

# Electronic Ballast for Mercury-Free Xenon Lamps

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## 1. Introduction

Bulbs of xenon head lamps most widely used today contain a trace amount of mercury. Getting rid of mercury from the bulbs is required for environmental reasons. The electrical characteristics of mercury-free bulbs are different from those of conventional bulbs especially in terms of luminous efficiency during run-up period and rated current in the stable state. This report discusses the development of an electronic control unit (electronic ballast) that drives a mercury-free bulb.

## 2. Xenon Head Lamp and Mercury-Free Bulb

A xenon head lamp has twice the luminance of a conventional halogen lamp, four times the service life, and yet consumes just two-thirds of the power, so it has increasingly been used to improve driving safety at night. Mitsubishi Electric has developed and manufactured electronic ballasts that drive the xenon bulbs used as the light source of xenon headlamps and the products are shipped not only in Japan but also to markets in Europe and North America.

The bulbs of today's mainstream xenon lamps contain a trace amount of mercury for emitting visible light and holding the valve voltage at a high level. However, mercury is one of the substances prohibited in principle in the European End of Life Vehicle Directive, and its use in xenon bulbs is exceptionally permitted since it is technically difficult to replace it with another substance. Nevertheless, as xenon systems will eventually have to be mercury free, bulb manufacturers have continued work on developing mercury-free bulbs.

Although one newly selected material for mercury-free bulbs improves the bulb voltage, it does not perform the same as the conventional material. Table 1 and Fig. 1 show the differences in the run-up power and rated bulb current between the bulbs.

Table 1 Comparison between a conventional bulb and the mercury-free bulb

	Conventional bulb	Mercury free bulb
Run-up power	70 W	75 W
Steady state power	35 W	35 W
Rating bulb voltage	85 V	42 V
Rating bulb current	0.41 A	0.83 A

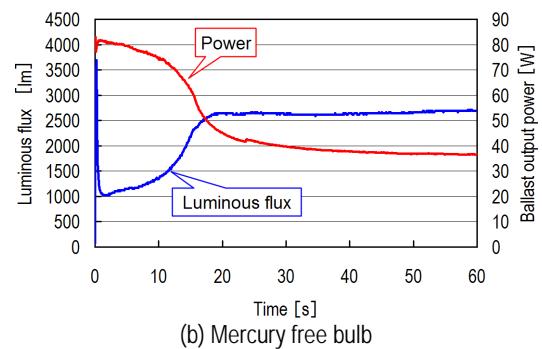
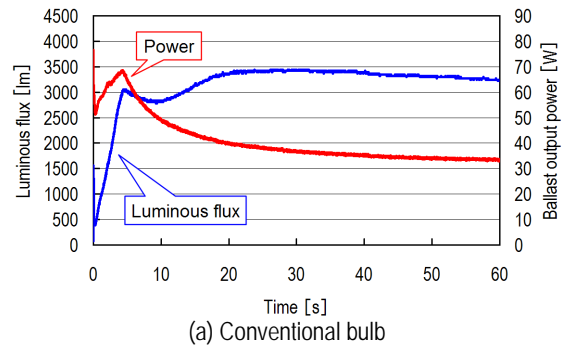


Fig. 1 Comparison of luminous run-up characteristics

## 3. Ballast for Xenon Headlamp

The xenon system at the heart of the xenon headlamp consists of a bulb, an igniter, and ballast. Of these components, the ballast has the following functions.

- (1) The ballast converts the battery voltage (rated level: 12V) into the voltage level required for the bulb (400V for open circuit voltage and rated 42V for stable state).
- (2) The ballast supplies 1 kV power for ignition trigger.
- (3) The ballast supplies a high power (75W) for quick luminous run-up while the luminous efficiency of the bulb is low during run-up. After the period, the ballast decreases the output power gradually to the rated power output of 35 W so that the brightness does not change suddenly as the luminous efficiency of the bulb grows.

Since the electrical characteristics of mercury-free bulbs are greatly different from those of the conventional bulbs as described above, conventional ballasts cannot drive mercury-free bulbs. Mitsubishi started shipping ballasts for mercury-free bulbs to European markets in 2007.

The delay in luminous run-up during lamp run-up of

a mercury-free bulb is partly compensated by an increase in initial power to the bulb and by an extension of the power supply time on the ballast. However, for the ballast itself, the power loss with regard to the input/output current increases. In addition, even in the stable state, the rated bulb current required to output the same power is double that of the conventional valve, because the rated bulb voltage of a mercury-free bulb is almost half that of a conventional bulb. Thus, the increased output current increases the power loss, which must be controlled properly because it raises the temperature of the ballast and lowers the reliability during operation.

Also, reduction in ballast size is another issue required for installation on vehicles (headlamps)

To develop ballasts for mercury-free bulbs, we aimed to reduce the power loss and product dimensions to equivalent levels of the conventional types or less.

#### 4. Technological Components of Ballasts for Mercury-Free Bulbs

First, we changed the DC/DC converter from a single system to a dual system. With this modification, the current per diode remains at the same level as the conventional ballasts even when the output current during stable illumination of a mercury-free bulb is doubled, thus suppressing an increase in forward power loss (forward voltage × current) per diode. In addition, the phase of the dual system is shifted 180° (Fig. 2) to control output/input ripples, thus improving the circuit efficiency.

Next, we replaced the drive-frequency fixed hard switching method of the conventional ballasts by the zero voltage switching (ZVS) method that reduces switching loss, and we used a newly developed application specific integrated circuit (ASIC) to drive the ZVS. The ASIC is equipped with an internal power supply

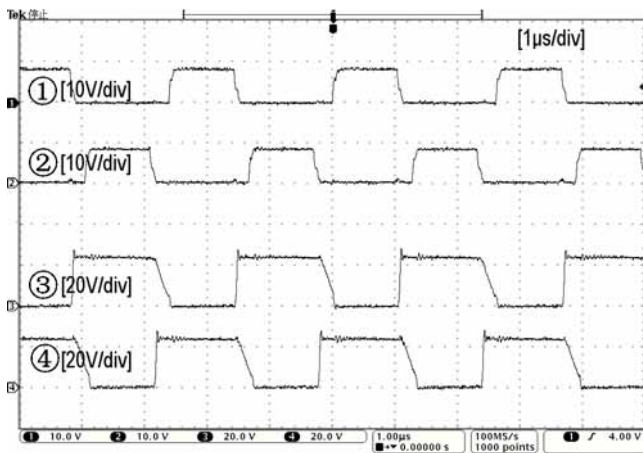


Fig. 2 FET gate voltage waveforms (①②) and drain voltage waveforms (③④) at ZVS

circuit and power control circuit that are made of discrete devices in the conventional ballasts, thus successfully limiting the increase in number of component devices and product size.

Thirdly, the DC/DC converter operates at high frequency and the transformer and smoothing capacitor have been made smaller. With the conventional hard switching method it was difficult to employ high-frequency operation because a high-frequency DC/DC converter increases the switching loss. However, with the new model, the ZVS method allows high-frequency operation without affecting the efficiency.

Lastly, we used an insulated gate bipolar transistor (IGBT) for the inverter element that changes the polarity of the output current. IGBT is characterized by the on-state voltage decreases and the on-state power loss decreases with increasing temperature. Furthermore, since the on-state power loss is proportional to the current, IGBT is more effective than MOS FET in reducing the on-state power loss in a high-current mode. (The on-state power loss with MOS FET in the conventional method was proportional to the square of the current.)

#### 5. Efficiency and Size of Mitsubishi Ballast

The ballast efficiency (bulb input power/ballast input power, Fig. 3(a)) during high power output at run-up has been improved by approximately 20 points against the conventional type, and yet the ballast efficiency during stable illumination (Fig. 3(b)) remains almost the same as the conventional type.

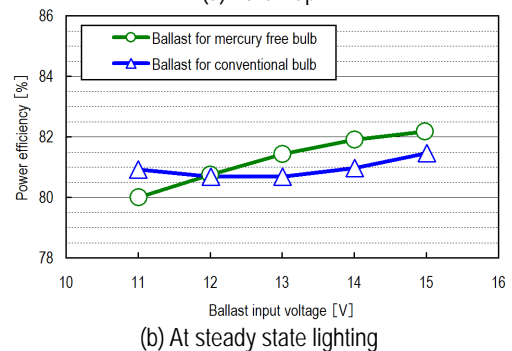
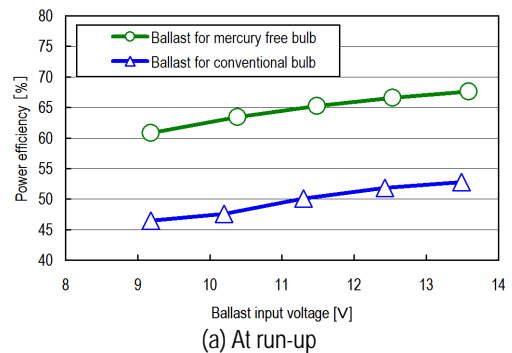


Fig. 3 Comparison of ballast power efficiency

**Table 2 Comparison of ballasts for a conventional bulb and the mercury-free bulb**

	Ballast for conventional bulb	Ballast for mercury free bulb
Volume	175 cm <sup>3</sup>	140 cm <sup>3</sup>
Weight	250 g	175 g

Furthermore, as shown in Table 2, the ballast size has been reduced by approximately 20% and the weight by approximately 30% compared with the conventional type.



**Fig. 4 Ballast for a conventional bulb (left) and ballast for the mercury-free bulb (right)**

## 6. Conclusion

Increased use of mercury-free type bulbs and stricter regulations on mercury use (exclusion of xenon bulbs from the exception list) are expected as environmental awareness and technological achievements progress.

We will gather the findings gained through developing the ballasts for mercury-free bulbs as discussed here, work together with bulb manufacturers, and promptly develop products. We will continue to provide the markets with products that meet the needs of automobile manufacturers and contribute to society.