Comparative study of solar lanterns

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Abstract

A study was conducted to compare solar lanterns using two-pin compact fluorescent lamps (CFLs) with those using four-pin CFLs with regard to electrical efficiency, cost and reliability. Results show that the efficiency and reliability of the two are almost the same, but the cost of the four-pin CFL version is more.

Keywords: Solar; Photovoltaic; Lantern; Light; Inverter; Oscillator

1. Introduction

The solar lanterns introduced a few years ago in non-electrified areas were based on two-pin compact fluorescent lamps (CFL) of 5 and 7 W power. The aim was to have the maximum light output for a given electrical power input. The CFL was found to have a large light output to power input ratio with small size and almost instant operational capability. This made it more attractive than the low pressure sodium oxide 18 W lamp. Although SOX-18 is more efficient it has a longer starting time. The other desirable feature, almost mandatory, was that the inverter or oscillator used to drive a CFL must have an electrical efficiency exceeding 80% at an operating frequency between 20 and 40 KHz. The lower limit was kept ostensibly above the highest limit of audio frequency, whereas the upper limit ensured that excessive hysteresis or eddy current losses of the inverter transformer did not reduce the DC to AC conversion efficiency. Also, an arbitrary increase in frequency does not increase the light output from a gas discharge tube but can contribute to radio frequency interference. Conventionally, a two-pin CFL is operated with an inductance ballast and a built-in starter to initiate the discharge, as shown in Fig. 1. When the bi-metallic strip in the starter opens, the

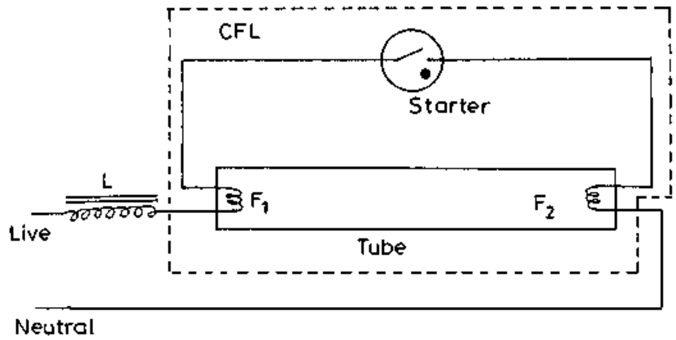

Fig. 1. Typical circuit for a two-pin CFL for 50–60 KHz use.

current i, through the ballast of inductance, L, is interrupted in time dt. This produces a high voltage, Ldi/dt, where di/dt is the rate of change of current, across the tube to produce a discharge. Thus, the two-pin CFLs' operation was confined to the low frequency region of 50–60 Hz. A four-pin version of the CFL was developed for operation at higher frequencies. This tube has no need for a starter as the heated filaments supply the electrons required to initiate a discharge from relatively low voltages across the tube.

2. Circuit design

The most efficient inverter circuit was a class-D quasi-sinusoidal oscillator published by Yarrow [1] and Baxandall [2]. This is a simple circuit with a few components and which

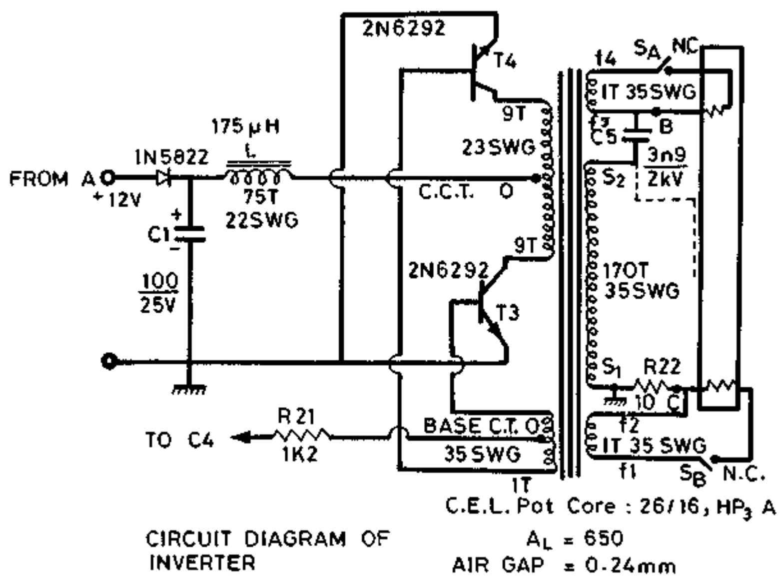

Fig. 2. Circuit diagram of the inverter used with 5 and 7 W CFLs.

eliminates all the problems associated with high efficiency square wave generators. Several solar lanterns were constructed using similar circuits for both two-pin and four-pin CFLs. Fig. 2 shows an inverter for a four-pin CFL. The difference between the two are two additional secondary windings to heat the filaments of the four-pin CFL. 12 V dc is fed to the circuit at point A. L is an inductor, with a ferrite bead core, whose inductance is approximately five times that of the primary of the transformer. This keeps the current almost constant when either of the transistors T_3 and T_4 conducts. The centre tap of the base winding is given to a switch through R_{21} to control ignition, by raising it to 12 V to switch on, or lowering it to 0 V to switch off, of the tube. C_5 is used as a ballast as well as to determine the inverter frequency. The transformer uses a gapped ferrite pot core. A double pole single throw switch was placed in the filament circuit of the tube and was kept in a normally connected position NC. After firing of the tube, the switch was opened to stop the flow of filament current to save power and also to ensure that blackening of the tube does not take place near the filaments.

3. Observations

A Hewlett–Packard model 54501A digitizing oscilloscope was used to measure the voltage at point B and the signal at C across a 10 Ω, 1% metal film resistance R_{22}, which was proportional to the current through the tube. A built-in multiplier gave the product of the I and V to display the power waveform, and since it is point by point multiplication, the power factor is automatically taken into account. The power was averaged over 16 cycles to get a stable reading. During the operation with two-pin CFLs, the two filament windings were kept open. While making measurements with the four-pin CFLs, the switch S in the filament circuit was thrown open once the discharge was established. Table 1 shows the comparison between the two types of 5 and 7 W CFLs.

Table 1
Comparison between the two types of 5 and 7 W CFLs

Type of CFL	Two-pin 5 W	Four-pin 5 W	Two-pin 7 W	Four-pin 7 W
DC input voltage (V)	11.95	12.06	11.98	11.56
DC input current (mA)	497.0	474.0	644.0	660.0
Inverter output voltage (V_{rms})	29.65	29.66	38.86	41.0
Inverter output current (I_{rms})	162.0	156.0	170.9	155.0
Power output (W)	4.78	4.58	6.36	6.20
Efficiency ∩ (%)	80.50	80.12	82.40	82.0
Inverter frequency (KHz)	30.0	25.8	31.7	29.8
Short circuit current DC (mA)	86.0	82.00	85.0	88.0
No load current DC (mA)	51.0	34.0	46.6	41.0
Power factor	0.99	0.995	0.958	0.976
Light intensity (Klux)[a]	4.3	4.3	4.1	4.2

[a] Measured on the surface of the lamp.

4. Results and conclusions

As seen from Table 1, the inverter efficiencies and light output in the two cases are almost the same. Also, the power factor in both cases is nearly unity, which shows that the lamps present a resistive load. This has other ramifications, one of which is that, during production of the lanterns, an expensive oscilloscope can be replaced by two true root mean square (rms) multimeters for measuring AC currents and voltages. In the absence of CFLs in the circuits, the 'No Load Current' is 10% or less of the maximum current. If the output is accidentally short circuited, the circuit is not overloaded or damaged, and the input current is limited to the values given under the title 'Short Circuit Current'.

In a four-pin CFL circuit, additional circuitry is needed to automatically throw open the switch S_{AB} to cut off the filament supply once the discharge is established to avoid wastage of power and damage to the filaments. This will make the circuit costlier because of the additional circuitry and less efficient because of the increased power consumption.

References

[1] Yarrow CJ. IEE 1959;106:1320.
[2] Baxandall PJ. IEE 1959;106:748.