A Battery Eliminator

by Ray Whitcombe

A Design for a convenient battery supply for 'D' series valve portables

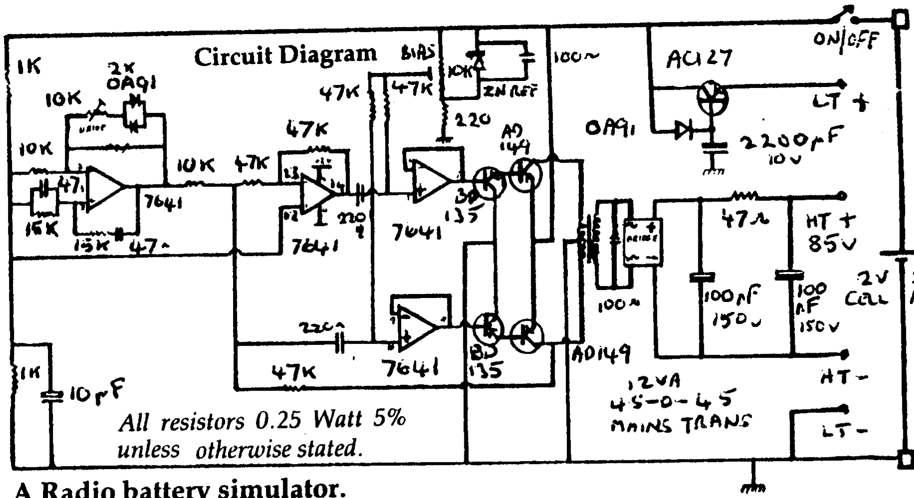
Just another of those solid state inverter designs? Ugh! Well I suppose that you are right, but take a while and consider just what is required to satisfy the title of this article.

The key word is 'convenient', ie: a unit which gives the least trouble to the user. To state this in another way, there should be no more difficulties encountered than in the original concept of going to your 'friendly radio dealer' and purchasing an 'All-Dry Radio Battery', fitting it, and switching on.

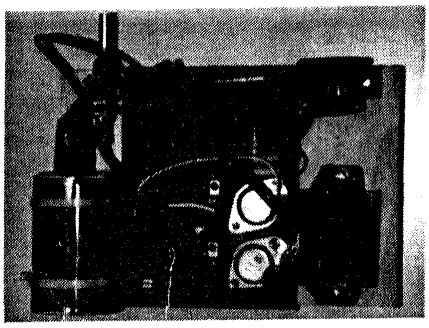
Easy enough with all this 'New Tech'? Or is it? Well, let's start the project on the right foot and make a list of design requirements.

Design Objectives:

1) The completed unit must be the same size as original battery. This was not difficult in my case as set used a B103.
2) The replacement battery should be 'cheap' to run. For this reason a rechargeable cell was chosen.
3) The battery should be 'easy' to handle, so the charging should be straightforward, ie: not multiple cells all at different discharge rates. So a single cell was chosen to furnish both H.T. and L.T. (If G.B. is required, then the best solution is an alkaline battery since the very low drain of bias circuits means that it can be almost 'fitted and forgotten'.)
4) As the battery has to supply the filaments, the voltage should be low. Taking the requirements as stated in (3), it would seem that the best solution would be a single cell. There are several possibilities, Lead Acid at 2v per cell, and Ni-Cad at 1.3v per cell. We would have to use at least two Ni-Cad's to have enough voltage for the 1.5 volt filaments, and in addition the standard sizes offer limited capacity. On the other hand we would require only one Lead-Acid cell, (2v). This could directly feed the filaments via a low power waste dropper, and may be able to run an inverter? (on only two volts! well we will try our best!)



A Radio battery simulator.



5) The cost of making the unit should be kept to a minimum, and only readily available components should be specified.
6) Last, but not least, the radiation generated by any inverter must NOT interfere with the LW or MW wavebands. To make matters worse the unit has to fit inside a small radio right next to the frame aerial! It would be an advantage not to have resort to complex screening and filtering, especially with reference to (5) above.

Design Solutions:

First let us consider the power taken by the radio, and then estimate the current consumption from a 2v supply. The filaments take 250mA, and the HT is in the region of 10mA at 90v, ie: 0.9 watts. For reasons to be explained later, the efficiency of the inverter will be around 60 per cent, hence the current at 2v will be around 750 mA, making a total of 1Amp. A 5 Ampere-hour cell will be sufficient to supply the set for more than 3 hours, this being considered long enough for present day demonstration requirements for such a radio. The cell chosen was a 2 volt, 5AH, 'CYCLON' sealed lead-acid cell. As only one cell is used, recharging is simple and optimum as there is no possibility of cell charge imbalance and the cycle can be completed in a few hours using a fast constant volts charge at 2.5 volts, initial current 5 to 10 amps.

The most important design consideration was considered to be the achievement of very low harmonic content in the inverter. Square-wave units, as used in camera flashguns, are very efficient, and operate from low volts, however they generate strong harmonics, as you may check by operating a flash gun near any radio. Another approach is to go for a sine-wave converter, or in other words an audio amplifier, not so efficient (around 50% for class B), but very low R.F. 'pollution'. The design employed is in fact a class B amplifier working into an output transformer in order to step up to 90 volts.

The biggest problem is to get such an amplifier to operate properly from a 2 volt line. Semiconductors need a bias voltage of 0.6v (Silicon) just to start, and then there are resistive losses in the various components, so our 2 volts is rapidly reduced! The best transistors at low voltage and high current are the now obsolete germanium types, in fact almost more obsolete than valves! However, some power output versions are still available for replacement purposes, mainly in car radio, and it is the power output device that concerns us. The AD149 was chosen, not because of its dissipation qualities (in this application little heat is generated and a heat sink is definitely not required) but because of its high current gain, its low saturation volts, low intrinsic emitter resistance, and the low 'germanium' base-emitter volts. It will be seen that the circuit does not employ any resistive current limiting to prevent thermal runaway, but at such a low operating voltage there is no possibility of this occuring considering the intrinsic resistances in the semiconductors together with the other components and wiring. In fact we cannot afford to have any extra resistance, and have to keep the wiring as compact as possible.

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Workshop

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The next consideration is the selection of a suitable transformer. Obviously one can wind a special, and undoubtedly this will give the best results, but for convenience and cost a study of possible standard types is worthwhile. A good compromise was arrived at by selecting a standard mains transformer, the specification being as follows:

Secondary = 4.5---0---4.5 volts R.M.S.
Power = 12 Volt Amps.
Regulation = 9%

Using the transformer as specified above, the operating frequency was found to be best at around 150Hz, this giving the best compromise between transformer efficiency, and smoothing requirements.

The low level circuits were constructed round a 7641 G-MOS op-amp I.C. this approach being chosen for ease, compactness, and the fact that the 7641 is guaranteed to operate down to ±1 volt line. In addition four identical op-amps are provided in the one package.

The first section of the 7641 is used as a diode stabilised Wein bridge oscillator to provide the 150Hz drive frequency. An amplitude control is provided. The second section is used as a phase inverter for the push-pull drive, while the remaining two sections are used as voltage follower drivers to the output stage pre-driver. A D.C. bias adjustment is provided at this point in order to vary the working point of the output transistors, this bias supply being stabilised by a 1.25 volt 'band gap' semiconductor device so that the output stage bias point does not vary as the 2v cell discharges.

The disadvantage about ultra low power devices like the 7641 is that they can only deliver 'flea power', hence in order to drive the current hungry AD149s we have to interpose a pre-driver. For this duty BD135s are used as emitter followers, thus giving current gain. Again relatively large transistors are used because of their low intrinsic resistance.

The 90 volts is obtained via a bridge rectifier connected to the output transformer, the primary of the mains transformer being used as the secondary and vice-versa. A smoothing circuit consisting of a reservoir cap', series resistor, and smoothing cap' was found to be necessary to reduce the ripple to a low level.

In operation it was found that considerable 150 Hz ripple was finding its way to the filament supply via the common impedance of the 2v cell. The original idea of using a forward biased diode junction to drop the 2 volt supply to 1.5 volts did not provide sufficient series impedance to operate a successful filter, so the diode dropper was replaced with a simple transistor circuit, using our old friend a germanium device, the base impedance being high enough to effect reasonable filtering with a 1500 μF capacitor.

Adjustments and Use

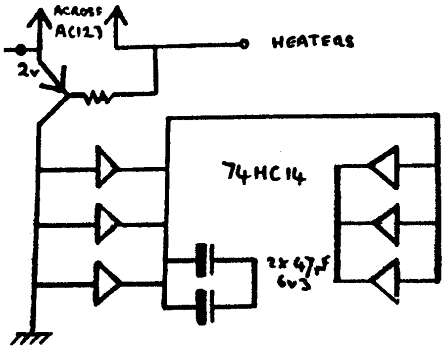
Although the amplifier is class B, the very act of connecting a bridge rectifier causes the waveform to be square-ish, but because the edges are 'soft' the harmonics thus generated do not extend very far. As in conventional mains operated equipment it is beneficial to connect a capacitor across the rectifier in order to reduce any interference caused by it. Also the connections to the bridge and the reservoir capacitor must be kept short, and any wires should be twisted so as to eliminate inductive loop interference problems, especially those between the bridge and reservoir, which are very 'hot'.

The unit is adjusted by observing the current drawn from the 2v cell and the output DC. If a 'scope is available the waveform can be observed as well. Adjust the amplitude to minimum, and then turn the bias pre-set to get approx. 300mA drawn by the inverter, (subtract the filament current if you have the radio on). Now turn up the amplitude till the output voltage reads 80 to 90 volts on radio load. If a 'scope is connectd the waveform will be observed to be well squared as stated above.

In use, the unit as described was found to satisfy the original requirements, with little or no interference although it was built completely unscreened. The only action needed was to position the transformer/rectifier so as not to be directly under the frame aerial, otherwise some L.W. breakthrough was apparent. Also with the volume down, a quite room, and ear in L.S. some 150 Hz could be heard.

A design for a current operated switch for the 'Battery Synthesiser'.

This design is not recommended for the beginner, since the operation of the circuit is 'beyond' the parameters of the devices used. However at this stage it offers the only low consumption option and the experienced should be able to get it to operate satisfactorily, albeit with some component 'selection'.



The purpose of this circuit is to switch on the DC/DC converter when the on/off switch of the set is operated, with no modification of the set. Another requirement is that any extra power drawn from the 2 volt cell should be insignificant. The main element of the circuit is a sensitive latching relay RS part 346-722. This has a coil operating voltage of 3.75 to 16 volts, hence putting it outside of the 2 volts available. I could find no latching relay more sensitive, and a latching one is required because it only takes current in order to change state.

By using a bridge drive circuit for the relay, theoretically the available voltage should be doubled to 4 volts, enough to operate the relay. A hi-speed CMOS logic IC was chosen for the drive because of simplicity. The speed was of course not required, but this logic family can operate down to 2 volts! The part is a 74HC14 (Six inverters on a chip). The relay coil is placed across the 'bridge', a series capacitor providing voltage storage. This capacitor has to be of a high value, and reversible. A normal electrolytic is therefore not suitable, however a solid dielectric aluminium 'miniature dipped' type is not only cheap, but will withstand reverse polatity up to 30 per cent of rated voltage. Two 47 μF 6.3 volt caps were used in parallel, Mullard type 122-53479.

The current-sensing was done from across the heater supply dropper circuit. A general purpose silicon PNP transistor is switched by the change of volts that occur across this circuit when the set is switched on.

In operation this circuit was found to operate satisfactorily, but it must be remembered that the voltage available demands that the main drive element, namely the 74HC14, works perfectly. This, it does not and selection may be necessary. Operation is always better when the cell is fully charged; this could be considered an advantage since you will not be able to switch on a cell that is in need of a recharge!

N.B. Make sure the relay is in the correct position by switching ON and OFF several times, a latching relay may be initially in either position!