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Constructional Project

WIND-UP TORCH



THOMAS SCARBOROUGH

An occasional twist of a knob provides light without battery power.

A COMMON problem with small torches is the short life-span both of the batteries and the bulb. The batteries of a small "penlite" torch will commonly last only two to three hours, and many bulb filaments burn no more than a few weeks before fusing. Besides this, torch batteries can sometimes be hard to come by, especially when camping or visiting remote areas.

The idea for a better torch was born a few years ago when the author was caught in a violent tropical storm on a remote dirt track, and his penlite torch rapidly faded and died.

LIGHTING THE WAY

With new light emitting diode (I.e.d.) technology, it is now possible to build a torch that quite adequately lights the way five to ten metres in front. In fact, since power consumption is so small, it is possible to power the light for a considerable length of time from a few turns of a small generator with a capacitor "reservoir" – the sole source of power for this torch (no batteries).

In addition to this, the white I.e.d. used in the circuit has a life expectancy of years, not weeks as in the case of a standard filament bulb.

While the light output of the Wind-up Torch is modest in comparison with some modern torches, it matches several

candlepower at medium power, and is thus quite serviceable. It will provide ample light around a camp table, for walking on a foot-path, or for reading.

The light output of the torch is continuously variable, and its expected service from each full wind is as follows:

- Book-light 90 minutes
- Medium-power beam 40 minutes
- Beam for walking 15 minutes

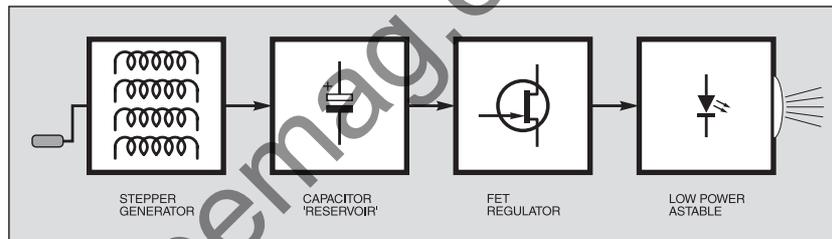


Fig. 1. Schematic block diagram for the Wind-up Torch.

TORCH OPERATION

The block diagram of the Wind-up Torch is given in Fig. 1.

Power is provided by a generator based on a stepper motor. A stepper motor was chosen for two reasons: such motors produce a good a.c. voltage at fairly low revs, thus obviating the need for complicated gearing. Also, since the demise of floppy disk drives, these motors are

readily and cheaply obtainable second-hand or as surplus goods.

The a.c. voltage from the stepper motor is full-wave rectified, regulated, and fed into a two Farad (2F) reservoir capacitor. Since a capacitor's characteristics are very different to those of an ordinary power supply, a special regulator is required between the reservoir and the I.e.d.

Unlike a battery, which gradually discharges, a capacitor releases a surge of power, which becomes a weaker and more steady flow with time. This may be likened to a breach in a dam wall: an initial surge of water becomes, after a while, a weaker and more steady stream.

The regulator is based on a field effect transistor (f.e.t.), which draws just a few microamps, and provides a very steady voltage from the falling voltage of the reservoir capacitor.

The final stage incorporates a very low power astable circuit, which pulses the white I.e.d. so as to conserve power. A compromise was sought that reduces power consumption to a minimum, while not reducing light level too noticeably, or causing any visual disturbance through the pulsed light. By pulsing the light, power consumption is greatly reduced, and torch-light extended more than ten times.

GENERATOR

A wide range of 12V stepper motors may be used for the generator and they come in various shapes and sizes. If they are purchased new, they can be costly. However, if an old floppy disk drive (working or non-working) is purchased and the stepper motor removed, the cost may be reduced considerably.

It is unlikely that a floppy disk drive has failed due to stepper motor failure, so even if a motor has been removed from a non-working drive, it is still likely to be sound. The stepper motor in the circuit was removed from an old 5-25-inch floppy disk drive.



More often than not, the four windings of a stepper motor are commoned, with the common (+VE) lead coloured red. It is easy to test with a multimeter which is the common lead. Measure the resistances across every combination of leads – if the resistances from one lead to all the rest are less than every other resistance measured, this is the common lead. If, on the other hand, some combinations of leads indicate open circuit, the motor's windings are likely to be separate.

The voltage produced by both types of motor is a.c., which needs to be converted to d.c., using full-wave rectification, as shown in Fig.2.

The circuit in Fig.2a illustrates how the four windings of a stepper motor are wired if it has commoned leads. Fig.2b shows the circuit if the motor has separate windings.

Since commoned windings are by far the most usual arrangement with stepper motors, the component layout of the Wind-up Torch (Fig.4 later) is designed specifically for such motors.

MAIN CIRCUIT DIAGRAM

The main circuit diagram for the Wind-up Torch is shown in Fig.3.

The rectified d.c. output from the stepper motor circuit is fed into capacitor C1, which serves to smooth the fluctuating output of the generator.

From C1, the voltage is fed via rectifier diode D1, which prevents reverse leakage of current, into two 1F (one Farad) reservoir capacitors, C2 and C3. These are "memory retention" (back-up) types and need to be treated with care, since they are both pricy and easily damaged.

The rectified d.c. voltage from the stepper motor will vary considerably, depending on its type and the speed at which it is turned. Since the maximum voltage rating of C2 and C3 is 5.5V, a 5.1V Zener diode regulator (D2) is incorporated into the supply line following diode D1. The Zener used has a 5W rating, although a 1.3W type was tested thoroughly without failure. Charge current is around 15mA on a moderate wind.

CIRCUIT OPERATION

The main regulator section of the circuit is based on f.e.t. TR2. This holds a very steady voltage as the reservoir voltage falls, and will likely show a marginal rise in voltage for some time.

When the Wind-up Torch is adjusted for use as a book-light (3V), it maintains over 95 per cent of voltage for about 90 minutes. At the highest brightness setting (3.6V), it maintains over 95 per cent of voltage for 15 minutes. The regulator was tested up to 5V without failure of the l.e.d. – however, this is not advised, and the circuit disallows it.

Originally, a simple resistor was tried as a regulator between the reservoir capacitor and astable IC1. This limited current consumption and was found to double the life of the reservoir voltage. Assume, however, that the resistance could be automatically reduced as capacitor voltage falls – this would further extend the reservoir's life.

In fact, by substituting a f.e.t. (TR2) for the resistor, and controlling its conductance, the circuit used here outperforms the simple "resistor regulator" by a factor of 10. Total power consumption of the regulator is just 15µA.

A f.e.t. was chosen for the task since, unlike a bipolar transistor which is current controlled, it is voltage (or field effect) controlled, and draws a minute current – a very necessary feature of this application. A negative voltage applied to the gate of the f.e.t. creates a field effect, and "pinches off" current travelling from drain to source – while a positive voltage at the gate increases conductance.

Bipolar transistor TR1, potentiometer VR1 and resistor R4 form a voltage divider which determines the conductance of the f.e.t. As the voltage (and therefore current) declines across capacitors C2 and C3, so TR1 becomes less conductive, the potential at its collector rises, and TR2's conductance increases. Therefore TR2

provides a very steady supply to IC1 and l.e.d. D3.

Note that transistor TR1 has an "A" suffix. This is important, and refers to the low gain of the transistor. Equivalents should be chosen carefully. The considerably larger BD241C may be used as a replacement, if transistors R1 and R2 are paralleled in the R1 position, and a link wire is substituted in the R2 position on the circuit board.

The purpose of capacitor C4 is to maintain a steady power supply for astable IC1, reducing peak current passing through TR2, which has a maximum rating of about 20mA.

The astable circuit is very straightforward, being based on an ICM7555IP timer, IC1. The importance of using this particular device is that it has a supply

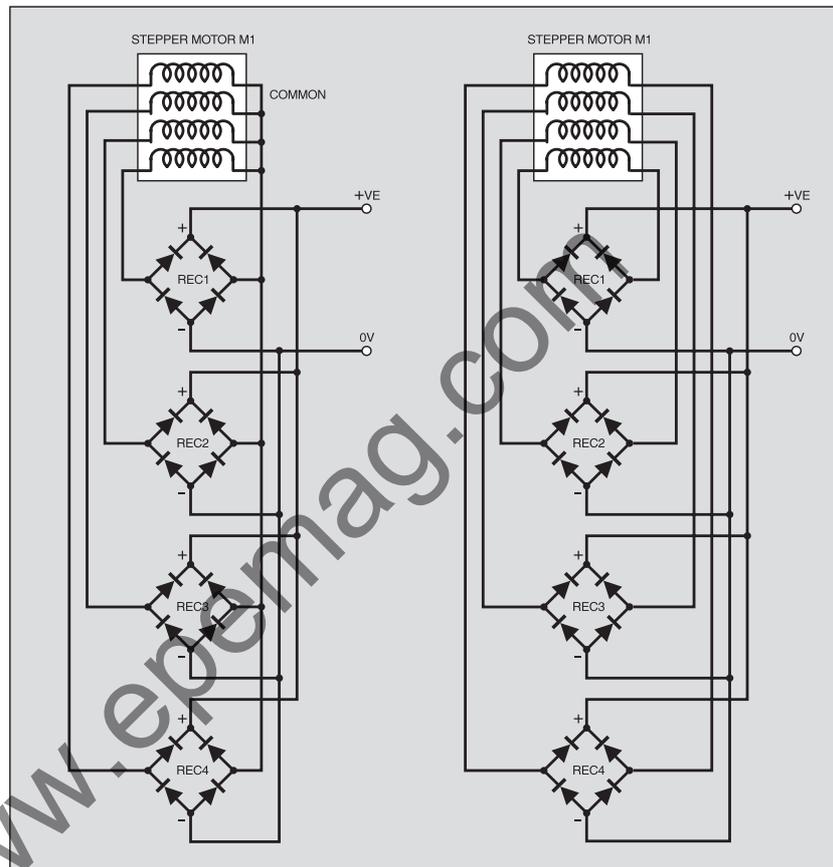


Fig.2. Bridge rectifying the stepper motor windings, (a) if the stepper motor has four common windings, and (b) if the motor has separate windings.

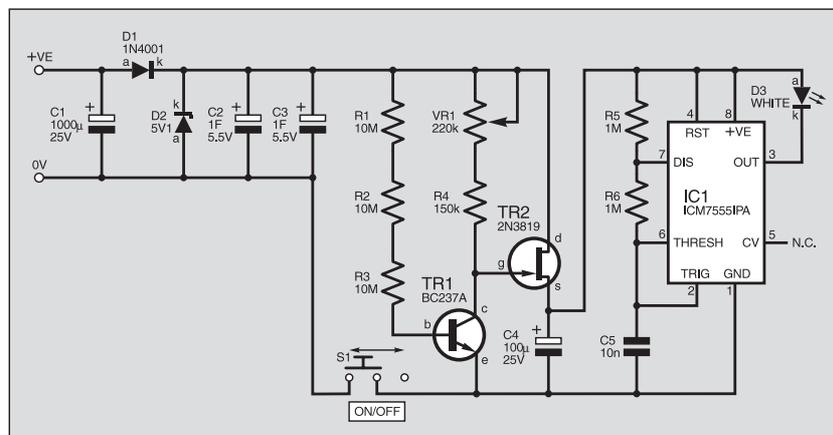


Fig.3. Main regulator circuit diagram for the Wind-up Torch. Power input terminals marked +VE and 0V are joined to one of the identical output points on the stepper motor diagrams in Fig.2.

current of just $60\mu\text{A}$, and will operate effectively down to 2V. It also has an output sink current of 100mA, which is more than adequate for the present application. A standard 555 timer should not be used, due to its vastly greater current consumption.

High values have been chosen for resistors R5 and R6, so as to keep power consumption to a minimum.

The timer (IC1) is used in oscillator mode and outputs a square wave at pin 3, the peak amplitude being the same as the voltage powering the i.c. This output drives l.e.d. D3, pulsing it on for the duration that the output is low. A ballast resistor is not required for the l.e.d. since the effective current flow is limited by the control circuit.

The high brightness white l.e.d. used is the product of recent advances in semiconductor technology, having been commercially available for about two years. It has a 400mcd output, which, when focussed, gives a beam of several candlepower. If focussed into a tight beam with a quality lens, it will light up objects at a distance of about 30 metres.

If a white l.e.d. is unobtainable, a high brightness coloured l.e.d. may be used in its place, although their light is not as effective, or as pleasing to the eye.

CONSTRUCTION

The Wind-up Torch circuit is built on a piece of stripboard having 15 holes by 24 copper strips. Details of the topside component layout, together with the underside details, are shown in Fig.4.

Commence construction by cutting a standard piece of stripboard down to size using a hacksaw. A small indentation may be cut in the stripboard at positions O15-P16 to pass wires if desired. Create the breaks in the underside of the stripboard with a drill or other appropriate tool.

Space is at a premium, but all the components should fit into place without difficulty, provided you use a miniature plate ceramic capacitor for C5, miniature radial capacitors for C1 and C4, and the specified bridge rectifiers.

Solder the wire links and solder pins (double-ended pins serve best), then the 8-pin dual-in-line socket. Continue with the resistors, diodes D1 and D2, and the four rectifiers (one for each motor winding), followed by the capacitors and transistors. Be careful to observe the correct polarity of the bridge rectifiers, transistors, diodes and electrolytic capacitors.

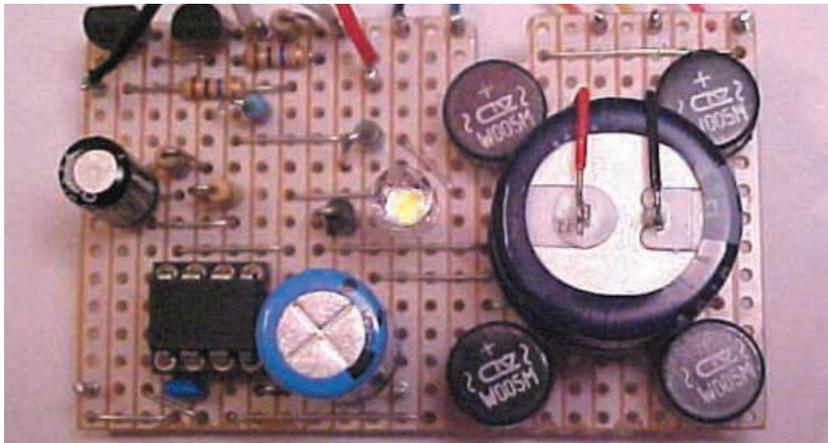
Solder in l.e.d. D3, leaving it with long legs for later adjustment, and be sure to orientate it parallel with the board for the best optical results.

Capacitor C3 is piggy-backed on top of C2 to conserve space. Additional memory retention capacitors could be used to extend torch life, but this would make winding more time-consuming.

Prepare four sheathed wires 10cm long, and solder them to potentiometer VR1 and switch S1, and then back to the stripboard. Finally, attach the stepper motor leads to the solder pins, and insert IC1, observing its correct orientation.

CASING

The Wind-Up Torch is built into a plastic case with slotted walls, but more



Complete prototype circuit board. Reservoir capacitors C2 and C3 are mounted one on top of the other. This construction differs slightly from the final version.

adventurous constructors might wish to choose a case of their own preferred shape and size.

In order to keep construction as simple as possible, the generator is operated simply by turning a small knob, attached to the motor spindle, between index finger and thumb (a larger knob necessitates movement of the wrist, and is not as convenient).

COMPONENTS

Resistors		See SHOP TALK page
R1 to R3	10M (3 off)	
R4	150k	
R5, R6	1M (2 off)	
All 0.25W 5% carbon film		
Potentiometer		
VR1	220k rotary carbon, lin	
Capacitors		
C1	1000 μ radial elect, 25V	
C2, C3	1F, memory retention, 5.5V (2 off)	
C4	100 μ radial elect, 16V	
C5	10n resin dipped plate ceramic	
Semiconductors		
D1	1N4001 rectifier diode	
D2	5V1 Zener diode, 5W	
D3	white l.e.d., 400mcd	
REC1 to REC4	W005 50V 1.5A bridge rectifier (4 off)	
TR1	BC237A npn transistor (see text)	
TR2	2N3819 n-channel f.e.t.	
IC1	ICM7555IPA low power timer	
Miscellaneous		
M1	12V four-phase stepper motor (see text)	
S1	s.p.s.t. (or d.p.d.t.) sub-min. slide switch	

Lens (see text); plastic case, 104mm x 54mm x 42mm (see text), small knobs with fixing nuts (2 off); stripboard, 0.1in, 15 holes by 24 strips; 8-pin d.i.l. socket; solder pins, double-sided; solder, etc.

Approx. Cost
Guidance Only
£18
 excluding motor and lens

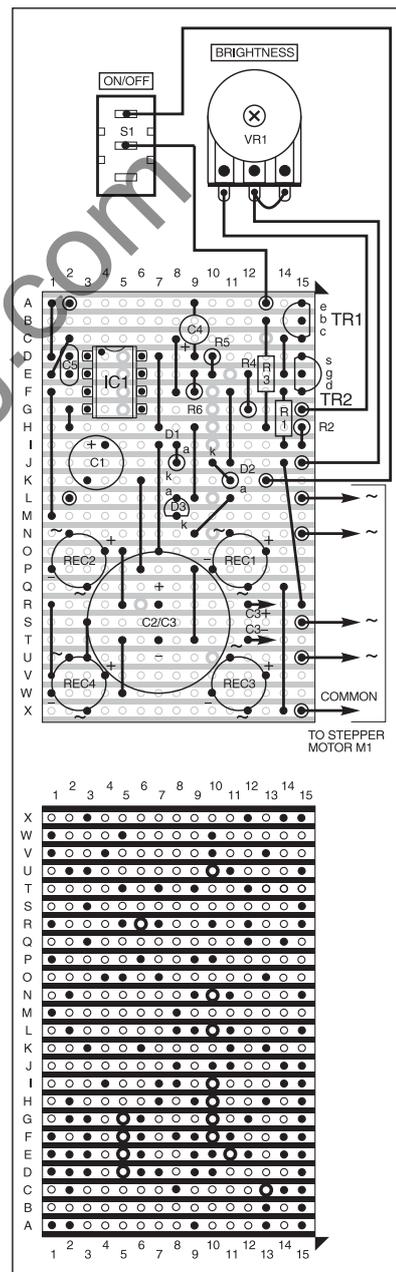


Fig.4. Wind-up Torch stripboard component layout, interwiring and details of breaks required in the underside copper tracks.

The knob should have a fixing nut to prevent any slippage. A regular stepper motor will easily produce sufficient charge in this way – more ambitious constructors could construct a crank handle with the help of a brazing iron or Meccano parts.

The motor is housed at one far end of the case, with its shaft pointing face downwards, and protruding through a hole in the case. If the motor has a mounting bracket, this may be used to brace it. Or, particularly if it is square in shape, it may be wedged into place with wooden wedges on each side, and glued into position.

If a stepper motor has been salvaged from a floppy disk drive, it is likely to have a large, bulbous head. In such an instance, the head may be removed fairly easily with a hacksaw, or a knob may be mounted over the head.

Holes are prepared in one of the narrow sides of the case to receive slider switch S1 and potentiometer VR1 (mounting on the flat side of the case may interfere with the light beam). A large hole is prepared for the lens at the opposite end to the motor. S1 is a slide switch, so as to prevent accidental switching when packed into a suitcase or rucksack. Prepare the holes for S1 and VR1 after having established the position of the lens or lenses.

LENS

The light of the white l.e.d. is fairly diffuse, and needs to be focussed into a beam. In order to focus it, a convex lens with short focal length (a short focussing distance) is required. A focal length of 30mm to 60mm is ideal. At any rate, the focal length should not exceed the available space in the case.

The lens diameter should also be large enough to catch sufficient light from the l.e.d., otherwise the torch's brightness will be compromised. Lenses may also be twinned in order to shorten the focal length. It may be necessary to crop the sides of a larger lens to fit it into the case. Lenses may be glued to a "slide" and slotted into the case, or may be glued at their edges to the inside of the case.

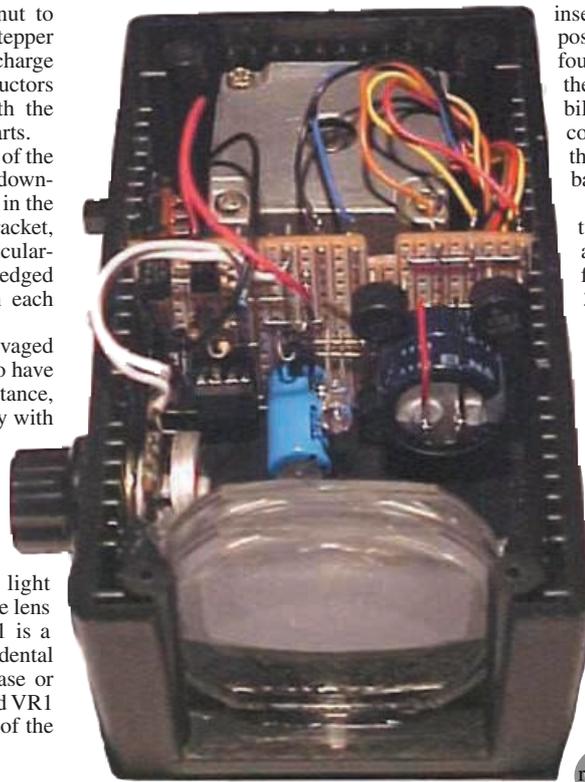
If ordered from a specialist supplier, lenses can be pricy. However, the author found adequate plastic lenses in a nearby toy shop. Those employed in this design were taken from two cheap "bug viewers" and twinned. Suitable lenses may also be found at fetes or in junk shops.

Once the motor and the lens have been installed, and holes for S1 and VR1 prepared, the circuit board is inserted into a slot inside the case. It may be secured with dabs of general purpose glue.

IN FOCUS

You will need to establish the correct distance from the circuit board to the lens, so as to obtain a beam of ideal width. It was found that if the torch's beam was too narrow, it was of little use in illuminating a page, or the full width of a path. A good compromise may be found as follows:

Aim the torch at a white wall, from a distance of about two metres. Adjust the distance between the circuit board and lens so as to find the most compact spot of light on the wall. Then shift the lens closer to the circuit board, until the diameter of the beam is about 50cm on the wall. It may



Close-up view of the "beam window" showing the lenses slotted into p.c.b. retaining guide slots. The circuit board is positioned further back in the slots, see photograph below.

even be necessary to adjust the position of the l.e.d. slightly on the circuit board.

The optical characteristics of the l.e.d. are such that banding (a bright circle of light) may occur at the perimeter of the beam. This may be cured by adding a strong, small convex lens (having a very short focal distance) directly in front of the l.e.d. to give an even distribution of light.

CALIBRATION

To check that the regulator is working correctly, measure the voltage across capacitor C4 (two solder pins have been

inserted on the circuit board for this purpose at positions A2 and L2). Wire up four AA batteries (6V) across C1 until the voltage at C4 seems to have stabilised. Do not leave the AA batteries connected for any length of time, since this places heavy demands both on the batteries and on Zener diode D2.

As Brightness control VR1 is turned through its full range, the voltage across capacitor C4 should vary from less than 3V to higher than 3-6V, but not higher than 4V. If the voltage rises above 4V, resistor R4 needs its value to be increased; if it does not rise above 3-6V, then R4 needs to be decreased. Differences in the tolerances of transistors TR1 and TR2 may in exceptional circumstances necessitate such modification.

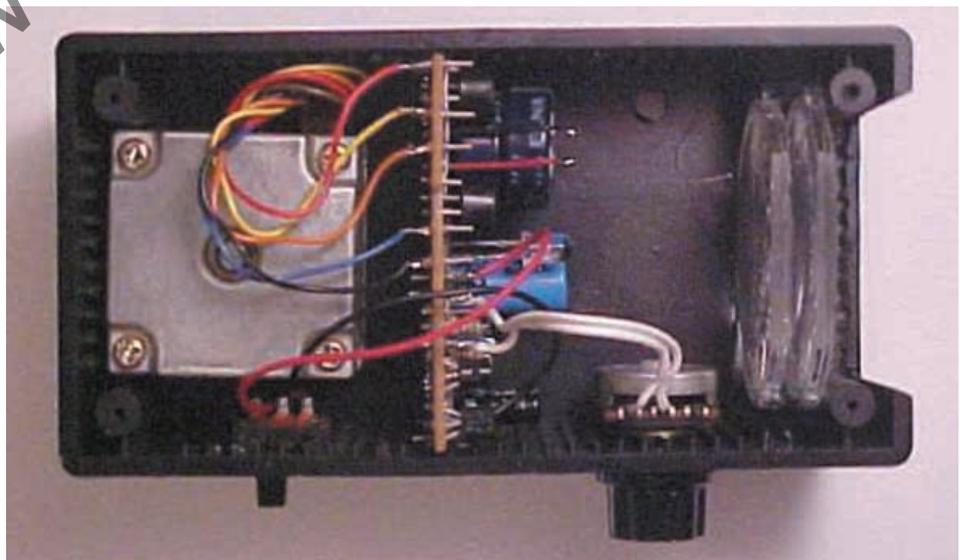
Mark off the 3V, 3.3V, and 3.6V settings on the outside of the case for reference.

IN USE

Set the Brightness control VR1 to 3V (book-light brightness). Turn the generator knob briskly between index finger and thumb (it may be turned in either direction).

Generally speaking, once a residual charge exists in the reservoir capacitors, a good wind of half a minute will fully charge the torch, and small "in between" charges will keep it going almost effortlessly. Note, however, that the very first time the Wind-up Torch is used, it may need up to five minutes to reach full charge, and one or two minutes of winding before the l.e.d. even illuminates. Do not despair – once a residual charge exists in the reservoir, subsequent charges will require only a fraction of the effort.

Assuming you begin with no charge at all in the reservoir capacitors, at first no light will be seen; then the light will pulsate in sync with your turning. Finally a steady light will shine. The Wind-up Torch will be fully charged a little while after a steady shine is observed.



General positioning of components inside the case. The Brightness control and On/Off switch are mounted on one of the narrow side panels.

JUMP START

Instead of such initial effort, the torch may also be "jump-started" by connecting four AA batteries (6V) across C1 until the l.e.d. begins to illuminate (as suggested for the calibration test). Then disconnect the batteries and continue winding. Be careful to observe the correct polarity. You may even wish to incorporate small batteries and a pushbutton switch into the design, attached to C1, to jump-start the torch after long periods of disuse.

The torch may also be wound up whilst it is switched off, then switched on at a later time. When switched off, it will hold its charge for a day before requiring recharging. If the torch's light has faded, and it is not likely to be used again immediately, switch it off so as not to lose what residual charge is in the capacitors.

Small adjustments of VR1 can mean large extensions of life, and vice versa. The torch's life shortens rapidly at higher light intensities, yet lengthens exponentially at dimmer settings. □

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Completed Wind-up Torch showing the small wind-up knob and l.e.d. lens beam window.

SHOP TALK

with David Barrington

PIC Dual-Chan Virtual Scope

Although using a PIC microcontroller does cut down on the component count, you would think that it is almost inevitable that with a project like this month's *PIC Dual-Chan Virtual Scope* that some of the components would appear to be a bit special and will cause local sourcing problems.

Not so! Nearly all the components used in the prototype model are RS types and readers should be able to order these through any *bona-fide* RS stockist in their area. Alternatively, they can be ordered through **Electromail** (☎ 01536 304555 or <http://rswww.com>), their mail order outlet.

Starting with the Maxim MAX492 dual, rail-to-rail, op.amp, this carries the RS order code of 182-2738. (Maxim can be found on the web at www.maxim-ic.com).

Regarding the Toshiba TC55257-85L 32Kbyte SRAM, of the several versions listed, either of the following will be OK for this circuit. The TC55257DPL-85L is listed as code 298-190 and the TC55257DPI-85L is coded 317-007.

The 20MHz version of the PIC16F877 is now quite plentiful and should be easy to obtain. However, for those readers unable to program their own PICs, a ready-programmed PIC16F877-20P can be purchased from **Magenta Electronics** (☎ 01283 565435 or www.magenta2000.co.uk) for the inclusive price of £10 (overseas readers add £1 for p&p). For those who wish to program their own PICs, the software is available from the Editorial offices on a 3.5in. PC-compatible disk, see *PCB Service* page. It is also available free via the *EPE* website: <ftp://ftp.epemag.wimborne.co.uk/pub/PICS/PICvscope>. The software is written in TASM.

The rest of the components are standard shelf items. If you wish to use the same RS case, this is listed as 267-2720. The printed circuit board is available from the *EPE PCB Service*, code 275 (see page 788).

Wind-up Torch

The first item we would like to cover concerning parts for the *Wind-up Torch* project is the 12V stepper motor. Some good news here, one which closely resembles the one used in the prototype is currently being advertised by **Magenta** (☎ 01283 565435 or www.magenta2000.co.uk), order code MD38. Also, we understand that a Philips 12V mini stepper motor advertised recently by **J&N Factors** (☎ 01444 881965) is still available and is a "bargain" at just £2 each; quote order ref. 2P457. These two motors have not been tried in the model.

Note that the BC237 transistor must be the one with an "A" suffix. This is important as it refers to the required low gain version. The only listing for the BC237A appears to be from **Cricklewood** (☎ 020 8452 0161, Fax 020 8208 1441). The author advises that the BD241C may be used as a replacement, but you will have to parallel resistors R1 and R2 in R1's position on the p.c.b. and add a link wire in R2's position.

The 1 Farad 5.5VW d.c. "memory back-up" capacitors are fairly expensive items and it might pay to shop around before buying, try **Greenweld**, **Bull Electrical**, **Cricklewood** and **J&N Factors** to name a few. The ones in the model came from **Maplin**, code JR01B and will set you back nearly £6 each plus p&p. They can also supply the following: plastic case (code YU52G) and the 5W Zener diode (code AY65V).

The high brightness "white light" l.e.d. used in the model also came from the last mentioned company and is the 5mm 400mcd version, code NR73Q. Although not tried, the author informs us a much brighter one has just been introduced in Germany (Conrad Elec., code 153745-11). This same company keeps focussing lenses for l.e.d.s, code 183621-11. Conrad's web site is at: www.conrad.de. However, you may still find that copying the author and extracting plastic lenses from toys is your cheapest approach here.

Fridge/Freezer Alarm

Only the temperature sensor chip is likely to be a problem when sourcing parts for the *Fridge/Freezer Alarm*, this month's "Top Tenner" project.

The TelCom TC622 single trip-point temperature sensor comes in two versions: the TC622VAT has a temperature range of -40°C to +125°C, with a claimed precision of ±1°C; and the slightly cheaper TC622EAT which has a range of -40°C to +85°C, with the same precision. Both types are suitable for this project and can be purchased from **Maplin** (☎ 0870 264 6000 or www.maplin.co.uk), code NU41U (TC622EAT) and NU42V (TC622VAT).

The latest news we have concerning the sensors is that stocks are running at around 150 pieces of the TC622EAT and about 300 of the TC622VAT. We understand that once stocks are exhausted they will not be replaced.

The *n*-channel power MOSFET device should be readily available, but if any readers do have trouble finding the VN10KM MOSFET it is currently listed by **Electromail** (☎ 01536 304555 or <http://rswww.com>) code 655-537 and **Maplin**, code QQ27E.

Most of our component advertisers will be able to suggest a suitable 6V or 12V solid-state buzzer for this project. The prototype used the **Maplin** 6V round buzzer, code FK81C. If you opt for a higher supply voltage, try the 12V version, code FK82D.

EPE Moodloop Field Strength Indicator

Some readers may experience difficulty in purchasing the AD8532 dual op.amp called for in the *EPE Moodloop Field Strength Indicator* project. This is intended for low voltage operation and has rail-to-rail outputs, ideal for this application. The one in the model came from **Maplin** (☎ 0870 264 6000 or www.maplin.co.uk), code OA16S.

Although the author states that the linear Hall Effect device is inexpensive and widely available, we have not found it so. The only listing for the type UGN3503U we came across was from the above company, code GX09K.

The LP2950 micropower 5V regulator was chosen as it is claimed to be better suited to battery operation than the standard 78L05 voltage regulator, has a smaller quiescent current and can operate with an input to output voltage difference of just 100mV. The LP2950 regulator also came from the above source, code AV35Q, but most of our components advertisers should be able to help regarding the 10-l.e.d. bargraph and the small hand-held case, with battery compartment. Remember, it is the bargraph with individual l.e.d.s that is required. **Maplin** supplied the bargraph (code BY65V) and case (type HH2-code ZB16S) used in the prototype.

PLEASE TAKE NOTE
Remote Control IR Decoder Sept '00
Source code (.ASM) files were added to the ftp site and *EPE*
Disk 3 on 12 Aug '00.