Construction Project:

CFL & FLUORO LAMP INVERTER

Fluorescent lamp inverters are not new, but how about one that can drive compact fluoro 'energy saver' lamps? This project can supply a load up to 40W at 350V DC from a 12V battery, is highly efficient and connects directly to a compact fluorescent lamp. But there's even more, as you'll see...

by PETER PHILLIPS

Battery powered inverters that can drive a fluorescent lamp have featured before in *EA*, and these projects have always proved popular. However, we have never described one that can directly drive a compact fluorescent lamp (CFL), or 'energy saver' lamp as they are also called. These lamps have been available now for about five years, and were described at length by Jim Rowe in the September 1991 edition, in Forum. Further discussion on these lamps can also be found in Forum, November 1992.

The main features of a CFL compared to an incandescent lamp are *five* times the efficiency, and *eight* times the lifespan. This means a 15W CFL has the equivalent light output of a 75W incandescent lamp, and it lasts eight times longer. As well, a CFL has a better 'light colour' than a conventional fluoro, making them more suitable for domestic use.

Anyone who relies on battery power is always interested in electrical efficiency. For these people, the CFL has probably been seen as a desirable, if unreachable solution to an efficient 12V DC lighting system. In fact, those who have tried to power a CFL from a DC to 240V 50Hz inverter have often found the life of the CFL reduced to a mere few hours. This is particularly true if the inverter output is a square wave, as is often the case.

The answer is to drive the lamps from a DC supply, not AC. Of course that's not all there is to it, and we'll have more to say about the CFL later, but first a closer look at other aspects of this project.

The project

This project comes from Oatley Electronics, with much of the design done by Conrad Marder. The inverter is based on a switching IC, type SG3525, and has MOSFETs as the switching devices. A specially designed transformer and high speed diodes complete the main component lineup.

The inverter is extremely efficient, and virtually no heat is generated in the circuit when it's driving a 20W load. This means virtually all the input power is fed to the tube and converted to light output.

The normal output voltage of the inverter is around 350V DC and several CFLs can be connected to the one inverter, up to a total load of 40W or so. Each lamp can be switched on or off as required, so you could have a conventional lighting system based on CFLs running from the one inverter. We'll have more to say about this aspect later, but as we said in the introduction, there's more...

Any fluorescent lamp is more efficient than an incandescent lamp, and battery powered fluorescent lamps have been marketed for years. However as many people will be aware, the lifespan of the tube in these units is often quite short. The main reason is that the tube is not being driven correctly, because the tube filaments remain cold during operation. The inverter we're describing here cannot directly drive a fluorescent tube, as it has no inherent current limiting. A conventional ballast can't be used, as the output of the inverter is DC. However Oatley Electronics has been able to obtain two types of electronic ballasts that can be used with this inverter.

The first, shown in Fig.1, suits an 18 to 20W tube. The output of the inverter is connected to the input of the electronic ballast, which as shown in the photo, connects to the tube.

The second, shown in Fig.2 is a more elaborate electronic ballast that features a dimming control. This unit is for 32 to 36W tubes, and an external DC voltage or a 100k ohm variable resistor can be connected to the unit to vary the brightness of the tube. As before, this ballast connects to the output of the inverter.

The important point is that in both cases the tube is being operated in the correct way. That is, the filaments remain hot during operation and are used to start the tube. This means the life of the tube is not compromised by the usual cold start and cold operation provided by many portable fluorescent lamps.

Electronic ballast

In an electronic ballast, the incoming 240V mains is applied directly to a mains-rated rectifier, usually comprising four 600V 1A diodes. The resulting DC from the rectifier is filtered with a 10 to 20uF 400V electrolytic capacitor, and is then applied to an inverter.

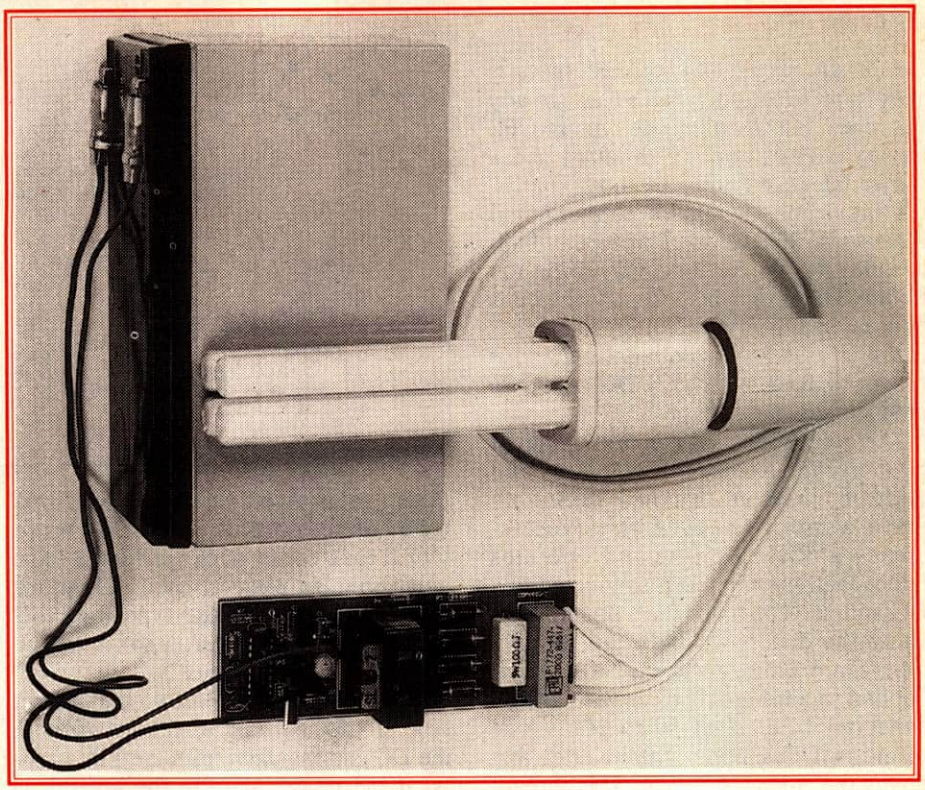
For this reason, an electronic ballast can operate from a 350V DC supply, of either polarity. In this case, two of the diodes in the bridge conduct continuously. In fact, the complete rectifier could be removed, but this is usually impractical and polarises the inputs.

Apart from giving a flicker free start, an electronic ballast offers a number of advantages over the conventional iron-cored ballast.

Perhaps the most important is the elimination of the strobing effect, due to the relatively high operating frequency of the inverter in the ballast. Fluorescent tubes operating at 50Hz are often traced as the reason for headaches and the like, so increasing the operating frequency solves these problems.

As well, there's no buzzing caused by loose laminations, the fluorescent tube has a longer life and the overall efficiency of the light is increased. So even if you are not interested in using the inverter with a CFL, there's plenty of reasons to use it with an electronic ballast and a conventional tube.

The prices of each system are given at the end of the article, including a price for the inverter kit *with* a CFL. In fact, before describing the inverter, we need to explain a few things about CFLs.



This project lets you operate a compact fluorescent lamp from a 12V battery. The overall high efficiency makes it ideal for boaties, campers and anyone relying on battery power.

About CFLs

It would be nice to be able to say that this inverter will work with all CFLs. However, this is not the case, as it appears there are at least three different types on the market.

While there's no reason to, most people assume that a CFL has an electronic circuit to achieve the high efficiency. In fact, the tube design is mainly responsible

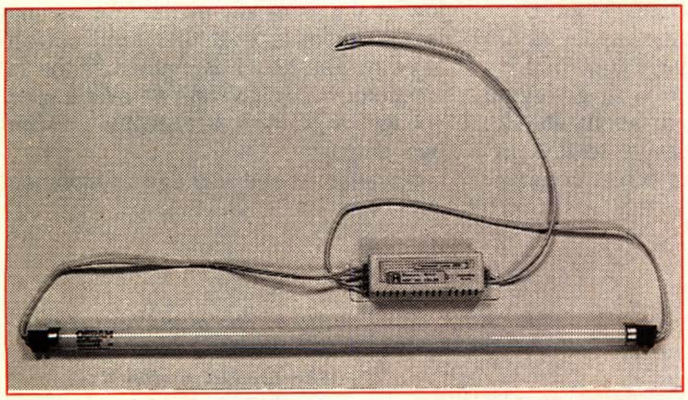


Fig.1 (above): This shot shows the 20W electronic ballast described in the article. The ballast connects directly to the output of the inverter and is shown here connected to an 18W 600mm fluorescent tube.

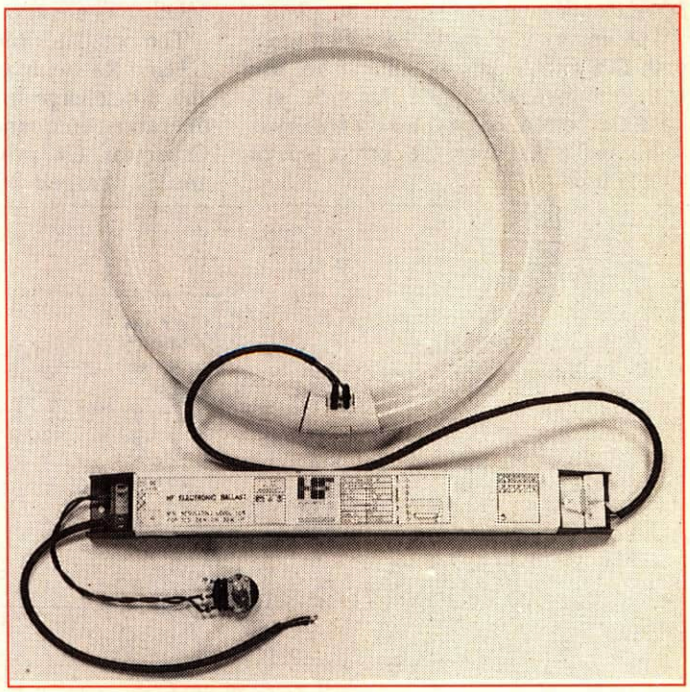


Fig.2 (right): The electronic ballast shown here is suitable for 32 to 36W tubes, and features a dimming control. It connects to the output of the inverter and gives flicker free start-up.

for the efficiency, and the electronics is simply an electronic ballast as already described. For instance, one type of CFL has an internal iron cored ballast and a starter integrated with the tube. That is, it's much the same as a conventional fluorescent light fitting. This type of CFL is quite heavy, and one version is the Philips SL series, where the actual tube is housed in a translucent dome. So, because it uses a conventional ballast, it cannot be operated from a DC supply as produced by our inverter.

The next type *is* all electronic, and at first glance seems identical to the electronic version that will work with this inverter. However, this type requires a 50Hz supply, and operates rather inefficiently when connected to a DC source. The block diagrams in Fig.3 show the difference between the two types. In (a), the incoming 240V AC is applied to a bridge rectifier with a filter capacitor of at least 10 to 20uF. The resulting DC supplies the inverter that drives the fluorescent tube. This type of CFL *will* work with the inverter described in this article.

The version that *doesn't* work with this inverter is shown in Fig.3(b). As before, the incoming mains supply connects to a bridge rectifier, but now the filter capacitor is less than a microfarad. A fifth diode (D1 in Fig.3) isolates the real filter capacitor from the bridge. With this circuit, mains current flows virtually all the time, unlike the previous circuit, where mains current flows for short intervals at the peak of each cycle. Also, the inverter operates from a DC-plus-100Hz unfiltered rectified AC supply.

The important point is that CFLs fitted with this circuit are not suitable for use with our inverter. While the tube will light, the current taken from the battery is nearly twice that when the correct type of CFL is used.

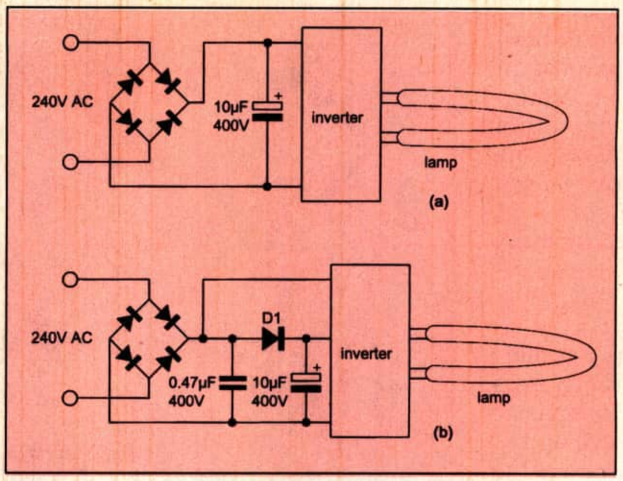


Fig.3: The basic internal circuit of a CFL that will work with the inverter is shown in (a). The version that will not is in (b). Notice in (b) that the 10uF filter capacitor is isolated from the mains by D1.

As far as we can make out, this type of circuit is used in those CFLs that come packaged as a base and separate plug-in tube. They are often cheaper than the type that will work with this inverter, and we've seen at least two brands.

The easiest way to tell if the correct type of CFL is being used is to measure the DC current taken from the 12V supply. If the power input to the inverter is about equal to the rated power output of the CFL, then all is well. If not, the wrong type of CFL is being used...

The circuit

The circuit of the inverter is shown in Fig.4. The main component is IC1, type SG3525. This IC is designed for use in switch-mode power supplies, and features totem pole output drivers that can quickly charge and discharge the input capacitance of the MOSFETs. This improves the efficiency of the inverter, as the turn-on and turn-off times of the MOSFETs are kept extremely short.

The oscillator timing components are C2 and R1, with a charge time of 12us and a discharge time of 1us, giving an operating frequency of about 75kHz. Capacitor C4 provides a 'soft start' and is charged by an 50uA constant current source inside IC1. This causes the duty cycle of the output signal from pins 11 and 14 of IC1 to slowly rise to 50% as C4 charges.

A soft start is needed because of the relatively large filter capacitor in an electronic ballast or a CFL. Further start-up current limiting is provided by R4, which for best reliability is specified as a wire-wound 5W resistor.

The inverter section consists of a push-pull inverter with the two primary windings of T1 connected to form a centre tap. The primary current is switched via MOSFETs Q1 and Q2. The secondary voltage is directly proportional to the turns ratio of the transformer, and is therefore determined by the DC voltage supplying the circuit.

The secondary voltage from T1 is converted to DC by a bridge rectifier comprising four high speed diodes. The usual output voltage is around 350V DC. The output voltage is not regulated unless it exceeds 370V, as regulating the voltage lowers the efficiency of the inverter and is not necessary in this application anyway. The reason is that a CFL or an electronic ballast can operate over a wide voltage range, with a relatively constant light output.

Because of the leakage inductance

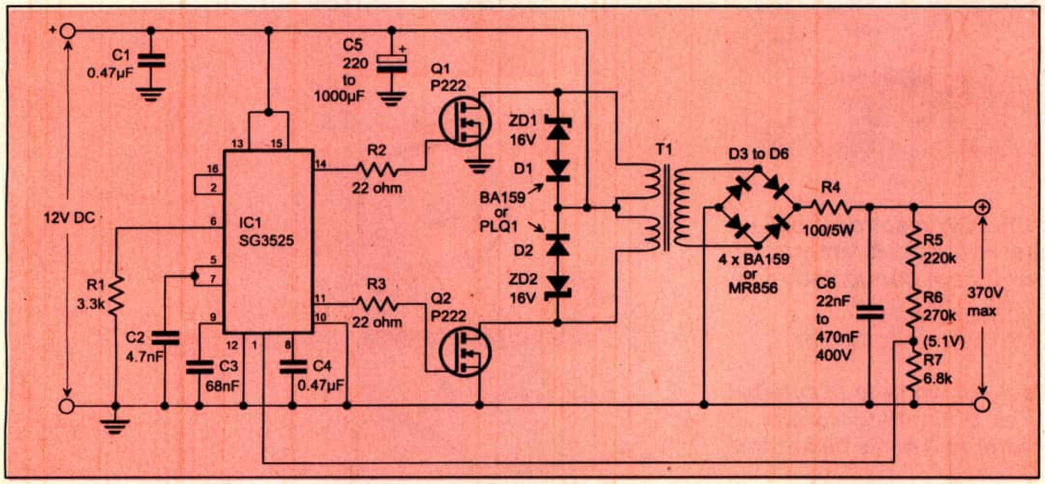


Fig.4: The circuit consists of a double ended inverter with the two primary windings of the transformer connected to form a centre-tap. The MOSFETs are driven with a square wave from IC1. Regulation of the circuit only occurs when the output voltage exceeds 370V DC.

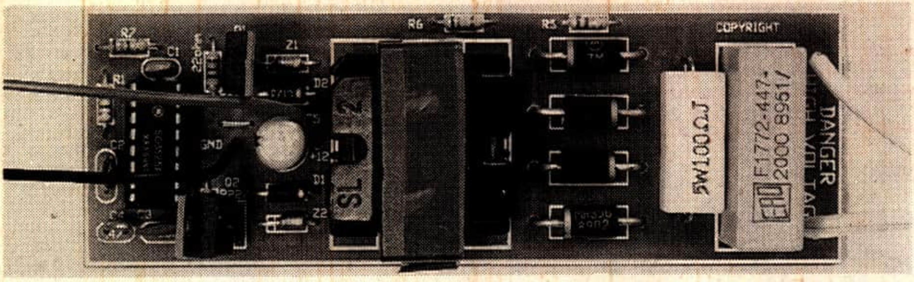


Fig.5: This photo shows a close up of the inverter PCB. The MOSFETs in this board are type MPT50N05E and have a different package to the specified P222 devices. See the layout diagram for details.

between the two primary windings of T1, spikes are generated at the drain terminals of Q1 and Q2 when these devices switch off. The spikes are clipped by ZD1 and ZD2, to prevent damage to the diodes in the bridge rectifier connected to the secondary of T1. Diodes D1 and D2 prevent the zener diodes conducting in the forward direction.

Construction

The kit of parts for the inverter includes a silk screened PCB that shows the component layout. Assembly is therefore very straightforward. The photo in Fig.5 shows a close-up of the inverter and Fig.6 shows the layout diagram.

As usual, install the passive components first, taking care with the polarity of the diodes and the electrolytic capacitors. An IC socket for IC1 is optional.

If the inverter will only be used with 20W loads or less, there's no need to add a heatsink to the MOSFETs. For 40W loads, you have two options: fit heatsinks to the P222 MOSFETs, or use MOSFETs type MPT50N05E. These latter devices are in a TO-220 style package which has a metal tab. They also have a higher current rating than the P222 devices. While they can power a 40W load without a heatsink, for best reliability a small heatsink should be added.

The P222 devices are in a TO-126 style package, but without the usual hole drilled through the package. This means the heatsink has to be of the clip-on type, as there's no way of otherwise attaching it. As we've said, the heatsink is only needed if you want to use the inverter with a load greater than 20W.

Testing

Once you've built the inverter, connect a suitable load to the output and apply 12V DC to the input. It's important to add a fuse between the battery and the inverter. Otherwise a fault could cause a large battery current to flow, causing considerable heat in the conductors and damage to the circuit. A 5A 3AG fuse in an in-line fuse holder will suit most applications.

Remember also that the output voltage is a lethal 350V DC. For this reason, use 240V mains rated wiring from the output of the inverter.

As a guide to its operation, the prototype inverter takes about 180mA from a 12V battery when no load is connected. When a Philips PL Slimline Electronic 20W CFL is connected to the inverter, the battery current is about 1.8A. As the light warms up, the current drops slightly. If the load current is excessive and the no-load current is correct, suspect the load. (Refer back to the sec-

Continued on page 87

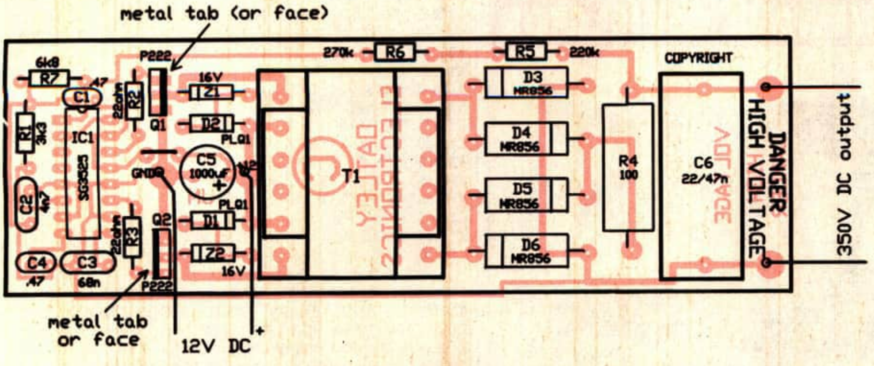


Fig.6: Here's the layout of the PCB. The MOSFETs can be either of two types, but both are installed with the metal tab or metal face as shown.

LAMP INVERTER

Continued from page 63

tion on CFLs for details of the different types of CFLs.)

Otherwise, carefully check your construction. If all is well, it's now a matter of deciding what to do with the inverter. There are plenty of options, as we'll now describe.

Applications

As we've already explained, there are three main options: using the inverter with one or more CFLs, with a 20W electronic ballast and fluorescent tube, or with a 36W dimmable electronic ballast and tube. The DC supply to the inverter can range from 10V to 15V.

The obvious application is internal lighting from a solar-powered 12V battery charging system. This could include boats, caravans, camp sites and of course, a residence. Because the one inverter can drive several lamps, you could even use conventional house wiring to connect the lamps.

This way, a conventional light switch can be used to operate a light driven from the inverter. While a typical light switch is only rated for AC, the current taken by a 20W lamp at 350V DC is less than 60mA, which should be well within the rating of a 10A AC rated switch. Because the inverter draws a no-load current, some arrangement is needed with a multi-lamp system to isolate the inverter from the 12V supply when all lamps are off.

Another application is a low voltage garden lighting system. With this arrangement, run a 12V supply to each lamp fitting, and install an inverter in each one. A low cost fitting made from a large Nescafe coffee jar and PVC plumbing is shown in Fig.7. This fitting was made with 90mm SWV pipe, which is readily available from most hardware shops. The jar was joined to the pipe with a 90mm joiner, and the total material cost was around $4.

The wiring to the fittings has to have a low resistance, to keep the voltage drop as low as possible. However, the light output of a CFL is virtually constant for an input voltage to the inverter down to about 10V. Remember too that the electronic ballasts referred to in this article can also be powered directly from 240V AC. So there's really quite a few options available. ❖

PARTS LIST

Resistors

All 1/4W, 5% unless otherwise stated:

R1	3.3k
R2,3	22 ohm
R4	100 ohm, 5W
R5	220k
R6	270k
R7	6.8k

Capacitors

C1,4	0.47uF monolithic
C2	4.7nF polyester
C3	68nF ceramic
C5	220 to 1000uF electrolytic
C6	22nF to 470nF 250V AC rated

Semiconductors

D1,2	BA159 or PLQ1 power switching diodes
D3-6	BA159 or MR856 power switching diodes
IC1	SG3525 switching IC
Q1,2	P222 or MPT50N05E MOSFETs

Miscellaneous

PCB 125mm x 40mm; transformer to suit; optional heatsinks; optional 16-pin IC socket; hook up wire.

A kit of parts for this project is available from:

Oatley Electronics
5 Lansdowne Parade,
Oatley West, NSW 2223.
Phone (02) 579 4985
Postal address (mail orders):
PO Box 89, Oatley West NSW 2223.

Inverter kit, PCB and all on-board components including transformer and P222 MOSFETs	$24.00
Inverter kit and 7, 11 or 15W CFL to suit	$36.00
Inverter kit and 20W electronic ballast	$36.00
Inverter kit & 36W dimmable electronic ballast	$40.00
Post and pack charges	$5.00