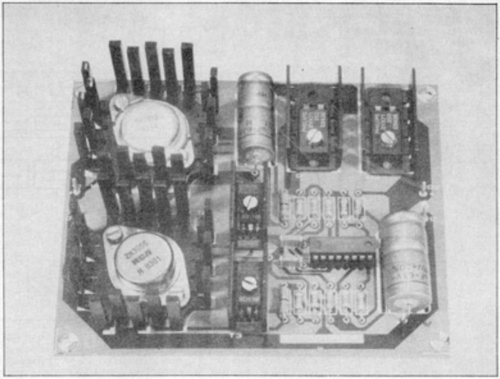


Mains-operated NiCd chargers are in plentiful supply, but a NiCd charger that operates from a car battery and enables fast charging is something special. The one described here can charge 9-, 12-, or 15-volt batteries.

DC OPERATED BATTERY CHARGER

Lowering the e.m.f. — electromotive force — of a car battery is easily done with the aid of a resistor, zener diode, or voltage regulator, but raising it is rather more difficult. The method chosen here is the familiar one of voltage doubling. How this is done in this charger is illustrated in Fig. 1.

In Fig. 1a, switch S connects the negative terminal of electrolytic capacitor C_3 to earth, so that both C_3 and C_4 are charged to the (car battery) supply voltage U_b:

$$U_o = U_{C4} = U_{D2} + U_{C3} = U_{D2} + U_b - U_{D1} = U_b \qquad (1)$$

In Fig. 1b, switch S connects the negative terminal of C_3 to U_b, so that the output voltage, U_o, becomes:

$$U_o = U_{C4} = U_b + U_{C3} - U_{D2} = 2U_b - U_{D2} \qquad (2)$$

When the switch is returned to earth as in 1a, the potential across C_4 remains at U_b, because C_3 cannot discharge. It is clear from this that U_o ($= U_{C4}$) will alternate between U_b and $2U_b - U_{D2}$. If the switching speed is high enough, the output voltage will approach $2U_b - U_{D2}$.

Circuit description

In practice, the switching is carried out by a Darlington pair of transistors: T_1-T_2 and T_3-T_4 in Fig. 2. These transistors are controlled by an integrated circuit Type LM3524. Two of its features make this device particularly suitable for the present application: the push-pull output stage, which can drive the switching transistors, and the error amplifier.

The error amplifier controls the width of the pulses at the input of the push-pull driver stage on the basis of the error signal at the output of the charger. The larger the deviation of the output current from the wanted value, the shorter the switch-on time of the power transistors carrying the output current.

The voltage doubling circuit consists

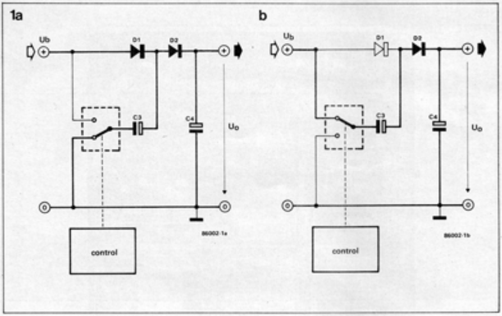


Fig. 1. In a, both C_3 and C_4 are charged to U_b minus the small drop across the relevant diode; in b, the output voltage is the sum of the voltages across C_3 and C_4 minus the drop across D_2. The switch is controlled by an oscillator, modulator, and regulator.

of capacitors C_3 and C_4 and diodes D_1 and D_2. These diodes are fast recovery power types in a TO-220 case, which is readily mounted onto a heat sink.

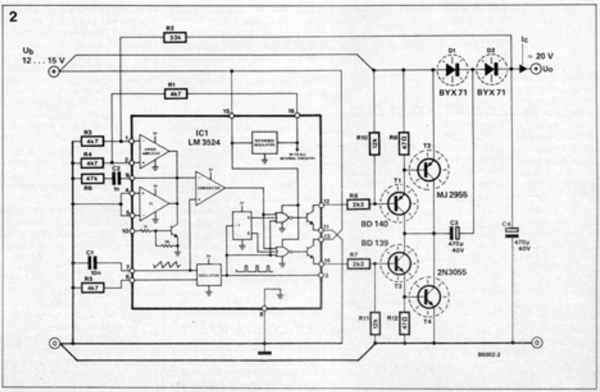
An oscillator in the LM3524 generates a rectangular signal for the T-type bistable and the two NOR gates, and a sawtooth signal that is applied to the non-inverting input of a comparator. The frequency, f_0, of the oscillator is

$$f_0 = 1/2\pi R_5C_1 = 1/295\times10^{-6} = 3400 \text{ Hz.}$$

A reference voltage of 2.5 V is provided by divider R_1-R_4 and applied to the non-inverting input of the error amplifier. The inverting input of this stage is provided with information as to the level of the output voltage via divider R_2-R_3.

The comparator here functions as a pulse-width modulator. Depending on the level of the error signal at its inverting input, and the level of the triangular signal at its non-inverting input, the comparator produces a rectangular signal with varying pulse-width at its output. This output constitutes the real control signal for the power transistors. To ensure synchronicity and a 180° phase shift, the comparator output is applied to the bases of the drive transistors via two NOR gates. Pulse-width control has the advantage that the average

Fig. 2. The circuit of the battery charger consists essentially of the control, which is contained in one Type LM3524 integrated circuit, power switching transistors T_1 to T_4 and the voltage doubler comprising D_1, D_2, C_3 and C_4.



Parts list

Resistors:

$R_1;R_3;R_4;R_5$ = 4k7
R_2 = 33k
R_6 = 47k
$R_7;R_8$ = 2k2
$R_9;R_{12}$ = 47 Ω
$R_{10};R_{11}$ = 12k

Capacitors:

C_1 = 10n
C_2 = 1n
$C_3;C_4$ = 470μ;40V
(axial types)

Semiconductors:

$D_1;D_2$ = BYX71
T_1 = BD140
T_2 = MJ2955
T_3 = BD139
T_4 = 2N3055
IC_1 = LM3524

Miscellaneous:

2 twisted vane TO220 heat sinks
2 twisted vane TO126 heat sinks
2 TO3 style heat sinks
PCB 86002

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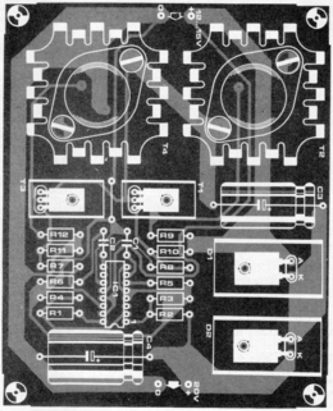

Fig. 3. The whole of the battery charger, down to the heat sinks, is contained on this printed circuit board.

load current remains substantially constant.

The current limiter — CL — in the LM3524 is not used in this application.

Construction and test

All components, as well as the heat sinks of the switching transistors, T_1 to T_4, and the power diodes, D_1 and D_2, are fitted on the printed circuit board shown in Fig. 3. If the board is fitted in a case, there should be sufficient space above electrolytic capacitors C_3 and C_4 to ensure good ventilation.

Once the board has been completed, the open-circuit output voltage should be measured. This should be somewhat higher than 20 V. Note that a perfect voltage doubling, i.e. from 12 V to 24 V, is not possible because of the saturation voltage of power switching transistors T_2 and T_4 and the forward drop across the power diodes.

Next, the behaviour of the circuit under load should be checked with reference to Fig. 4. Our laboratory prototype has an open-circuit output voltage of 20.2 V. Under normal load conditions, the output voltage remains substantially constant (±0.5 V) until the load current exceeds 3 A.

Fast charging

During fast charging, the charging current must, of course, be limited in accordance with the requirements of the cells or battery under charge. For example, NiCd cells are normally charged with a current, I_c, of 120 mA to 400 mA. If ten of these cells are charged in series, there will be a drop, U_d, of 15 V across them. A current limiting resistor, R_s, should then be used, whose value is calculated from

$$R_s = (U_o - U_d)/I_c = (20-15)/0.4 = 12.5\ [\Omega]$$

The power, P_s, dissipated in R_s is calculated from

$$P_s = I_c^2 R_s = 0.4^2 \times 12.5 = 2\ [\mathrm{W}]$$

Sintered-plate cells are normally rated at 1.2 Ah, and may be fast-charged with a current of 2.5 A for thirty minutes.

HS:GS

Fig. 4. The output current vs output voltage shows that the output voltage remains substantially constant for load currents up to 3 A.

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