Novel circuit provides instant turn-on

# Electronic starter for fluorescent lamps

Do your fluorescent lights go blink, blink, blinkety-blink when you switch them on? This substitute electronic starter solves that problem and gives a smooth, rapid start every time you switch on. All the parts are housed in a standard starter case so the light wiring does not have to be modified.

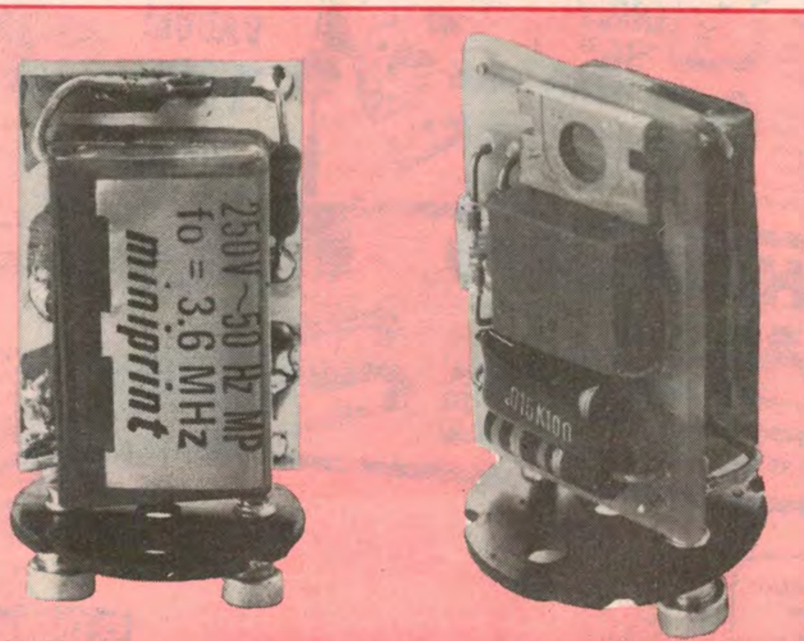
**by LEO SIMPSON**

Are you one of those poor unfortunates who has to rise in the dead of the night for what the Americans euphemistically call a "comfort break"? And do you find the blinkety-blink flashing of a fluorescent light switched on in pitch dark a trifle off-putting, if not to say, blinding? As luck would have it, this problem is made worse when temperatures are low, which adds to the misery.

This new electronic starter not only solves the problem of random flashing and temporary blindness when fluorescent lights are switched on but also reduces RF interference. It may also contribute to extended tube life. With that list of advantages we realise that you are just rearing to know how it works, so let us first discuss how a fluorescent light works and starts normally.

There are a surprisingly large number of fluorescent light circuits including instant start, rapid start, lead-lag ballast and so on but the configuration most commonly found in domestic and commercial lighting installations is still the starter-preheat system shown in Fig. 1.

While this circuit looks fairly simple, it is in fact quite complicated in operation, as are most types of fluorescent light circuit. However, we will attempt to give as straightforward a description as possible. Essentially, the circuit has two modes of operation, start and run. In the start mode, the starter is involved (no, we're not putting you on) and in the run mode, the starter is effectively out of circuit.




*Here are two views of the electronic starter showing component details.*

Everyone is familiar with the ubiquitous fluorescent light tube but few people are aware of their make-up. Basically, the glass tube has a filament heater at each end and contains a minute quantity of mercury and a mixture of inert or noble gases at very low pressure.

The filament heaters are usually made of triple-coiled tungsten wire which is coated with an emissive material such as barium or strontium oxide. In the start mode, current is passed through the two filaments to raise them to red heat. At this temperature they emit electrons freely (thermionic emission) which rapidly disperse in the tube so that an electric discharge can occur through the inert gas when a high voltage is applied between the two filament electrodes.

The electric discharge first occurs through the inert gas which rapidly heats up and thereby vaporises the small quantity of mercury. The mercury atoms are then excited by the arc discharge and they release energy which is mainly in the form of ultraviolet radiation at a wavelength of 253.7 nanometres.

This ultraviolet radiation then impinges onto the white phosphor coating on the inside of the tube which then "fluoresces" to emit visible light. About 20% of the ultraviolet radiation is transformed to visible light while the rest is liberated as heat.

We can now return to the circuit of Fig. 1. When the electric discharge is established in the fluorescent tube, it has a low and essentially negative resistance. Effectively, this means that once the arc is started the current will rapidly increase until the tube overheats and burns out. To prevent this, a "ballast" is connected in series with the tube. The ballast is an iron-cored inductor which "saturates" at a predetermined current level and

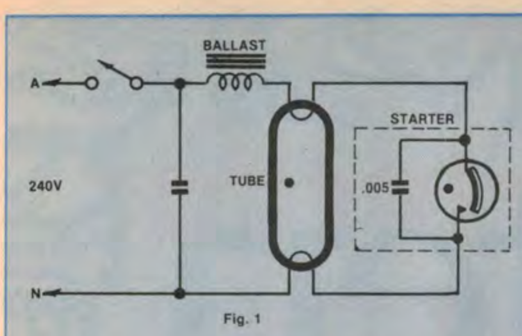



*Fig 1: Common fluorescent starter circuit.*

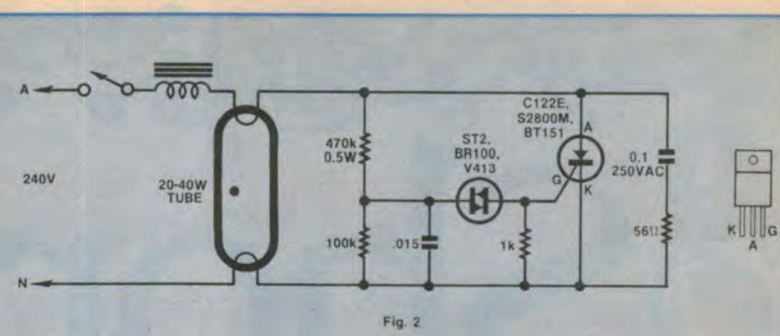



*Fig 2: Circuit diagram for our electronic "instant" starter.*

thereby limits the current through the tube to a safe level.

So that is how the ballast functions in the "run" mode. In normal operation, the tube actually strikes and extinguishes during every mains half-cycle so that it actually flashes at a rate of 100Hz.

## Power factor correction

The purpose of the capacitor across the mains input is to correct the low power factor of the ballast. In other words, the capacitor compensates for the lagging current of the ballast and makes the overall loading of the circuit appear more resistive. These power factor correction capacitors are not normally present in fluorescent light fittings in home installations but are generally required for those used in commercial and industrial situations.

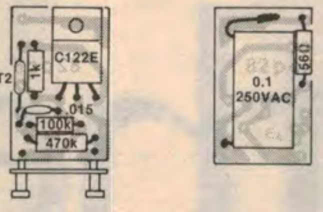
As well as limiting the current through the tube to a safe value during the "run" mode, the ballast also plays a crucial part in the "start" mode. This mode occurs as follows:

When power is first applied, a small current flows via the ballast, tube filaments and starter bulb which is filled with argon (or some other inert gas). Within a few milliseconds the ionising and resultant heating of this gas causes a set of bimetallic contacts in the starter to close and a relatively heavy current then flows through the tube filaments and ballast.

While the tube filaments heat up and begin emitting electrons, the starter bulb then cools again and the bimetallic contacts open to interrupt the filament current. The ballast does not like this and generates a large peak voltage which then fires the fluorescent tube, if all goes well.

In practice, though, the starter usually needs more than one attempt to fire the fluorescent tube. For example, the mains voltage may be a little low, the ambient temperature may also be low and the starter may interrupt the filament current just when it was low or passing through zero, in which case, little or no peak voltage would be generated by the ballast.

Typically then, the starter needs several "strikes" before the tube fires reliably. This is why fluorescent lights




*Component overlays for both sides of the PC board.*

characteristically flash several times, in that annoying fashion we all know so well, when they are first turned on. And it also explains why the light generally fires straight away if you switch it off and then on again, after a period of operation.

Note that the circuit of Fig. 1 shows a capacitor internally connected across the starter. The capacitor is usually a ceramic or Mylar dielectric type of about .005μF and is included to suppress RF interference which occurs at the moment of contact opening. The capacitor also provides some suppression of the RF interference produced by the electric discharge in the fluorescent tube itself.

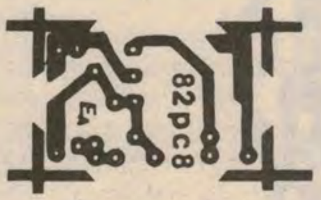
Apart from this secondary suppression of RF interference by the starter capacitor, the starter plays no further part in the circuit operation once the tube has fully fired.

## Flashing is not good

Not only does the initial flashing of fluorescent tubes annoy nocturnal humans but it may also seriously degrade tube life, due to excessive cycling of the filaments. To explain, the usual reason for eventual tube failure is that the filament emissive material becomes exhausted or the filament goes open circuit. If a tube is run continuously (ie, never turned off) its life will be almost twice that for a tube which is run with a cycle of three hours per start.

The answer to this problem is not to

> We estimate the current cost of parts for this project to be approximately
>
> **$5**
>
> This includes sales tax.




*Shown above is the full-size pattern for the PC board.*

run the tubes continuously but to replace the starters more often or at least, replace the starter when the tube is replaced. Inevitably, though, the starter will noticeably deteriorate long before the tube approaches the end of its life. So this is where our electronic starter comes in. It will not deteriorate, it will give a reliable start every time and should give a longer tube life (although we have no data to support this theory at the time of writing).

Offsetting all the advantages of the electronic starter is its higher price. At around $5 it is a lot dearer than a conventional starter. We would not advocate replacing every starter in your home with this new device but there are probably one or two lights, say in your kitchen or bathroom, with which you will gain a worthwhile benefit.

Fig. 2 shows a fluorescent light fitting with the electronic starter in place of the conventional type. Essentially, the electronic starter is a silicon controlled rectifier (SCR) which feeds half-wave rectified AC to the filaments, via the ballast.

As the filament current drops to zero, at the end of every alternate half-cycle, the SCR turns off and the ballast generates a high voltage peak which then fires the tube. In effect then, the electronic starter gives the fluorescent tube a stream of repeated "strikes" until the tube fires sufficiently well to sustain conduction and give full illumination.

In practice, the tube comes on immediately the power is applied but at a relatively low level of brightness. Then, after one or two seconds it comes up to full brightness without flicker or any other drama. At the same time, the ballast makes a louder than normal buzzing noise during the brief turn-on period and thereafter makes no more noise than is normal.

The method of triggering the SCR is as follows: Mains voltage is applied via the ballast and tube filaments to a voltage divider network consisting of a 470kΩ and a 100kΩ resistor, to charge a .015μF capacitor. When the voltage across the capacitor rises to about 30V, the ST2 or equivalent Diac (a four-layer semiconductor) device breaks down and dumps the capacitor's charge into the SCR gate. This fires the SCR which then continues to conduct until the ballast current drops to almost zero at the end of the mains half-cycle.

The resulting voltage peak generated by the ballast is damped by the RC network across the SCR. This has the desirable effect of preventing damage to the SCR (by limiting the peak voltage) and also lengthening the time for which high voltage is applied to the tube so that a "strike" can occur.

Looking at it another way, the 0.1μF capacitor could be regarded as providing a series resonant network, in conjunction with the inductance of the ballast. This resonance is then excited by the voltage spike, generated by the back-EMF action of the ballast, and is damped by the 56Ω resistor plus the series resistance of the ballast itself.

The 1kΩ resistor connected between gate and cathode of the SCR prevents any likelihood of spurious triggering of the SCR when the tube is in the "run" mode. Note that once the tube is fired and running, the voltage across the electronic starter is low enough at about 100VRMS to prevent the starter from playing any further part in circuit operation, as with a conventional starter.

There is, however, a further bonus provided by the electronic starter in the form of the 0.1μF snubber capacitor. This has the effect of improved suppression of RF interference from the fluorescent tube. The electronic starter also produces much less "hash" at initial turn-on than a conventional starter so it all adds up to a much "quieter" fluorescent light, in the RFI sense.

We should point out that this circuit has already appeared in the June, 1982, issue of "Elektor" and may or may not be subject to a patent application in this country.

## Construction

While the foregoing circuit description may have been fairly long and detailed, the construction of the electronic starter is quite easy and straightforward. In fact most hobbyists will probably have the job finished inside 10 minutes. That does not allow for soldering iron warm-up time.

As shown in the photographs, the starter circuitry is mounted on a small PC board, coded 82pc8 and measuring all of 19 x 29mm. Huge, isn't it! When the components are assembled, onto both sides of the board, the whole assembly is then shoe-horned into a conventional starter case.

Start construction by cannibalising a conventional starter. You need to remove the starter innards without damaging the circular lid which carries the two connector pins. Clip off the starter lamp and capacitor but leave the leads long enough, say about 5mm or so, so that they can be soldered to the PC board assembly.

For obvious reasons, you should not use a starter with a metal case.

Six components are mounted on the component side of the board, while two are mounted on the copper pattern side. Mount the small components first on the component side. Note that the Diac is a non-polarised component so it can be installed either way around.

## Don't use an ST4!

It is most important that you use a Diac in this circuit and not the GE asymmetrical trigger device, the ST4. Make sure you are not fobbed off with this device, as seems to be common practice amongst uninformed counter staff. **The ST4 will not work.** There, you have been warned. We obtained BR100 Diacs from Jaycar but parts suppliers should have no problems laying in any one of the Diac types we have listed.

The SCR should be rated at a minimum of 500V and any one of the types listed will do nicely. Bend the three leads close to the SCR body before installing. Take care when doing this. Use a pair of long nose pliers to avoid undue strain on the case/lead join.

Now install the capacitor and resistor on the copper side of the board, as shown in the photographs and wiring diagram. The capacitor must be rated at 250VAC, as specified.

Finally, solder the board to the starter lid terminals. Then carefully check all connections visually. You could also use a multimeter, switched to the "ohms" ranges, to check the circuit components for continuity. The Diac should read open circuit and the SCR should be 570kΩ between anode and cathode (this is the value of the resistor string).

Now carefully slide the whole assembly into the starter case. This is a squeeze but it will fit. You are now ready to test the unit.

We have tested several prototypes of the starter on 20W, 40W and 65W lamp fittings but we are not certain whether the circuit is really suitable for 65W fittings. To be on the safe side we recommend that you try the unit on a 20W or 40W fitting. Just remove the existing starter, carefully install the electronic one and turn it on. You should be greeted by a smooth and fuss-free start. If not, the most likely fault is a dud SCR.

If the tube is old and will not fire with the electronic starter, do not leave it switched on, otherwise the ballast will burn out.

We should make a special note about the use of this starter in a dual 20W fitting which use two starters and one ballast. In some fittings, the electronic starter will not work, depending on the characteristics of the ballast and the polarity of the two starters. In view of this uncertainty, we do not recommend that the starter be used in these fittings, as well as the 65W fittings mentioned earlier.

## PARTS LIST

*1 fluorescent starter (to be cannibalised)*
*1 PC board, 19 x 29mm, code 82pc8*
*1 C122E, BT151 or S2800M 500V SCR*
*1 ST2, BR100 or V413 Diac*
*1 0.1μF/250VAC metallised dielectric capacitor*
*1 .015μF metallised polyester capacitor (greencap)*
*1 470kΩ/½W resistor*
*1 100kΩ/¼W resistor*
*1 1kΩ/¼W resistor*
*1 56Ω/¼W resistor*