

Examination of T8-T5 Electronic Ballast Adaptor

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Abstract — This paper presented an examination of conversion from T8 conventional fluorescent lamp into a T5 lamp with electronic ballast. Without changing the T8 fixture, a T5 fluorescent lamp can be fitted into the fixture with a T8-T5 electronic ballast adaptor, which provides both power factor correction (PFC) and high frequency switching. The power factor of the overall lighting system was regulated to be 0.98, and the electrical efficiency was 95%. All these features cannot be achieved with the conventional magnetic ballasts.

I. INTRODUCTION

The lighting system provides many opportunities for cost-effective energy saving without any sacrifice.

The lighting retrofit is now a part of the Energy Conservation program over the world and reduction of energy consumption by implementing energy conservation schemes is needed. Incandescent lamps convert about 10 per cent of electrical energy into light and the remainder into heat or invisible light such as infra-red, whereas fluorescent lamps turn 25~33 per cent of the input energy into visible light. Fluorescent lighting is now widely used in industrial and commercial applications mainly due to its high efficacy and longer lifespan compared to incandescent lamps. Today T8 lamps are dominant the largest market share, however, T5 fluorescent tubes have better performance than T8 in terms of efficacy and color render index (CRI). The complete fixture with T5 also provides additional features such as high efficiency, quick start, longer lamp lifetime and no flicker effect. Therefore, The T5 fluorescent tube and electronic ballast is becoming popular.

II. COMPARISON BETWEEN T8 AND T5 TUBES

While T8 lamps play a crucial role in the lighting industry, T5 lamp has emerged in the market and is gaining popularity. As the T5 tube is slightly shorter in length than T8 and is operated by a different control gear as well, the entire luminaries may need to be replaced in a lighting retrofit from T8 to T5. To avoid the replacement of luminaries, adaptor with control gear is also available in the market for fixing T5 tube to T8 luminaries.

The advantages of T5 lamps over T8 lamps can be summarized as follows [1]:

- The smaller size of T5 lamps allows for smaller luminaries.
- The smaller lamp diameter of T5 lamps makes it easier to design optical systems that distribute light in the intended directions.
- The higher output of T5 high output (T5 HO) lamps may reduce the number of luminaries per project.

A disadvantage of T5 lamps, if they are inappropriately used, is glare. Glare – These sensation produced by luminaries within the visual field that are sufficiently greater than the luminance to which the eyes are adapted,

which causes annoyance, discomfort, or loss visual performance and visibility. Glare can be prevented, though, by choosing luminaries that shield the light sources from viewing. Another measure to avoid glare is to decrease the visual size or solid angle of these light sources.

TABLE I
COMPARISON OF LUMINOUS EFFICACY BETWEEN T8 AND T5

Lamp type	Lamp code	Lamp power	Minimum allowable luminous efficacy lm/W
T8	MCF	<18W	50
		>=18W, <40W	55
		>=40W	65
T5	MCF	<14W	60
		>=14W, <30W	65
		>=30W	70

From code of practice for Energy efficiency of lighting installations [2]

Nominal Lamp Wattage:

This column of data refers to nominal lamp wattage of a single lamp, excluding the lamp control gear loss, quoted from the lamp manufacturer's technical specifications.

Luminous Efficacy:

For a particular lamp, its luminous efficacy is quoted directly from the lamp manufacturer's technical specifications. Alternatively, with reference to Table (Fig.1) of the Code, the luminous efficacy of a lamp can be calculated as follow:

$$= \frac{\text{Lamp's Luminous Flux at Prescribed No. of Initial Operating Hours}}{\text{Nominal Lamp Wattage}}$$

III. COMPARISON OF CONVENTIONAL FLUORESCENT LIGHTING AND ELECTRONIC BALLAST

Conventional fluorescent lighting systems operate from the mains using a simple series choke as the ballast whose function is to create sufficient voltage with the glow starter to start the lamp and also to limit the lamp current after it has started. Such a system is simple and low-cost; however the drawbacks are a low input power factor, audible humming noise, extra loss in the choke, delayed start, stroboscopic and flicker effects, and no dimming control. Electronic ballasts for high-frequency operation of fluorescent lamps have been increasingly adopted as an energy efficient solution in residential, commercial and industrial lighting applications [3]–[6].

Typical advantages of using electronic ballast include: improved efficiency of the overall systems, higher lumen output per watt and a longer lifetime of the fluorescent lamps. Electronic ballast operates at a high frequency of

20-60 kHz whereas the conventional magnetic ballast operates at 50/60Hz. The high frequency operation of the fluorescent lamp improves the efficacy by approximately 10 per cent because of the increase in phosphor excitation. Flicker is also eliminated. Instant start is possible even at low supply voltage. Lamp life time is hence extended because coating of the filament can last longer. Electronic ballasts also consume less power than conventional ballasts because the electronics are more efficient than the bulky magnetic chokes. The combined benefit in energy efficiency is around 25 per cent with the same light output level. Table 2 shows a comparison of performance between conventional ballast and electronic ballast.

TABLE 2
COMPARISONS OF PERFORMANCE BETWEEN CONVENTIONAL AND ELECTRONIC BALLASTS FOR T8 36W FLUORESCENT LAMPS

	Conventional	Electronic
Power consumption	46W	37W
Luminous flux	3000 lm	3000 lm
Efficacy	64 lm/W	80 lm/W
Total harmonic distortion	11%	6%
Power factor	0.5	0.96
Weight	900g	300g

IV. T8 CONVENTIONAL LIGHTING SYSTEM CONVERTING TO T5 ELECTRONIC BALLAST

The study of this paper was to examine the mechanism and principle, which converted a T8 lighting system into a T5 electronic ballast. The most basic conventional fluorescent lamp circuit was showed in Fig 1, the lamp operated from the mains using a simple series choke as the ballast whose function was to create a sufficient voltage with the glow starter to start the lamp and also to limit the lamp current after it has started.

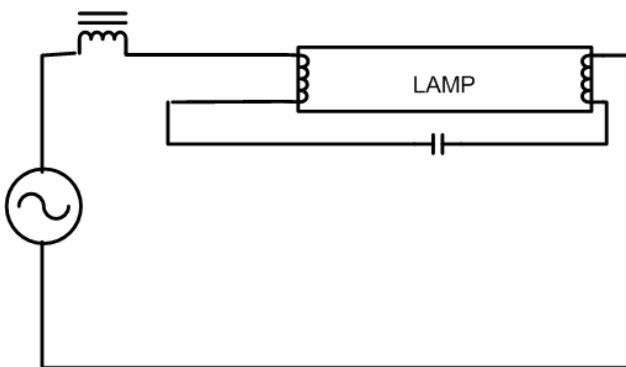


Fig. 8: T8 Conventional Lighting System Circuit Diagram

Before installing the T5 lamp into the T8 fixture, it was still necessary to make a slightly modification that was change of the starter capacitor into a fuse. Then, a T8-T5 adaptor was mounted in an end of lamp socket; afterwards, the T5 could be installed into the fixture. Details were demonstrated in Fig. 2.

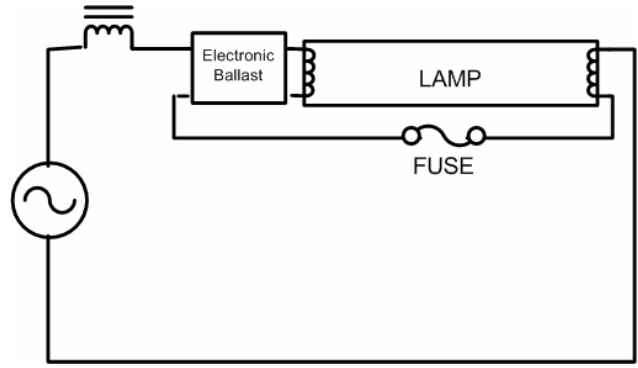


Fig. 2: Electronic Ballast for T5 Fluorescent Tube

This electronic ballast was divided into five parts: input filter (1), bridge rectifier (2), passive power factor correction circuit (3), half-bridge inverter (4) and self-resonant tank (5, 6 and 7). The block diagram of electronic ballast for T5 fluorescent was shown in Fig. 3:

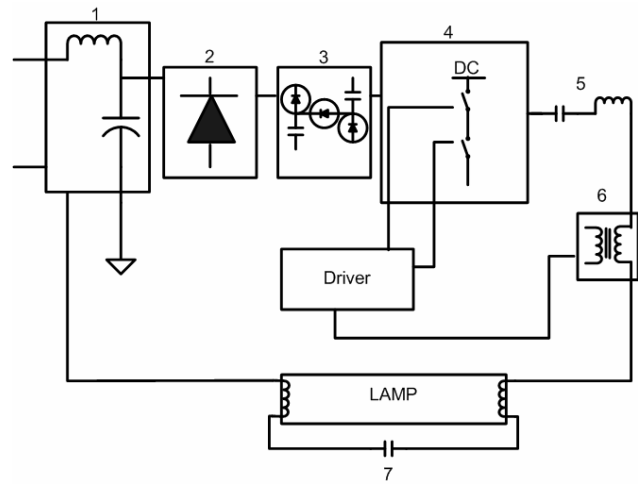


Fig. 3: Block Diagram of Electronic Ballast for T8-T5 Adaptor

The input filter (1) was used to attenuate the inverter switching spikes, which otherwise would appear on the AC input lines. It also smoothed out the harmonics in the current waveform of the passive PFC. The AC input was converted by the full-bridge rectifier (2) into DC voltage.

In this passive P.F.C circuit, the reservoir capacitors were charged in series via the diode during each half cycle of rectified AC input.

Each capacitor was charged to the peak value of AC voltage minus three diode drops – two in the bridge rectifier and one in the PFC between the two capacitors.

The voltage of capacitor was charged to half the peak AC voltage following the sinusoidal waveform down to $V_{peak}/2$. At this time, the capacitors were essentially in parallel and supply load current until the rectified AC input again exceeded $V_p/2$ on the next half cycle.

The discharge duty cycle for the capacitors was approximately 37% followed by an idle period during which time the load was being supplied directly from the rectified AC input. At the peak of the input AC voltage there was an additional current to re-charge the capacitors up to V_{peak} . The magnitude and duration of this current was a function of the depth of discharge and the value of the resistor in the charging circuit. [7]-[8]

The self-resonant L-C circuit and the pulse transformer

was the voltage fed self-oscillating half-bridge has been widely used in the ballast design. The two switches in the half-bridge circuit were switched alternatively so that an AC power flows through the lamp load. The drive signal of the half-bridge switches was derived from sensing either the voltage or the current flowing through the pulse transformer. Compared with the current fed self-oscillating half-bridge solution, this has advantages of design simplicity, lower voltage stress and higher operation frequency[9].

V. RESULT OF EXAMINATION

Figures 4 and 5 show the input voltage and current of AC source for the cases with and without passive PFC respectively.

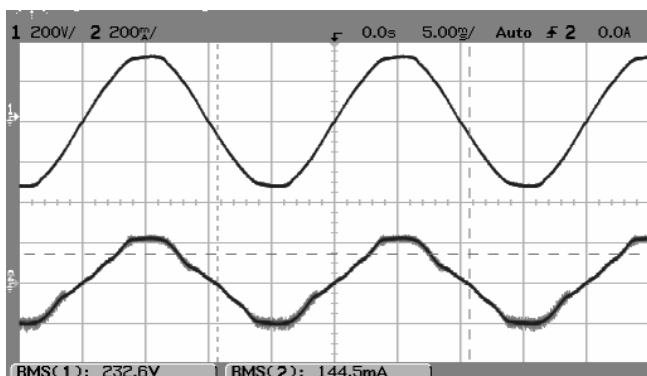


Fig. 4: Voltage and Current Waveform of Input Source with PFC

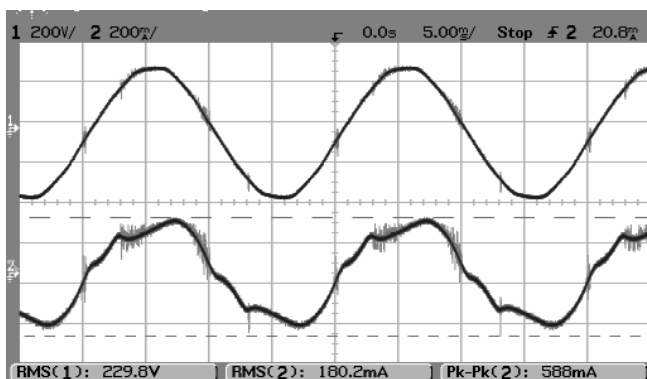


Fig.5: Voltage and Current Waveform of Input Source without PFC

Though, the phase shifts between current and voltage waveforms were small for both cases, the distortions of current without PFC was much severe than that with PFC. The power factors for the ballasts with and without PFC were 0.99 and 0.94 respectively, while the THDs for them were 8% and 24% respectively. In this application, the PFC circuit provided not only power factor correction but also minimization of harmonics of input current. Many low-cost electronic ballast do not use power factor correction, hence the electromagnetic interference was likely a problem in meeting some international EMC standards, such as CISPR and FCC.

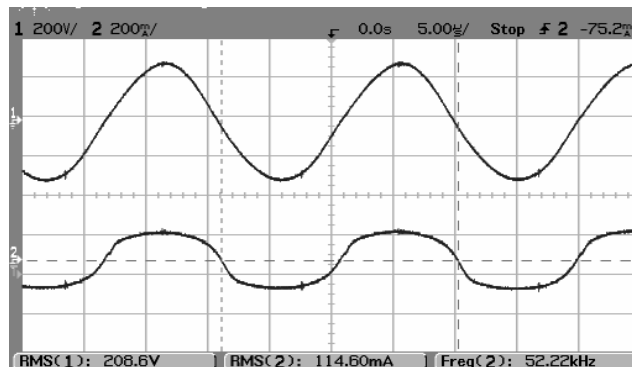


Fig. 6: Voltage and Current of Fluorescent Lamp

Figure 6 shows the switching frequency of the T5 lamp, it was measured to be 52 kHz. This frequency range was chosen so as to avoid the signal interference with other infra-red remote controller, which usually operates with the range around 40 kHz. In addition, mercury gas inside the fluorescent lamp will stay ionized constantly at the frequency around 50 kHz.

VI. CONCLUSION

This paper presented the study of T8-T5 electronic ballast adaptor. It has the most significant advantages, including power factor correction, high frequency high efficiency switching, quick start and no stroboscopic and flicker effects. However, the main point for this adaptor is the effort-less modification that can be done by almost any non-technical person. It is recommended for the retrofit program to convert the conventional T8 system into the T5 system.

VII. REFERENCES

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