Elektor staff are a versatile lot! The present design came into being because one of our designers is a fervent spelaeologist, more popularly known as a caver. Regularly he risks life and limb in all sorts of dark caves, only to emerge hours later into daylight, covered in mud, sweating, and dead-tired, but happy and content. A good, reliable light source is, of course, indispensable for those treks in the dark. Many of the caver's lamp units in use today are powered by rechargeable (lead-acid or NiCd) batteries. Such batteries are inexpensive over their life — provided they are used often and regularly — and provide a near-constant output voltage. Dry batteries are relatively inexpensive to buy, offer small volume and low weight, and can easily be carried as spares. The last three points are, of course, of inestimable value during caving and in many other applications! Unfortunately, dry batteries have a serious draw-back: their output voltage falls linearly with time, so that at the beginning of their life the lamp burns brightly, while long before they are exhausted, the lamp begins to resemble a glowworm! Not only is this highly undesirable from a safety point of view, but it also makes for low efficiency. Our versatile designer decided, therefore, to design a voltage source for battery-operated lamps which offers a substantially constant output at high efficiency.

constant voltage source . . .

. . . for battery operated lamps

The design is basically a dc/ac converter based on a cleverly thought-out circuit which keeps the power supplied to the lamp, and therefore the light intensity, virtually constant over the normal life of the battery. The circuit itself has very low power consumption so that the efficiency of the whole is high.

The principle

To control power at high efficiency, it is best to make use of pulse-width control. As the power supplied to the lamp must remain constant, the control should work so that the pulse width increases as the battery voltage decreases. To be sure, it is quite simple to design a pulse-width control whereby the pulse width is inversely proportional to the supply voltage. That is, however, not the solution to the requirement, because the power to the lamp is given by $P = U_b^2/R$, where U_b is the battery voltage and R is the resistance of the lamp. What is required is compensation of U_b^2, and this is achieved by using two pulse-width controls, operating at different frequencies, but with identical duty factors (see figure 1). One reference voltage determines the pulse-width setting of both controls (the pulse width remains inversely proportional to the battery voltage). The outputs of the controls are multiplied in an AND gate, resulting in a signal of which the pulse width is inversely proportional to U_b^2!

The circuit

The constant voltage source is based on one IC — a quad comparator type LM 339 — and a couple of transistors (see

1

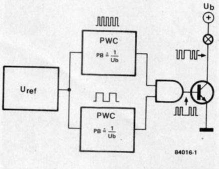

Figure 1. Simplified block schematic to show the ingenuity of the voltage source: two pulse-width controls together with a multiplier ensure that the power fed to the lamp is kept constant.

2

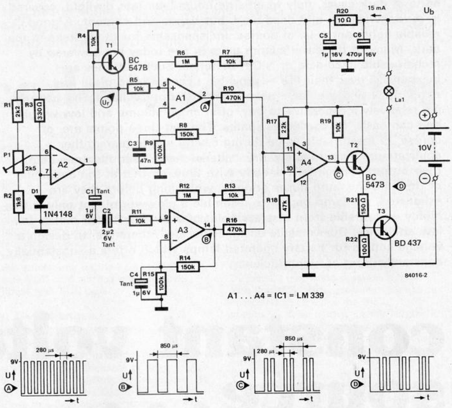

Figure 2. The circuit diagram: a voltage quad comparator with open-collector outputs and three discrete transistors are the active components on which the voltage source is based.

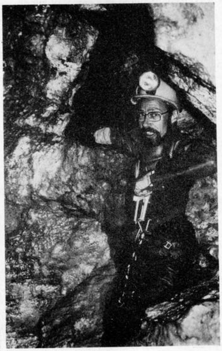

figure 2). One stage of the LM 339, A2, in conjunction with transistor T1, forms a voltage reference source for pulse-width controls A1 and A3. The voltage source is formed by diode D1 to which the output of T1 is applied via R3. The reference voltage is set by P1. For a supply voltage, U_b, of 10 volts, the reference voltage, U_r, can be preset between 1.0 and 3.0 V by P1.

The two pulse-width controls (PWCs) operate at frequencies of about 1.2 kHz and 3.6 kHz respectively. The frequency separation is necessary to prevent (visible) interference between their output signals. The outputs of A1 and A3 are fed to the non-inverting input of A4 via R10 and R16. Opamp A4 is connected as an AND gate so that its output is only '1' if both A1 and A3 have a '1' at their output.

The circuit terminates in an economical output amplifier based on transistors T2 and T3. Power transistor T3 is a type BD 437 which has a low collector/emitter saturation voltage.

With values shown in figure 2, the constant-voltage source is suitable for lamps of 3.5 . . . 6.3 V consuming not more than 1 A. A graph of the efficiency, η, of various

Some arithmetic

In the following,
U_b = battery voltage
U_e = effective value of pulse voltage
D = duty factor of BOTH pulse-width controls
P = power supplied to lamp
R = resistance of lamp

The duty factor, D, is inversely proportional to U_b

Each PWC delivers a (pulse) voltage of which
$U_e = U_b\sqrt{D}$

Multiplier A4, an AND gate which only recognizes logic levels, multiplies pulse-widths but NOT voltages: its output is, therefore
$U = U_b\sqrt{D}\sqrt{D} = U_bD$

The power supplied to the lamp is therefore
$P = U_b^2D^2/R$

As both U_b and D are expressed as second-order quantities which are inversely proportional, and R is constant, it is evident that P is independent of U_b.

3

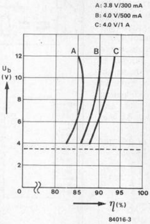

Figure 3. Characteristics showing the efficiency of three different lamps versus the battery voltage: the efficiency rises with larger lamp currents.

lamps versus U_b is given in figure 3. The circuit is suitable for use with input voltages, U_b, of 3.5. . .15 V. The average current consumed is about 15 mA.

Calibration

Calibrating the voltage source is fairly simple. Connect a suitable lamp to the lamp terminals and a variable, stabilized power supply to the battery terminals. Set the output of the power supply to the nominal voltage of the lamp used. Connect an oscilloscope to pin 2 of IC1 and adjust P1 until A1 just commences to oscillate.

If no instruments other than a multimeter are available, the voltage source may be calibrated as follows. Connect a suitable lamp to the lamp terminals, and the multimeter (resistance range) between pin 6 of IC1 and the junction of P1-R1. Adjust P1 for minimum resistance. Remove the multimeter and connect a suitable battery to the battery terminals. Adjust P1 for good brightness of the lamp.