, and Q of 2 to 3 is sufficient.

A 'plane' Q curved line tends to occur owing to a proportion of a big inductor and a small capacitor as the following equation, and R tends to become big as a number of turns increases.

$$Q = \frac{2\pi fL}{R}$$

In the present circuit, it is arranged so that a DC power supply voltage is relatively high, L is small, and Q is not extremely big.

Figure 4 concretely shows circuits inside the integrated circuit U_2 , which possesses an oscillation circuit 1 and a gate driving circuit 2, and change in level of an oscillation signal is prevented by inserting a Zener diode 8 of 15 V into V_{cc} . It is possible to use a front end oscillator such as 555 IC as the integrated circuit U_2 .

10

In conclusion, in Figure 3 (and in Figure 1 and Figure 2), the present circuit switches the step-up circuit CH₁ (using the switch means 6) at a frequency for lighting a fluorescent lamp, prevents current delay beyond the ON waveform, and suppresses higher harmonic of current by sending a power factor and an electric current curved line along a sine wave.

According to 'Guidelines on Suppressing Higher Harmonic of General Purpose Household Electric Appliances' concerning JIS C 8117, a limit Y (%) is prescribed depending on each higher harmonic degree n as the following Table 1.

Table 1

Limit Y

Higher Harmonic Degree n	Maximum Value of Fundamental Wave Input Current of Lighting Apparatus Expressed in Percentage (%)
Even Higher Harmonic	
2	2
Odd Higher Harmonic	
3	30
5	10
7	7
9	5
11 ≤ n ≤ 39	3

According to the electronic ballast (circuit) for a fluorescent

lamp of the present invention shown in Figure 3, results of actual measurement in the following Table 2 are obtained.

Table 2

Higher Harmonic Degree n	Maximum Value of Fundamental Wave Input Current Expressed in Percentage (Limit) : Y(%)	Higher Harmonic Degree n	Maximum Value of Fundamental Wave Input Current Expressed in Percentage (Limit) : Y(%)
01	100	26	0.4
02	1.1	27	0.6
03	21.0	28	0.2
04	0.5	29	2.2
05	4.8	30	0.8
06	1.3	31	0.9
07	4.0	32	1.7
08	0.4	33	0.6
09	3.4	34	1.3
10	0.9	35	0.7
11	2.5	36	0.5
12	2.0	37	0.3
13	1.9	38	0.9
14	0.4	39	1.0
15	1.9	40	0.2
16	0.6	41	0.8
17	2.2	42	0.9
18	1.1	43	1.6
19	1.7	44	0.1
20	1.7	45	1.0
21	1.4	46	1.4
22	1.9	47	2.0
23	0.1	48	3.4
24	1.3	49	1.3
25	1.1		

On the basis of this Table 2, a graphical representation of Figure 5 is obtained. That is to say, the axis of abscissas indicates higher harmonic degrees (n), and the axis of ordinates indicates 'maximum values indicated in percentage against fundamental wave input current (limits) : Y (%)'.

The foregoing Table 1 and Figure 5 show that good results were obtained sufficiently satisfying the limits Y (%) described in Table 1 of the foregoing 'Guidelines'.

Therefore, according to the present invention, it is possible to sufficiently suppress occurrence of higher harmonics and improve higher harmonic environment of an electric power system for selling. Self-starting is available, and a time until the lamp lights is shortened. Moreover, man-hour on manufacture is decreased and the electronic ballast can be easily produced on a large scale with low cost. Furthermore, dimmer is easy.

While preferred embodiments of the present invention have been described in this specification, it is to be understood that the invention is illustrative and not restrictive, because various changes are possible within the spirit and indispensable features.



I claim:

1. An electronic ballast for a fluorescent lamp provided with:
 - a gate driving circuit for outputting driver signals of 40 to 60 KHz in frequency owing to high frequency signals from an oscillation circuit oscillating at a frequency of 40 to 60 KHz;
 - a low side MOSFET and a high side MOSFET where the driver signals of said gate driving circuit are inputted respectively;
 - a switch means controlled by the gate driver signal comprising a rectangular wave of said low side MOSFET and a triangular wave of an oscillation signal of the oscillation circuit; and
 - a step-up circuit for boosting original electric current and being controlled by said switch means to supply a fluorescent lamp discharged from a direct current bus with electric power in order to suppress higher harmonic current.