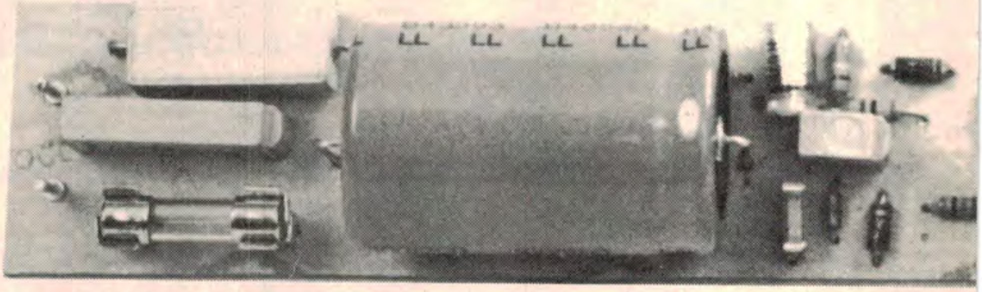
Electronic ballast for

For instant starting, higher

Electronic ballast circuits for fluorescent lamps have recently become widely used in Europe and a similar trend is expected in Australia in the future. Siemens Ltd, a German company, have supplied us with a working prototype module for evalution. What advantage does it have over the conventional circuit and how does it work?



Features of electronic ballasts are many and impressive. They offer instant tube starting, and absence of flicker due to the high operating frequency. Also they will drive more than one tube, produce no audible hum, and do not require power factor correction. Their efficiency is also greatly increased. Losses are up to 60% lower than the ballast losses of a conventional system, while the higher operating frequency increases light output of the fluorescent lamp by up to 15%. By using Siemens' new, more efficient "Lumilux" fluorescent tubes even further power savings can be obtained.

They do have one drawback, however, and that is a much higher initial cost when compared to conventional ballast/starter systems. For this reason this article is presented as one of general interest only. It should not be regarded as a constructional article, as the cost to hobbyists of mains-rated power FETs is currently too high to make the circuit an economic proposition.

Basically, the electronic system comprises a DC power supply derived by rectifying and filtering the AC mains waveform and a solid state high frequency oscillator driving the tubes via small chokes. High voltage Metal Oxide Semiconductor Field Effect Transistors, MOSFETs, are used as the oscillator drivers.

Before delving into this electronic ballast circuitry, a discussion of the conventional ballast and starter circuit will enable us to compare the advantages and disadvantages of each system. Fig. 1 shows the circuit for a conventional fluorescent starter circuit. This basically consists of the ballast and starter. We shall ignore the capacitor connected across the mains for the present.

When power is first applied, a small current flows through the ballast, tube filaments, and starter. The starter is filled with an inert gas. This ionises and the resultant heating of the gas causes the bimetallic contact within the starter to close. A heavier current then flows through the tube filaments and ballast.

The tube filaments heat and begin to emit electrons. At the same time the starter cools and the bimetallic contact opens and interrupts the filament current. The resulting back EMF from the ballast generates a large peak voltage which ignites the tube. When the electric discharge is established in the fluorescent tube, it has a very low resistance and the ballast inductance is needed to limit the maximum current supplied to the tube.

In normal operation, the tube ignites and extinguishes during every mains half cycle so that it actually flashes at 100Hz. Note that the .005μF capacitor across the starter suppresses RF interference caused by the starter contact opening and the discharge within in the tube itself.

The advantages of this system are simplicity, economy and ready availability. Now for the disadvantages: Firstly there is the starting characteristic. Typically at first turn on, the starter needs several attempts to ignite the tube resulting in a slow and flickering start. The second disadvantage occurs when the tube approaches the end of its life when lamp-end flicker becomes a problem. Thirdly, there is the need to replace the starter periodically since it has a limited life.

Other disadvantages concern the choke. Due to iron core losses and the resistive (I^2R) losses in the windings, power is consumed by the choke. Iron core losses are very small compared to these I^2R losses and can be neglected. A typical low loss choke for a 40W fluorescent tube dissipates between 5 and 8W. This means that about 11% of a fluorescent light power bill is used in heating the choke.

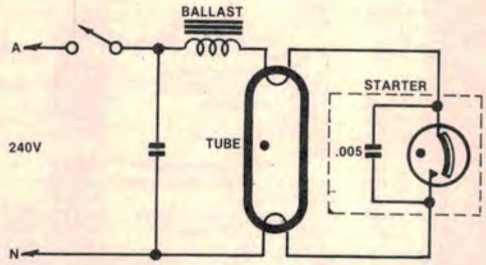


Fig. 1

The conventional fluorescent starter circuit is simple and economical but also has disadvantages, including high power consumption.

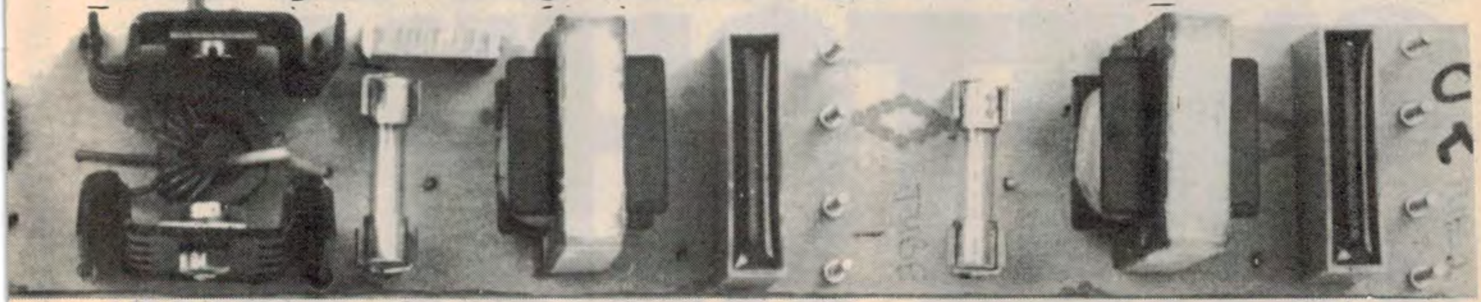
Power factor

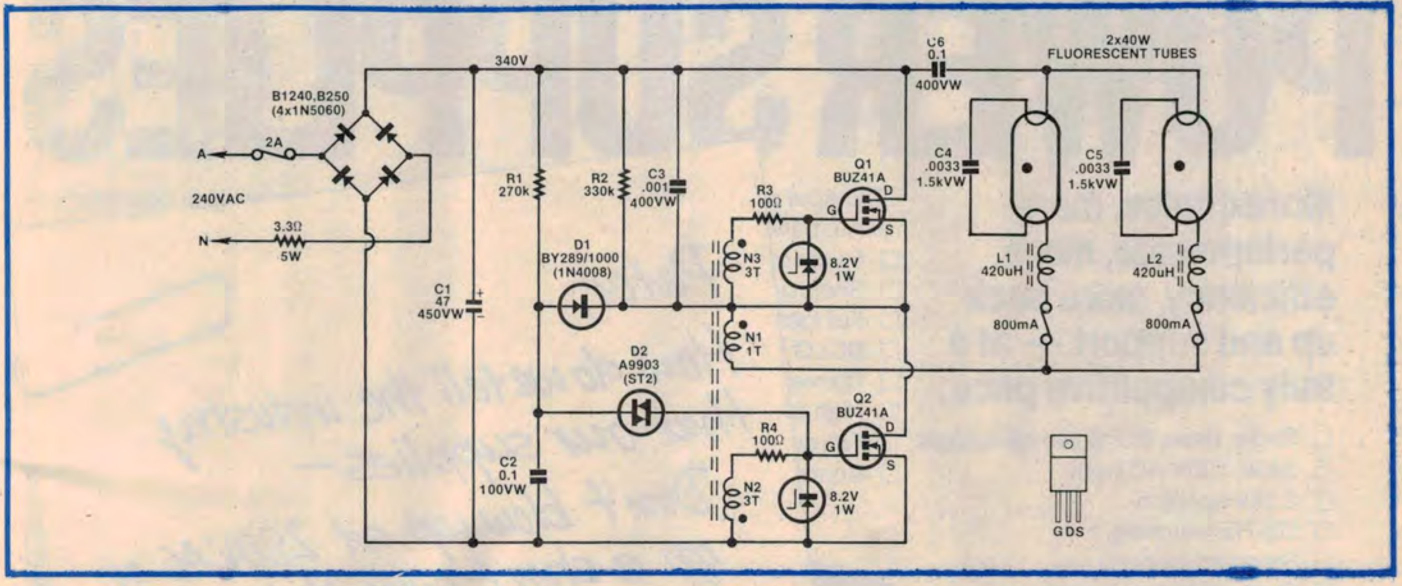
In general a 40W fluorescent tube is supplied with about 416mA and has 96V RMS across it. This same current passes through the choke but, due to its inductance, the current lags behind the voltage. At the active and neutral terminals the power factor (the cosine of the angle between the current and voltage) is typically 0.48. Now we can calculate the power dissipated by the combination of tube and choke. The formula is E × I × power factor. So we have 240V × 0.416A × 0.48 = 47.9W. Since 40W is consumed in the tube, the choke dissipates the remaining 7.9W.

By connecting a capacitor across the active and neutral terminals the power factor is improved since the capacitor provides a current leading the voltage. If the capacitor were made large enough

fluorescent lamps

efficiency and greater light output





the lagging current of the inductor would be cancelled by the leading current of the capacitor. A 3.5μF capacitor improves the power factor to 0.85. Now the line current reduces to 235mA, and the phase between the current and voltage is much closer than without the capacitor.

Recalculating the power dissipated in the choke and tube, we obtain, 240V × 0.235A × 0.85 = 47.9W. Again 40W is consumed in the tube and 7.9W dissipated in the choke, but the significant point is that the line current is reduced to 235mA.

This reduction in the line current may not at first appear important since after all the same power is used regardless of power factor. However, the line current contributes to I^2R losses in the incoming supply lines. Consequently the lower the line current the lower these losses become. (And remember this is a square law.) These losses do not affect the consumer directly, although, the electricity supply authorities are interested in keeping the power factor as close to unity as possible. This reduces losses within their alternators, transformers and supply lines.

By contrast, the electronic ballast appears to solve every problem inherent in the conventional ballast system but with a few advantages and disadvantages of its own. Because of the very high frequency of operation, the electronic ballast provides virtually instant starting and complete freedom from visible lamp flicker. The high operating frequency also allows the use of smaller and more efficient chokes which reduce circuit losses and allow a more compact lamp housing.

The very much higher operating frequency (around 120kHz) should also minimise strobing effects which, in the past, have prevented the use of fluorescent lights in some factory situations. Strobing effects can make rapidly rotating machinery appear to be stationary or rotating very slowly, and thus create a safety hazard. While strobing can still theoretically occur, even at 120kHz, the risk of it matching typical machine speeds would seem to be minimal.

The lack of audible hum will probably also mean that recording studios which previously would not use fluorescent lights can now install them and obtain energy savings.

Electronic starter circuit

Circuitry for the electronic ballast consists of a DC power supply, an oscillator comprising MOSFETs, Q1 and Q2 and associated components, and the current limiting chokes, L1 and L2, for the tubes. This circuit is for driving two 40W fluorescent tubes.

A 340V DC power supply is derived by full wave rectifying the mains voltage and filtering with the 47μF/450VW capacitor, C1. A 3.3Ω resistor connected in series with the AC supply limits the surge current through the diodes when power is first switched on.

At first switch on, C2 begins to charge via R1. When the voltage across C2 reaches about 32V (after about 3ms), Diac D2 breaks down and conducts current from C2 into the gate of Q2. Q2 then turns on and generates a current pulse through the N1 coil of the transformer, L1 and L2, the heater windings of the tubes, C4 and C5, and finally C6.

Back EMF

Once C2 is discharged, gate current no longer flows and Q2 turns off. L1 and L2 now produce a high voltage back EMF due to the interruption of current flow. Provided the heaters are sufficiently warm to support continuous ionisation, the tubes will ignite. If not then the cycle will begin again to further raise the heater temperature. Capacitor C2 charges and dumps current into the gate of Q2 which again turns on, pulsing current through the tube heaters and L1 and L2.

This process continues until the tubes light. The resultant heavier current flowing through N1 of the transformer induces voltages in both N2 and N3 windings sufficient to trigger the gates of Q2 and Q1 respectively. N2 and N3 are connected out of phase and the negative voltage from N2 to the gate of Q2 switches Q2 off. The positive voltage from N3 switches Q1 on. Current now flows in the opposite direction through C6, the tubes, L1 and L2, the coil N1 and MOSFET Q1. Capacitor C6 now begins to discharge.

This reversed current flow through N1 induces positive gate voltage at N2, turning Q2 on again. The negative gate voltage at N3 turns Q1 off. C6 now begins to charge since the current through N1 is once again reversed.

High frequency oscillator

The circuit now operates as a high frequency 120kHz oscillator with L1, L2 and C4 and C5 controlling the free running frequency. L1 and L2 also are used to limit the current supplied to each fluorescent tube. Each time Q2 is on, C2 is discharged via diode D1 so that the Diac, D2, is kept from firing.

The zener diodes between the gate and source of each MOSFET, Q1 and Q2, limit the maximum Vgs voltage while the 100Ω resistor in series with each transformer winding limits the zener current.

If the tubes are removed from the circuit, R2 and C3 are used as the load for Q2. This keeps the circuit operating with D2 triggering Q2 and Q1 remaining off. The circuit is ready to start the tubes should the power be on while the tubes are installed.

Note that the chokes are quite small. These are iron cored with a 2.5mm air gap which prevents the core saturating. A 10mm diameter ferrite toroid is used for the transformer core to support the N1, N2 and N3 windings. The MOSFETs used are SIPMOS (Siemens Power MOS) BUZ41A, and these are mounted on small heatsinks to aid heat dissipation.

Performance of the electronic ballast is quite impressive. The instant start of the fluorescent tube and the lack of flicker are immediately obvious. When power is switched off, the brightness of the tube gradually dims until it extinguishes. This is due to storage in the DC power supply.

Some of the efficiency can be credited to the slightly increased light output from a fluorescent tube when operated at a high frequency. Power savings are also had by the use of the small chokes. These are low loss due to the large wire diameter and small number of turns around a small core. They can be small and still provide the necessary current limiting since operation is at a high frequency.

The high frequency of operation can cause problems with electromagnetic interference (EMI). We made comparisons of the interference caused to medium and shortwave radio reception by electronic and conventionally ballasted fluorescent lamps in the near vicinity to a receiver. While not rigorous, these tests showed that the levels of radiated interference were comparable.

Current waveform

A related problem is the shape of the current waveform for the electronic ballast circuit. While the electronic ballast does not require a power factor correction capacitor as does the conventional ballast there is still a problem for the energy supply authorities in that the rectifier uses a capacitive-input filter. This means that the current waveform is in the form of a short duration pulse at the peak of each mains half-cycle. The result is distortion of the mains waveform and the generation of unwanted harmonics.

For commercial users though, the large scale use of electronic ballasts will lead to large savings in annual office and factory lighting bills.

Anyone requiring further information should direct their enquiries to Siemens Ltd, 383 Pacific Highway, Artarmon, NSW, 2064, or 544 Church St, Richmond, Victoria, 3121.