# Light and power from dc supplies

Generating mains-independent light and power from batteries is fraught with many unrealised difficulties. Whether you want dc back-up to operate equipment when the mains goes 'off the air' or a wholly independent 240 Vac supply, you should know the problems up front.

**Roger Harrison**

THAT'S THE TROUBLE with Electricity Commissions — they've insidiously crept into our lives and made us quite dependent on them. For those occasions when we cannot avail ourselves of their 'services', we have to rely on other sources to provide light and power. The old kerosene pressure lamp has its advantages — and disadvantages — but how on earth do you keep a disk drive running when the ac mains 'browns out'? As storage batteries are ubiquitous, the 12 V car battery in particular, it's natural that we turn to them to provide back-up and mains-independent supplies.

## Back-up supplies

For equipment designed to be powered directly from a nominal 12 Vdc source or from either 12 Vdc or 240 Vac, back-up supplies are employed to maintain continuity of supply, the battery being kept charged from the mains, but the battery acts to maintain power supply to the equipment in the event of mains failure. This sort of system is commonly installed with burglar alarms, amateur radio repeaters and geophysical monitoring equipment, for example.

The 'power budget' of such systems is carefully considered to provide maximum service period from the battery supply when mains is unavailable. Hence a single 12 V storage battery — generally a low maintenance type — is employed. Let's learn a bit about lead-acid batteries first.

The fully-charged, no-load terminal voltage of a lead-acid cell is between 2.3-2.4 volts. This drops under load to about 2.0-2.2 volts. When discharged, the cell voltage is typically 1.85 volts. The amp-hour capacity is determined from a 10-hour discharge rate. The current required to discharge the battery to its end-point voltage of 1.85 V/cell is multiplied by this time; e.g: a 40 Ah battery will provide four amps for 10 hours before requiring recharge. Note however that the amp-hour capacity varies with the discharge current. The same battery discharged at a rate of 10 amps will not last four hours; on the other hand if it is discharged at 1 amp it will last somewhat longer than 40 hours. The typical discharge characteristics of a (nominal) 12 V battery are shown in Figure 1.

The ideal initial charging current for the fully discharged battery (cell voltage under 2.0 V) should be about 20 amps per 100 amp-hours of capacity (i.e: 8 amps for a 40 Ah battery). Once the electrolyte begins to gas rapidly, the terminal voltage will be around 13.8 volts and rising rapidly. At this point, the charging current should be reduced to somewhere between 4-8 amps per 100 Ah until charging is complete.

At the end of charging, terminal voltage may rise to about 15.6 volts or more, but this decreases slowly after the charger is removed, the terminal voltage then usually reading around 14.0 to 14.4 volts (see Figure 2).

Back-up supplies are generally of the 'trickle-charge' type or the 'battery condition' sensing type. Two good examples are ETI projects 597 — Emergency Lighting Unit (December 1980) — and 1503 — Intelligent Battery Charger (August 1981). The ETI-597 trickle charges a 12 V battery when the mains is on and provides automatic switchover when the power drops out. It's cheap and simple, but needs to be *used* for the batteries to stay in condition so that they deliver their rated capacity when

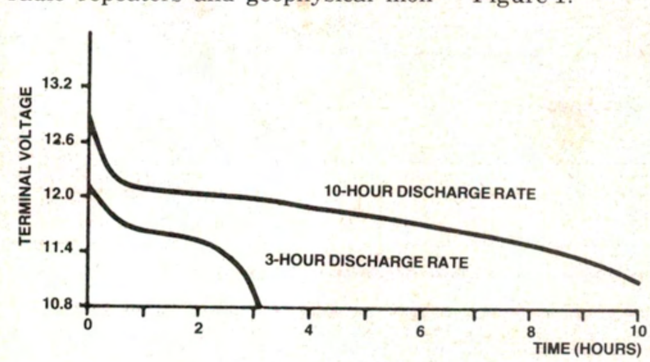



*Figure 1.* **Typical discharge characteristics of a 12 V (nominal) lead-acid battery.**

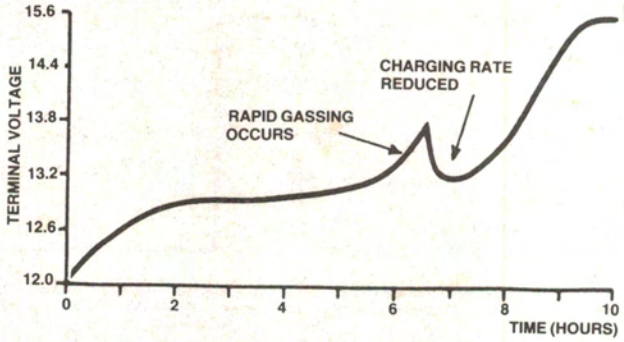



*Figure 2.* **Charging characteristics of a 12 V (nominal) lead-acid battery. The 'kink' in the curve near six hours is explained in the text.**

needed. Back-up supplies of this sort are only practical where the load on the supply is not too heavy — generally 20 W or so.

To drive a heavier load, upwards of 50 W for example, it's best to power the equipment from the battery *all the time* and have a charger which senses the battery terminal voltage, charging the battery when the terminal voltage falls to a preset level and turning off when the terminal voltage rises to the desired operating level again. This is what the ETI-1503 does. There is a slight element of luck involved as to how charged the battery will be at any one time, but the lower limit is usually set so that the equipment will operate for a specified period. The ETI-1503 can be used with batteries with a capacity up to 100 Ah. Such a battery can drive a 10 A load at the 10-hour discharge rate — which effectively means it's a good back-up supply for equipment with a power budget of up to 120 W mean consumption. This means that actual consumption can be greater than that from time to time provided that consumption falls below the mean level for an equivalent period. An amateur VHF or UHF repeater is a good example. Whilst 'listening' only — no stations active on the input channel — consumption is quite low. When 'activated' by a station or stations, the repeater spends most of its time transmitting, and consumption can be four to ten times that during inactive periods, depending on the power output of the transmitter employed in the repeater.

As stated earlier, the major consideration with back-up supplies is the power budget of the equipment being supplied. If you anticipate the necessity of operating the equipment for periods exceeding, say, eight hours, then a battery of adequate ampere-hour capacity needs to be used. It is always prudent to choose a battery with 20-50% more capacity than strictly necessary.

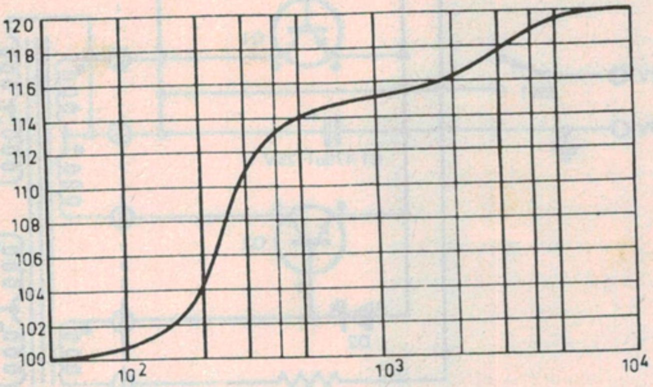


*Figure 3.* **The light output of a fluorescent tube increases with increasing supply frequency in the manner shown in this graph. The property is exploited in dc-ac square wave inverters for lighting.**

## dc-ac inverters

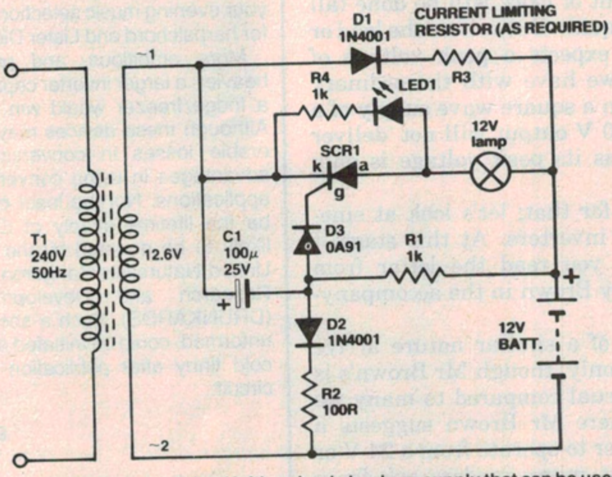
Like storage batteries, 240 Vac mains-operated equipment is ubiquitous! The huge variety of products have been designed to be *convenient,* thus making themselves *necessary.* Or so it seems. Why on earth anyone would want to take an electric razor on a camping expedition and expect to power it from an ersatz 240 Vac supply is beyond this writer — but then I haven't had a shave in more than 15 years except when my appendix was removed and then they didn't shave my face!

There are two common approaches to providing 50 Hz ac power for mains operated appliances: provide square wave drive of the appropriate amplitude, or derive a sinewave (or pseudo sinewave) supply of appropriate amplitude. Both are fraught with hidden difficulties. If you want any substantial amount of power output — like 200 W — you're in hot water — and probably unable to boil a billy, to boot!

A square wave dc-ac inverter has the advantage of simplicity and efficiency — depending somewhat on the design. Inverters generally take two forms: *self-excited,* usually employing a feedback winding on the transformer, and *driven,* where an oscillator drives a switching circuit, generally with transformer output. Where the precise frequency of the ac output is unimportant, self-excited inverters are employed. Where a stable 50 Hz output is required, a driven inverter is necessary.

Lighting is one area where self-excited dc-ac inverters find application. The common tungsten filament incandescent light globe is a poor choice for lighting where a dc supply is employed. They have an efficiency of less than a fifth of that of a fluorescent light of the same power rating — viz: around 12 lumens/watt for the tungsten filament lamp versus better than 60 lumens/watt for a fluorescent tube. A 20 W fluorescent tube would provide as much light output as a 100 W incandescent globe! Those figures are based on 50 Hz ac supply. Fluorescent tubes *actually improve in efficiency* when driven from a higher frequency supply. Figure 3 shows how the light output of a fluorescent tube increases with increasing supply frequency. Driving the tube from a supply frequency of 10 kHz or more will result in a 20% increase in light output.

The circuit of a self-excited inverter driving a fluorescent tube is shown in Figure 4. This is taken from Project ETI-516 of November 1972. It ran at around 2 kHz and employed a ferrite-cored transformer. Consumption was 2.5 amps. An incandescent globe to pro- ▶



**Circuit of the ETI-597 'Emergency Lighting Unit', a simple back-up supply that can be used for other than lighting applications.**

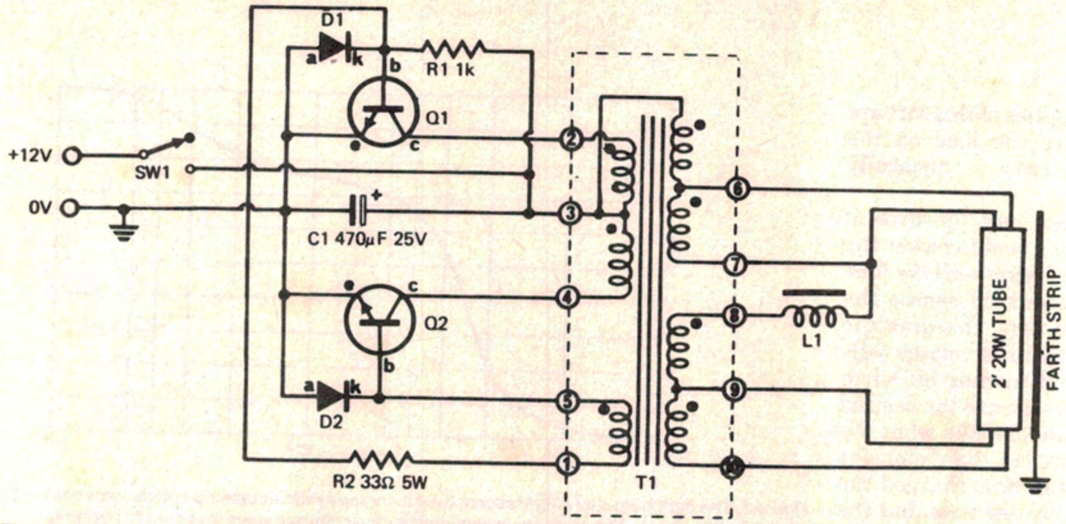



*Figure 4.* **ETI project 516 (Nov. '72!) employed a self-excited dc-ac square wave inverter operating at 2 kHz to drive a 20 W fluorescent tube — an efficient solution to providing light from a dc supply.**

vide a similar light output would draw around 10 amps! Such inverters have one drawback — the transformer core 'sings' owing to the magnetostrictive forces on the core pieces (which generally come in two pieces). That can be solved in two ways — put the inverter in a 'soundproof' box or operate the inverter at a frequency above audibility. The first solution was employed with the ETI-516 inverter, but is inevitably only partially successful (though often acceptable). The second solution will be described next month in Project ETI-1505.

When it comes to powering 240 Vac-operated equipment or appliances a number of considerations have to be looked at. First, will the equipment operate from a square wave supply? Many appliances employing an ac or ac/dc motor will operate quite happily from a square wave supply. One of ETI's correspondents employed battery back-up for his computer's disk drives, supplying these with 240 V, 50 Hz square wave ac from a driven inverter. The general arrangement is shown in Figure 5. A 100 Hz oscillator drives a flip-flop, which drives a pair of HEXFETs connected in push-pull across the secondary of a toroidal transformer. Battery supply was 24 V. The transformer is operated 'back-to-front' here, where input is applied to the secondary and the load connected across the primary. Toroidal transformers perform much better in this application than conventional types as core losses are lower and primary-to-secondary coupling is generally better. Some losses are involved, the saturation voltage of the HEXFETs generally being the greatest source. Hence the use of a 20-0-20 V winding and not a 24-0-24 V winding.

The saturation voltage loss in switching devices driving a transformer is an important consideration. One or two volts lost from a 24 V supply represents only about 4% to 8% loss, but at 12 V it's twice that! Any further losses only magnify the problem.

A square wave ac supply is inherently rich in harmonics. These can play havoc with audio and digital equipment and it's often difficult to suppress interference generated by the supply. Then again, some equipment — particularly anything containing a transformer and rectifier, will produce entirely different performance from when it's operated from a sine wave supply. The problem arises because the peak and RMS values of a square wave are the same, whereas the peak/RMS ratio for a sinewave is 1.414. To deliver the same *work value* as a sine wave supply, the peak output voltage of a square wave dc-ac inverter is generally set at 240 V. When driving a motor or resistive load, the square wave supply will deliver the same amount of power as a sine wave supply; i.e: the same amount of *work* will be done (all else being equal). But, where the load or equipment expects a peak voltage of 340 V (as we have with the ordinary mains), then a square wave supply of a nominal 240 V output will not 'deliver the goods' as its peak voltage is only 240 V.

So much for that; let's look at sine-wave dc-ac inverters. At this stage, I recommend you read the letter from reader Barry Brown in the accompanying panel.

Requests of a similar nature arrive quite commonly, though Mr Brown's is a little unusual compared to many we receive. Where Mr Brown suggests a dc-ac inverter to operate from a 24 V or 32 V supply, many readers ask for a

**Dear Sir,**

Despite the financial burden of component costs for an ever-expanding range of new projects, please find enclosed my cheque for subscription renewal. Would you consider a three-to-six-month moratorium on new projects to enable those of us who are more enthusiastic about starting the new than finishing the old to clear some of the backlog?

No?

Well, to an area with possibly more appeal — that of small domestic power supplies. With most homesteads using 32 Vdc power for lighting and almost all travellers using 24 or 12 Vdc power, a stable inverter producing 240 Vac at 50 Hz in the 500 W-1 kW range could be of enormous benefit to many people. With an increasing range of domestic electronic equipment becoming available, the only way for many people to enjoy these products is to crank over the, if available, 240 V diesel generator. This is great stuff during the day, especially with auto-start, but can be a bit distressing when you discover that your evening music selection is really a duo for harpsichord and Lister Diesel.

More ambitious, and probably a lot heavier: a larger inverter capable of starting a fridge/freezer would win many friends. Although these devices may have considerable losses in conversion, there are advantages in using converters for many applications. Not the least of these would be the lifetime supply of European carp likely to be donated by the Darling River United Naturalists Kangaroo Appreciation, Research and Development Society (DRUNKARDS). Such a society, although unformed, could be initiated at the drop of a cold tinny after publication of a suitable circuit.

**Barry Brown,**
**Young NSW.**

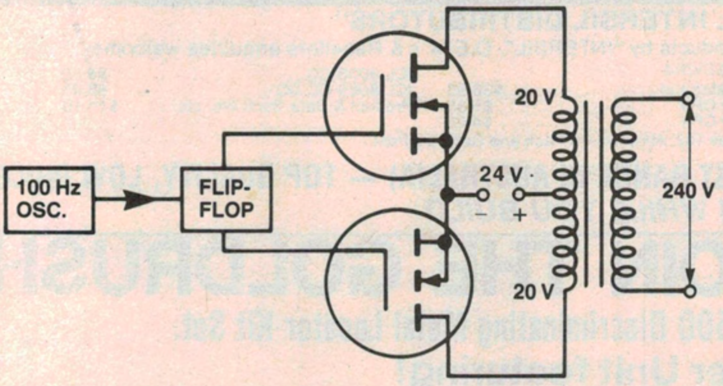



*Figure 5.* **Example of a 'driven' dc-ac square wave inverter with nominal 240 Vac output. This technique has been employed by one of our correspondents as a computer back-up supply.**

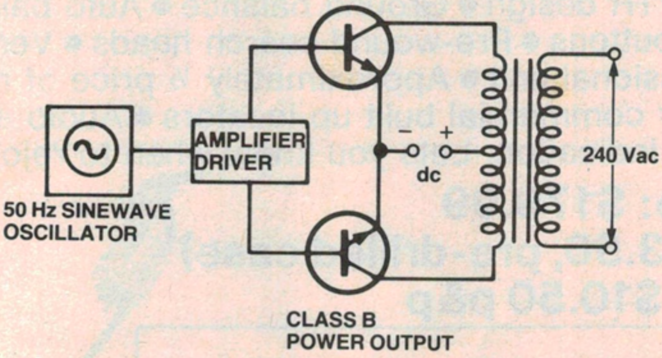


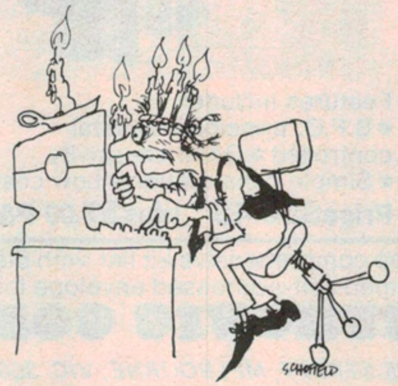

*Figure 6.* **Class B driven sinewave inverter technique for providing 240 Vac from a dc supply.**

1 kW or similarly rated inverter to run from a 12 V battery. The latter is impractical, for the following reasons.

Consider this: a sinewave dc-ac inverter needs to be of the driven type. Hence it generally consists of an oscillator driving a class B power amplifier — usually a push-pull type. The theoretical maximum efficiency obtainable with a class B power amplifier is 78%. With losses and power consumption of drive circuitry taken into account the dc power input to ac power output efficiency of an inverter of this type is generally around 65-70%. Thus a 1 kW dc-ac inverter to run from a 12 V battery *would draw in excess of 120 amps* at full load! Few batteries available would supply that sort of current for long. With currents of that magnitude, special arrangements have to be made for primary circuit conductors. A resistance of 5 milliohms (0.005 ohms) will result in a power loss of more than 70 watts. Then again, special consideration has to be given to heat dissipation in the power output stage. The devices used would dissipate something over 400 W at peak load. No load dissipation would probably be in the vicinity of 40-50 W, which is no mean amount to get rid of.

Apart from the weight of a heatsink, consider the weight of a 1 kVA (or 1000 W) transformer (assuming a single transformer is used). We'll leave the expense to your imagination.

The problems are reduced somewhat when a much higher dc supply voltage is available. However, in the latter case other techniques of dc to ac conversion present themselves — but that should be the subject of another article as it's a whole new ballgame.



Where a 12 V battery supply only is available, there is a practical limit to the maximum power of a dc-ac inverter, and that's probably around 300 W output. At typical efficiencies, the dc input power is around 450 W, or close to 35-40 amps current from the battery.

As you would already appreciate, this brings its own special problems. A battery to supply that sort of power for any appreciable or worthwhile period would need to have a considerable ampere-hour capacity. Your typical 40-60 Ah car battery would barely deliver an hour's worth of power. If the inverter is installed within the vehicle, or close by, and you are willing to keep the engine running during operation, then the battery will deliver the goods for quite a period, provided you can 'set' the throttle to suit so that battery charge is maintained. At this stage, I might point out that an alternator coupled to the motor would provide a more efficient energy conversion.

To gain, say, four to six hours of operation for a 300 W inverter, you would need a battery system of more than 200 Ah capacity.

A more practicable power level for a sinewave dc-ac inverter would be around 120 W. Such an inverter would pull 12 to 15 amps from the battery, a much more manageable figure.

Having seen the primary side of the problem, let's consider the secondary side — the load. How many appliances do you have rated at less than 300 watts? Very few. The humble electric kettle is rated from 1 kW to 2.4 kW. Monochrome TV sets, particularly portables, may only consume 100 W, but a colour TV may draw three times that or more. A 'low power' (say, 30 W/ch.) domestic hi-fi will draw around 100 W, depending on how much equipment is in use and how loud you like it. Anything more ambitious has a proportionately larger consumption. A 300 W dc-ac inverter is best considered where the full output is only required intermittently.

## Conclusion

As can be seen, many factors have to be taken into account when considering obtaining light and power from a battery supply — whether it be in a back-up application, for lighting or 240 Vac substitution. The ubiquitous 12 V battery is not up to the job in some instances — in which case higher voltage dc systems are better considered.●