LIGHTING ELECTRONICS

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Abstract

The recent surge in the use of electronic elements in lighting, spurred on by the energy saving campaign, has seen the rapid introduction of fixed and controllable high-frequency electronic ballasts for use with fluorescent lamp lighting systems. The use of these ballasts offers versatile utilization with reduced system operating cost and enhanced visual comfort.

This paper will describe the operation and benefits gained from such luminaires and indicate further application of electronics in lighting.

INTRODUCTION

The fluorescent tube is the most widely used source for industrial and commercial lighting. For this reason the lighting industry spends a fortune on its improvements. In the last decade, many tube sizes, shapes and colours have emerged, from the 2.4m straight tube to the compactly twisted tubes which are made to look similar in size to the GLS lamp and give instant efficient light. The efficiency was further improved by the use of rare earth activated phosphors. These triphosphor tubes are 10% more efficient than halophosphate and have excellent colour rendering quality with Ra over 80.

The search for further efficiency is now concentrated on the operation of the tube. It has been recognized for over forty years that running tubes on higher frequency than the main supply improves the efficacy of the tube. But until recently the only economical use was from dc power supply for emergency or transport lighting. The exploitation of electronic circuit technology to convert mains supply to high frequency supply to the lamps is now viable and economic. By increasing the lamp's operating frequency to approximately 20-50 kHz, a 10% improvement in efficiacy can be achieved. (fig. 1). This gain is affected by a reduction in electrode loss voltage and by the reduction in lamp current for a given arc power.

This gives a choice of maintaining the lamp power at the 50Hz value, gaining 10% in light output; alternatively, the lamp light output could be kept to the 50Hz level and use 10% less power. In the interests of energy saving, the lighting industry chose the latter option. A further benefit is that, at these high frequencies, the efficacy of the lamp is independent on whether the gas is argon or krypton.

HIGH-FREQUENCY BALLAST (HF BALLASTS)

Most high-frequency ballasts (fig. 2) use a half-bridge inverter to produce a high-voltage, high-frequency supply, which will provide power to the lamps. Power to the inverter comes directly from the mains supply through a rectfier and reservoir capacitor. This provides sufficient smoothing to avoid modulation in supply to the lamp and thus prevents flicker and stroboscopic effects. It is also essential to the improvement in lamp efficacy already referred to. The lamps are connected to the inverter output by reactive ballasting components in a manner similar to operation on conventional 50Hz supplies except that a high frequency, smaller and lighter components are practicable. Often, two parallel ballast circuits are fitted in twin lamp luminaires. There is, however, still a considerable demand for single-ballast inverters, in spite of the disadvantages in cost.

To comply with standars for luminaires, we must ensure that the harmonic content of the current drawn by the ballast is low and that a good power factor is achieved. This cannot be done by using a simple rectifier and smoothing capacitor. Many ballast manufacturers overcome the problem by including a rather bulky inductor filter in the input circuit, while others have developed more sophisticated electronic techniques.

Lamp starting with HF ballasts is better controlled than with 50Hz switch sart circuits. Lamps will always start the first time without flickering. Some ballasts start lamps instantly by applying a high voltage to the lamp. If this is done very quickly damage to the lamp is negligible and many thousands of starts can be achieved. Other ballasts are designed to pre-heat the cathodes for approximately one second before starting the lamp. Many tens of thousands of lamps starts can be achieved in this way. Control of cathode current is also necessary, if lamps are to be successfully dimmed.

Benefits of High-Frequency Operation

The benefits of the HF ballast lie not only in improved lamp efficacy and lower ballast loss, but also in reduced ballast size and weight, cool operation, silent start and running. There is no flicker or stroboscopic effect and the ballast will not make repeated attempts to start defective lamps.

Luminaire Weight

The typical electronic ballast (HF) weighs about 0.6 kg which is less than the weight of a single 50Hz wire-wound choke. But the electronic ballast is a complete control gear requiring no additional power factor correction capacitor or starting device. The weight of a typical twin 1500mm batten is reduced by 1.5kg to just 4kg; substantially reducing the load imposed on ceilings and support systems as well as being much lighter for handling during installation.

Optical Interference

The neat linear packaging of the single-piece electronic ballasts simplifies luminaire assembly and minimises the number of cavities (that are) in the lamp compartment in which light may be lsot. In a typical 4-lamp prismatic troffer requiring only two electronicballast the light output ratio is improved by as much as 4% over that produced by a luminaire fitted with normal mains gear. The reduction in the number of bits and pieces in the lamp compartment also makes cleaning of the lumnaire interior easier during maintenance.

Temperature Effect

The use of an electronic ballast imposes no constraints on lamp types or optical control options that may by used in a luminaire. The lamp compartment size is ususally the same as that used for mains-ballasted lamps. But with electronic-ballasted luminaires the power dissipated in the housing is some 15-30% lower. This reduction in heat, allows the lamps to run near their optimum working temperature (40°) and the luminaire surfaces to run about 5° C cooler. Of course the benefits are greater in tightly enclosed luminaires but even with a bare batten a 3°C reduction in bulb wall temperature can be obtained. Lower working temperatures also improve the realiability of the luminaire. Furthermore the 'stuck starter' condition is eliminated making F-mark compliance much easier to achieve. The body temperature need never go above 90° C in normal ambients and should not suffer paint discoloration.

Air-Handling Operation

Electronic ballasted luminaires can be used as return-air devices in the same way as mains-ballasted lamp luminaires. The only difference is in the permissible air flow rate around the lamp. Clearly the lamp in a HF luminaire runs cooler, particularly the 1200mm length, and therefore requires less air for optimum light output. (10 l/s for a 4 x 1200 low brightness luminaire). For handling large volumes of air, by-pass arrangements are recommended. The by-pass technique will permit the removal of the lighting heat without overcooling the lamp. It is worth noting that when using HF luminaires in schemes there will be reductions in both the refrigeration and air handling load on the air conditioning plants.

Lighting Systems

The noise emission of HF ballasts is now so low that luminaires may be used in concert halls and recording studios. Lamps operating on HF are free from visible end flicker. The results of recent research work on flicker and light modulation effects show that the average incidence of headaches and eye-strain by office worker is more than halved by the use of HF lighting, reducing many hours lost at work because of headaches blamed on the lighting. The high-frequency lamps operating on 30kHz will emit no visible flicker but can produce some 100Hz modulation. 100 Hz modulation can be resolved by the brain and can effect sensitive people.

Reliability

Successful appliciation of the HF ballast demands reliability in operation for the life of the unit. With at least 60 components in the HF ballast , we must expect a higher likelihood of failure than with the conventional wire-wound ballast. Failure are minimised by prudent circuit design, careful choice of components, modem automatic manufacturing and regorous tesing. Premature failures, due to manufacturing defects, are most likely to occur during the first stress period as the unit is rapidly taken up to its working temperature. Each unit should be subjected to a burn in test, at maximum case temperature. This isolates any problem units and gives high service realiability.

In normal operating conditions at which the case temperature does not exceed 70°C, the meantime between failures is calculated to be over 450,000 hours. Therefore 10 years of service life is easily attained. But exceeding the maximumrated operation temperature will drastically reduce reliability and life.

Econonomics of Application

The most important considerations in lighting economics are the cost of the equipment, the power dissipated, the hours in use and the cost of electricity. One can, however, easily summarise the economic case by stating that the increased cost of HF luminaires can be offset against a 10% increase in luminaire light output and a 20% reduction in luminaire power consumption. The economic justification cna best be illustrated by a specific lighting project. The project was in the UK and therefore the lighting conditions ard costs are based on UK values. A similar approach can be carried out based on RSA practice.

> An office block of ten floors each 24m x 12m x 2,8m lighting to be for 500 lux with glare index of 19, giving pleasant appearance with the luminaires recessed into the 1200 x 300 ceiling system. The office is occupied for about 3000 hrs per year and the energy tariff is 5p/kWH.

The recommended lighting system is base don twin lamps, 1200 x 300 low brightness batwing luminaires, fitted with tri-phosphor lamps of output 3200 lm with Ra of 85.

Table 1: Summary of Scheme Solution and Economics

Luminaire version	50 HZ	HF
UF at R14 (70/50/20)	0.62	0.69
Luminaires per floor	36	32
Luminaires for building	360	320
Luminaires + lamp cost	£90.23	£110.36
Total luminaire cost	£32482.8	£35315.2
Fixing cost/luminaire	£30.00	£30.00
Total fixing cost	£10800.00	£9600.00
Power per luminaire	94W	72W
Total power load	33.84kW	23.04W
Annual energy cost	£5076.00	£3456.00
Cleaning cost/luminaire	£3.00	£3.00
Annual cleaning cost	£1080.00	£960.00
Expenditure in first year	£49438.80	£49331.20
Saving after one year		£107.60
Saving after two years		£1740.00

This clearly shows that HF lighting schemes can be economic with pay back within a year (table 1). In addition, however, with 10kW less power dissipated in the HF scheme, the air-conditioning plant size may be decreased, saving on capital and running cost of the building. A further consideration is the rate of increase of energy costs.

Installtion Guidance

There are a few points to remember when installing HF luminaires. When determining fusing requirements, it must be borne in mind that some makes of ballast take a high in-rush current for one or two milliseconds when the supply is connected. It is important therefore that anti-surge fuses are used and obviously, these should be of High Rupture Capacity types.

Residual Current Devices, (RCD), may be used with HF ballasts. Most of the earth leakage current is due to the 50Hz component which flows through the normal Y capacitors and this totals only 0.25mA per ballast. High-frequency currents are also present but these are very small if the unit is to comply with RFI requirements. Furthermore these currents flow through the stray capacitance existing between cables in the supply trunking and are not seen by the RCD. Typically, a 10mA trip can cope with up to 20HF ballast.

In common with other electronic products, the ballast should not be subjected to high voltage insulation resistance tests. They should be isolated from the installation wiring, as recommended in the 15th Edition of the

I.E.E. Wiring Regulations 920. Provided live and neutral are connected together, however, and the test voltage is limited to 50 volts, reputable ballasts should not be harmed although misleading readings may occur.

All high-power, high-frequency devices are liable to radiate energy in the radio bands. HF ballasts are no exception. Design of the circuits and luminaires must ensure that radiated fields or voltages fed to the supply comply with relevant standards, for example CISPR 15 and BS 800. 3,4.

Electro-magnetic fields must also comply with standards, for example VDE 00107 Section 7 (5), if HF ballasts are not to interfere with equipment like heart pacemakers medical instruments or even VDU screens.

Fluorescent lighting has long been required to comply with standards for supply current waveform and power factor, for example IEC 555 (6), and most HF ballasts easily meet these requirements.

HF ballasts are generally designed to switch off if a lamp fails to start or goes out - for whatever reason. Not all are capable of restarting automatically if the faulty lamp is replaced and it may be necessary to break and re-make the supply.

For reliable starting of tubes under a wide range of conditions, an earthed starting aid should be placed within 15mm form the surface of the tubes. The earthed luminaire body provides an ideal starting aid.

Controllable HF Ballasts

Further energy savings can be made by correctly managing the use of lighting system. There are many methods of switching availabe. User attitude surveys, however, show adverse reaction to switching unless it is at very high levels i. e. 3:1 ratio. A more subtle method is offered by the controllable HF ballast. These HF ballasts have the same advantage of efficiency, weight, size, temperature and visual comfort as the standard HF ballast but also offer flexibility in light control and saving of energy. The controllable HF ballast has additional circuit elements and a control input signal port (fig. 3). The output control is achieved by changing the frequency of the inverter out-put. As the frequency is increased above the design value of 30kHz both the lamp current and light output is proportional to the change in lamp power (Fig. 4). For normal usage the lamp output varies between 100% and 25%. The control signals to the ballast are distributed via a simple low voltage control line.

APPLICATION TECHNIQUES

Daylight Link

The most obious application is to reduce the light output of the luminaires when daylight is available. The ballasts are connected to a photocell that monitors the light level on the work plane. As more daylight falls onto the work plane from the windows so the output from the luminaires is smoothly reduced to 25%. With a further 50% increase in daylight level, the luminaires are switched off. This procedure can make a 60-80% saving in energy where the daylight factor is above 5% and causes no annoyance to the occupants (Fig. 5).

Constant Illuminance

In this arrangement the controllable ballast maintains constant illuminance on the task area between the maintenance period of the system. A single photocell controlling the ballasts is set in the middle of a large work area. The initial output of the system is pre-set so the only 80% of the initial lamp output is used. As the output from the lamp falls because of ageing or the accumulation of dirt on the luminaire optic, more power is fed to the lamp to increase the output and maintain a constant illuminance until the end of the useful lamp life (Fig. 6).

Variable Illuminance Controller

This permits setting of the luminaire output to suit tasks in a zone. the controller is connected to the HF ballasts within a zone by the control line and gives the low-voltage control signals. This enables the user or building owner to adjust and set light output for any given zone, with a standard layout of luminaires, appropriate to the task requirements. The smooth variation in output can range between 100% and 25% and will be proportional to the control setting. The luminaires can be switched on and off by the controller, which can also be driven by a clock or the existing building managemnet system. Up to 50 ballasts may be connected to one controller (Fig. 7).

Conclusions

Mains-operated HF ballasts provide efficient and economic lighting solutions. The controllable version now reaching installations provides more flexibility for adjustment and control of illuminance. The use of electronics, however, will make an impact on other lighting systems. Electronic transformers for low voltage halogen display lighting are already in use (Fig. 8). We can foresee the use of electronic ballasts for driving high pressure metal halide and sodium lamps. Whilst here these may make little energy savings, the improvement in the quality of light and reduction in ballast weight will be an adequate justification.

REFERENCES

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(3) CISPR 15. 1985. Limits and methods of measurement of radio interference characteristics of fluorescent lamps and luminaires.

[4] BS800. 1983. *Radio Interference Limits and Measurements for household appliances, portable tools and other electrical equipment causing similar types of interference.*

[5] VDE 0107/06.81. *Erection and testing of electrical installations in hospitals and medically used rooms.*

(6) IEC 555. (Part 2 Harmonics. 1982) *Disturbances in supply systems caused by household appliances and similar electrical equipment.*

Table 2: Comparison of Twin-Lamp Circuits

	50Hz Ballast		HF Ballast		
Lamp Length	Lamp Power	Circuit Power	Lamp Power	Circuit Power	Saving
M	W	W	W	W	W
1,8	2x70	160	2x60	131	29
1.5	2x58	142	2x50	108	34
1.2	2x36	94	2x32	74	20

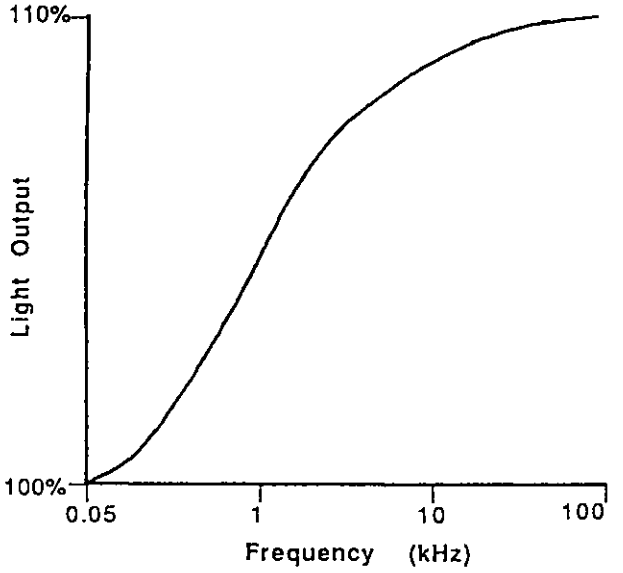


Figure 1: Improvement in lamp efficacy at high frequency.

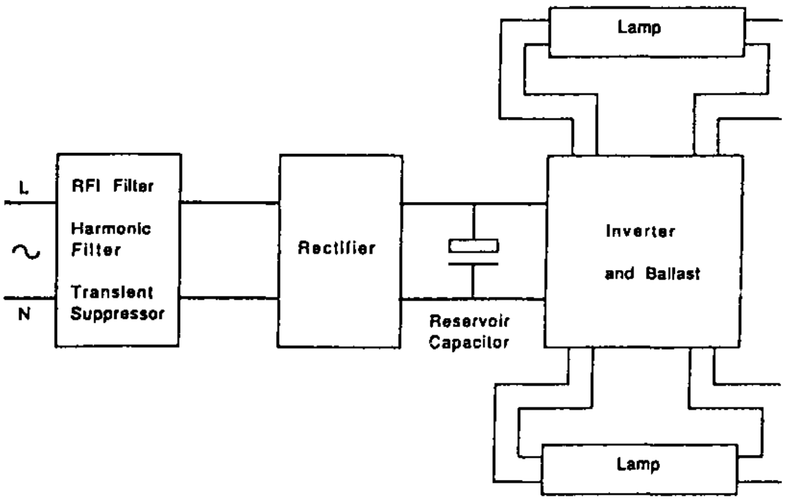


Figure 2: Block Diagram of HF Ballast.

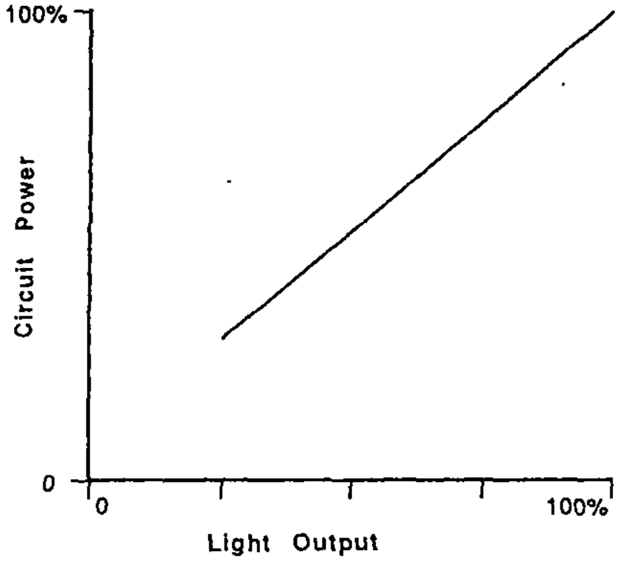


Figure 3: Circuit Power versus Light. Output for dimming ballasts.

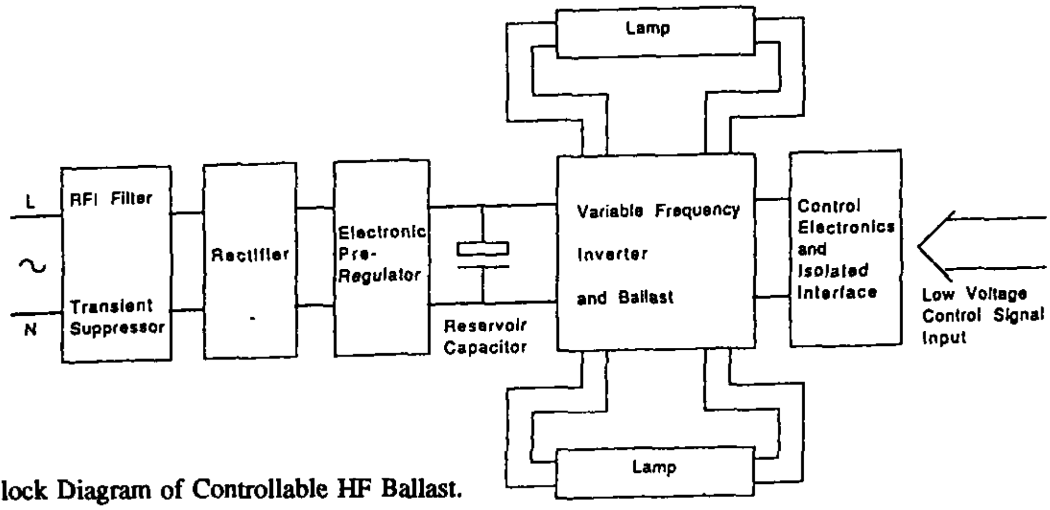


Figure 4: Block Diagram of Controllable HF Ballast.

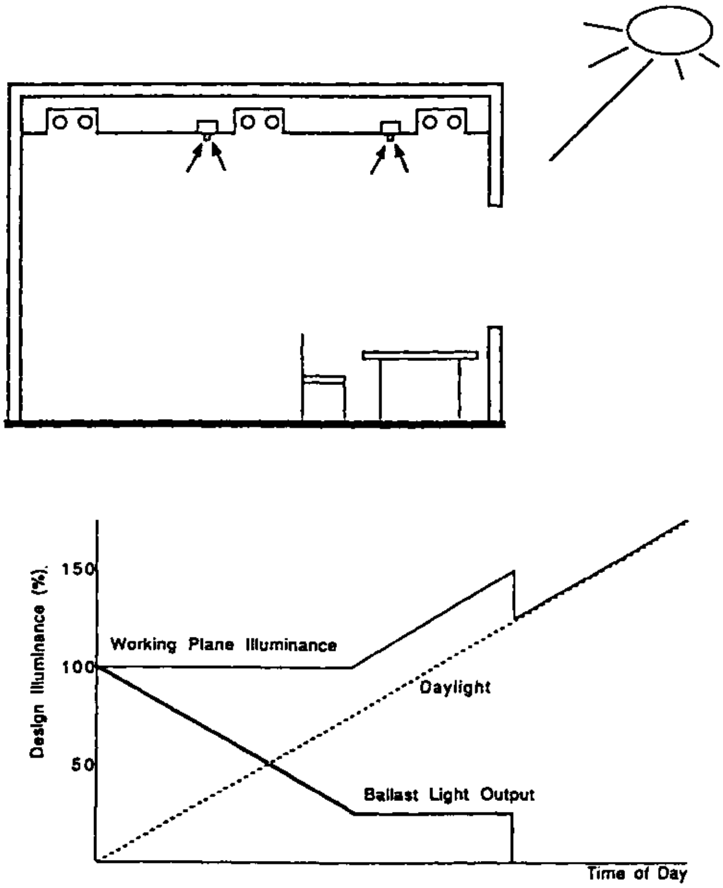


Figure 5: Daylight Link.

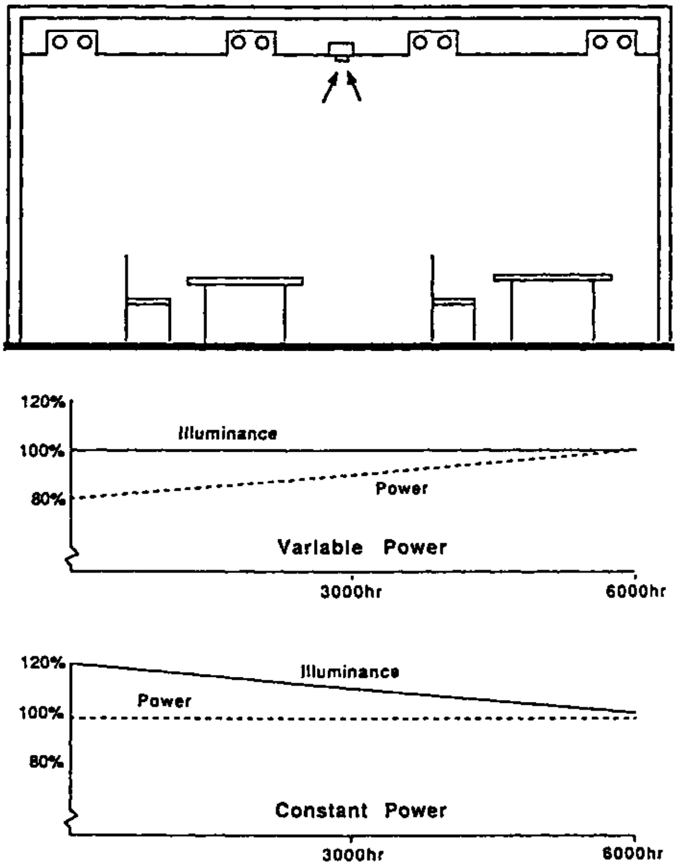


Figure 6: Constant Illuminance.

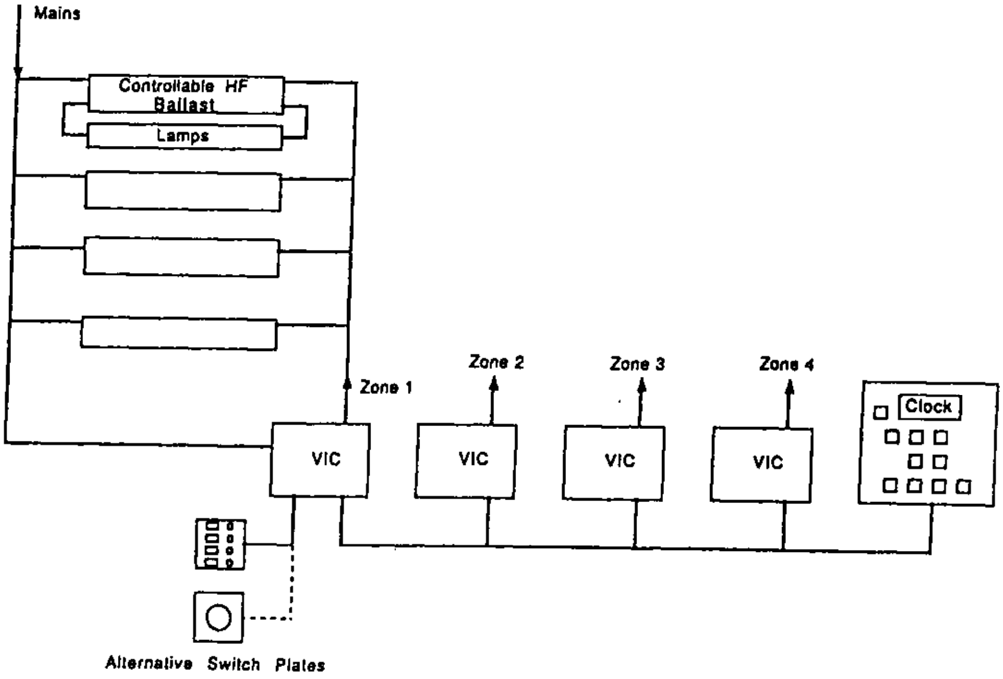
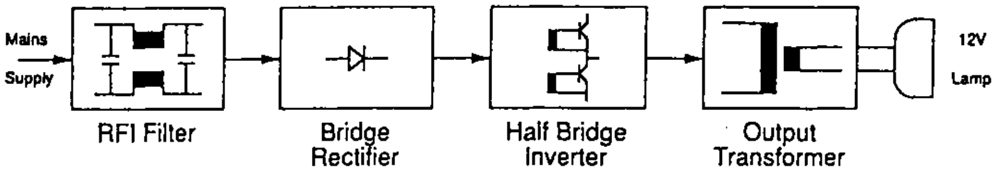


Figure 7: Block Diagram of VIC Control System.



Transformers should comply with BS800, CISPR 14/15 and possibly VDE0871B.

Mains supply voltage is rectified but is essentially unsmoothed.

Self oscillatory 1/2 bridge inverter operating at 20 kHz or higher. It produces a square wave, modulated at 100 Hz.

Steps down to 12 volts. Small size because of the high operating frequency. Voltage isolation to meet SELV.

Figure 8: Electronic Transformer Block Diagram.