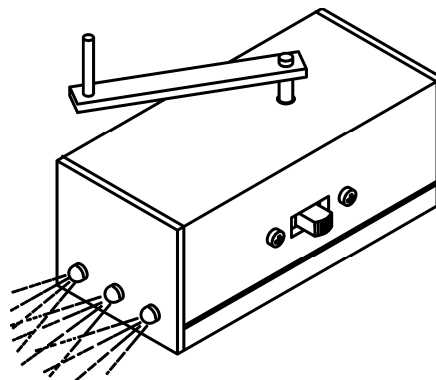


# WIND-UP TORCH

## DESCRIPTION

The *WIND-UP TORCH* provides light, using 3 super bright LEDs. The torch has a 3 stage gearbox connected to a small DC generator, which is turned by hand. The power provided by this generator is used to charge a small Lithium ion battery. The battery provides power for illumination, and a switch allows selection of low level lighting (a single LED) or a bright light (3 LEDs).

When discharged, the battery is recharged by turning the handle for approximately one minute.



The electronic components provided for the *WIND-UP TORCH* include a Printed Circuit Board, the circuitry components, the generator, gears and other components to construct the gearbox. To complete the project, the student is required to design and make the torch's housing and handle.

## INVESTIGATION

This project provides a number of different areas, which may be investigated. The most common areas to look at are DESIGN considerations, and TECHNICAL issues. Some ideas are listed below, to provide a starting point.

- How does a generator work? Is the DC generator the only type?
- Why was a 3 stage gearbox used? How does it work – what are the 3 stages?
- Was the use of a 3 stage gearbox the only way to achieve the charging? What other choices exist?
- Can the battery be charged faster? How? Can it be done safely (ie. without affecting the battery life)?
- Why were LEDs chosen over incandescent bulbs?
- ... and the list can go on, and on .....

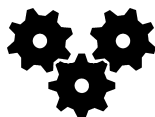
## 1. COMPONENTS REQUIRED

### 1.1 COMPONENTS SUPPLIED

The following parts are supplied in the kit:

1x	DC generator	2x	Gear Box Plates
1x	Printed Circuit Board (PCB)	1x	10 Tooth (M0.6) Pinion Gear
1x	100 $\mu$ F 25v Electrolytic Capacitor	1x	30 Tooth x10T (M0.6) Spur Gear
7x	1N4004 Diode	1x	40 Tooth x10T (M0.6) Spur Gear
3x	10 $\Omega$ Resistor (Brown, Black, Black, Gold)	1x	50 Tooth x10T (M0.6) Spur Gear
1x	470 $\Omega$ Resistor (Yellow, Violet, Brown, Gold)	1x	3.0mm x 50mm Steel Rod
1x	2SC8050 Transistor	4x	7 mm Brass Spacers
1x	4.3 Volt Zener Diode	2x	2mm Brass Spacers
3x	LED's - Clear Super Bright	3x	3mm I.D. Washer
1x	3.6V Battery (Lithium ion)	1x	4.5 mm I.D. Washer
1x	Battery Holder - Lithium Ion	8x	2.6mm x 12mm Self Tapping Screws
1x	Slide Switch - DPDT Centre Off (large)	2x	2.6mm x 5mm Self Tapping Screws
1x	3mm x 20mm Knurled Shaft	3x	3mm x 8 mm Bolt
1x	4mm x 33mm Knurled Shaft	1x	3mm Nut

Note: I.D. = Inner Diameter (for washers)



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Note: the gears used in this kit are 0.6 Module, and are NOT the same as used in other *SCORPIO* kits, or the other individual gears available.

## 1.2 ADDITIONAL REQUIREMENTS

The following also need to be procured: fine electrical wire and material for the other components (the torch's housing, handle and knob).

## 2. THE DESIGN

### 2.1 THE PROJECT STAGE

Before commencing work, the student should spend time planning the project. This should include a plan showing:

- the sequence of work to complete the project
- a timeline, showing anticipated completion dates for the various sections of work.
- What items need to be recorded for eventual evaluation or reporting about the project

### 2.2 THE PLANNING STAGE

The *WIND-UP TORCH* consists of a case, within which the various components are mounted. Before starting construction, the student needs to determine the case's shape and dimensions. This will allow the student to carefully plan and lay out all the components (mechanical, electrical and electronic) on a sheet of paper, looking at the torch as a complete unit, and not just as separate parts.

### 2.3 DESIGN CONSIDERATIONS:

#### 2.3.1 THE SUB-SYSTEMS

The *WIND-UP TORCH* consists of two sub-systems.

- The mechanical system is made up of a gear train containing 4 gears. At one end of the gear train is the handle. Turning it once causes the DC generator to turn 60 times, giving it a turns ratio of 60:1 (ie. 60 rpm).
- The electronic system consists of a bridge rectifier, a voltage regulator, a rechargeable battery and a switch (to select the intensity of the lights operation).

NOTE: The DC generator produces about 6 volts when connected to the electrical system.

#### 2.3.2 THE CASE

The case for the prototype torch was made from 50mm x 50mm cable duct. The ends were cut from 3mm PVC sheet and glued in position. The torch's case is functional, and the cable duct's clip-on lid enables easy access for construction purposes. The duct is available from "Electrical wholesalers" and the PVC sheet from "Plastics fabricators" – refer to the Yellow Pages phone book.

While functional, the case is not really aesthetically appealing. With a little thought and planning you should be able to design and make a much better looking and functional case.

## 3. ASSEMBLING THE GEARBOX AND GENERATOR

The gearbox consists of a number of gears, assembled between 2 plates. The generator is attached to one of these plates. Note: refer to the Exploded Gearbox diagram for the location of the components.

### 3.1 ASSEMBLING THE GEARBOX

The 2 gearbox plates each have 2 lots of 4 holes (all 2.3 mm diameter). The 4 holes (shown in the Exploded diagram with the screws going to them) are for holding the plates together, the other 4 are used to attach the gearbox to the torch's case.

#### 3.1.1 PREPARATION - DRILLING

3.1.1.1 Before starting assembly, you must enlarge the four holes that are used to hold the two plates together - on **one plate only**. These holes are to be enlarged using a 3 mm drill.

3.1.1.2 Use this (modified) plate to mark out and drill the 5 holes in the torch case. The holes required are 4 off 3mm holes for attaching the gearbox case to the torch case, and the 4.5mm hole for the generator's shaft.

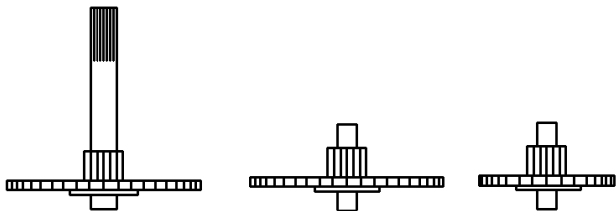
Note: The generator will be attached to the unmodified plate.

### 3.1.2 ASSEMBLING THE GEARS

- Cut two 12mm lengths from the 3mm rod, and de-burr the ends.
- Tap the rods into the 30 and 40 tooth gears. The rod must be tapped through the gear, so that equal lengths of the rod protrude from each side of the gear.

Hint: This can be done by supporting the gears on a vice (with the jaws open about 3mm) or on a piece of wood with a 3mm diameter hole drilled into it.

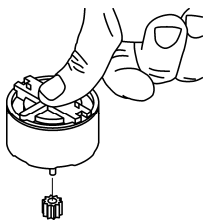
- Place the 50 tooth gear with the small gear facing up. Position the 4mm knurled shaft's end (where the knurling starts about 4mm from the end), into the gear's hole. Tap the shaft into the gear, until the bare end of the shaft protrudes about 3mm past the other side of the gear.



*Gear and Shaft assemblies*

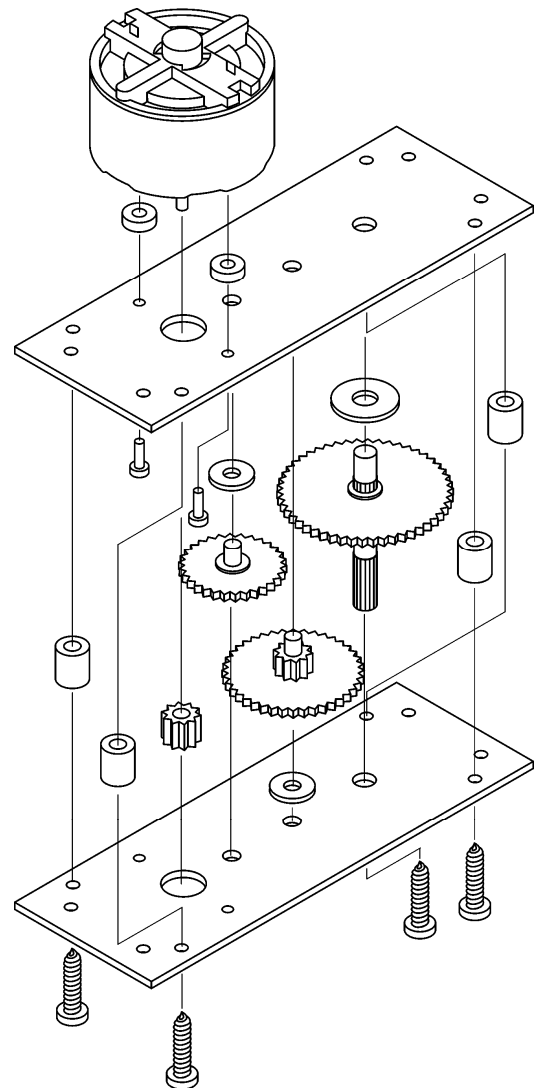
### 3.1.3 THE GENERATOR

- Press the 10 tooth pinion gear onto the generator's shaft



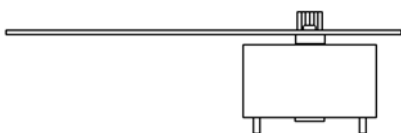
Hint: Put the 10 tooth pinion gear on the bench, place your thumb on the middle of the generator (as shown), push the shaft into the pinion gear until the shaft hits the benchtop.

- Fit the 2mm spacers between the generator and the top gear plate. Use 2 off 2.6mm x 5mm screws to attach the generator to the (unmodified) gear plate – finger tight at this stage.



*Gearbox Exploded view*

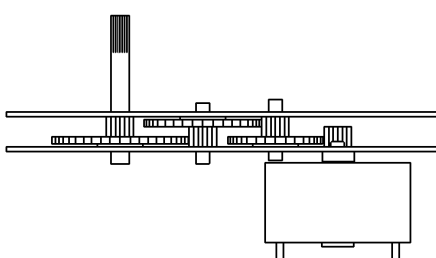
### 3.1.4 ASSEMBLING THE GEARBOX



*Generator to plate*

To assemble the gear box, begin by holding the steel plate with the generator attached, with the generator underneath. Assemble the gears as per the Exploded view, ensuring washers are in the indicated places.

- After the 30 tooth gear and its washer are assembled to the plate, check that the generator's pinion gear meshes snugly with the 30 tooth gear. When working satisfactorily, tighten the 2 screws holding the generator to the plate.
- Now the 40 tooth gear (with the washer on top) and 50 tooth gear and its washer (below) can be assembled to the gearbox plate.



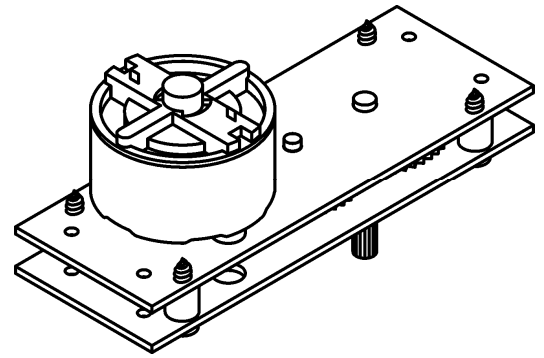
To install the second plate on top:

- Begin by placing the 4mm knurled shaft into the 4mm hole. Note: The knurled section of the shaft is a tight fit - press the plate firmly and it will slide past the knurling.
- Carefully align the other two 3mm shafts with the remaining holes.

Slide the plate down onto the gears.

Hint: Use a piece of sticky tape around the centre of the plates to hold them together temporarily.

- Place the four 7mm spacers between the plates and in line with the holes for the 12mm screws.
- Insert 4 of the 2.6mm x12mm screws through the holes you enlarged in the plate. Press down firmly with the screw driver. With enough pressure on the screw driver the screws will cut a thread into the other plate. Tighten the screws. Remove the sticky tape.
- A small spray of WD40 or similar lubricant will reduce the friction on the gearbox and allow it to turn more easily. In fact, until this is done, you may have difficulty turning the handle easily.



### 3.1.6 TESTING THE GENERATOR

The gearbox is now completed. The generator's power output should be tested before installing the gearbox into the torch's case (refer section 7).

## 4. OVERVIEW - HOW THE WIND-UP TORCH OPERATES

### THE ELECTRONIC SYSTEM:

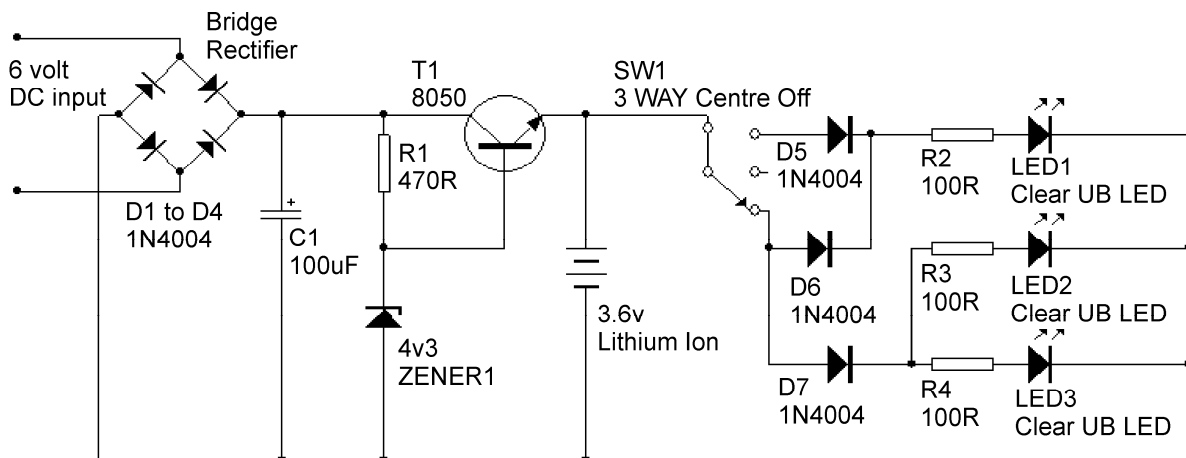
As mentioned in section 2.3.1, the electronics system of the torch contains a bridge rectifier, a series pass zener regulator, a 3.6 volt Lithium ion rechargeable battery and a switch (to select the operation of either a single ultra bright LED or three ultra bright LED's). When the handle of the torch is turned, the DC generator produces about 6 volts DC.

### THE BRIDGE RECTIFIER:

Bridge rectifiers are usually used to convert AC voltage to DC voltage. In this case, the generator produces a DC voltage. This allows the connection of the wires from the generator to the PCB in either direction. The bridge rectifier connects to the series regulator.

### THE SERIES REGULATOR:

The series regulator is made up of Transistor T1, Resistor R1 and a Zener Diode ZD1. The transistor is connected as a voltage follower. The zener diode fixes the base of the transistor to 4.3 volts. This causes the transistor's emitter to be about 0.7 volts less than the zener diode's voltage.



### THE BATTERY:

The transistor's voltage is 3.6 volts, and it is connected to the rechargeable battery. Each time the handle is turned, the battery is charged up. Note: the more the handle is turned, the more the battery is charged.

Note: The centre off slide switch is used to select either one or three ultra bright LED's. Using one LED gives less light and the battery lasts longer between charging.

## 5. CONSTRUCTING THE PRINTED CIRCUIT BOARD (PCB)

SUGGESTION: If you are experienced at assembly, testing and fault finding PCB's, you may wish to assemble all the components according to the PCB overlay. However, the following information is worth reading, regardless of your experience.

### 5.1 GENERAL INFORMATION

- The location of the components is as printed on the PCB.. The copper tracks are on the underside of the PCB. The outline of the tracks is visible through the PCB - these will act as a guide, to help locate the components onto the PCB.

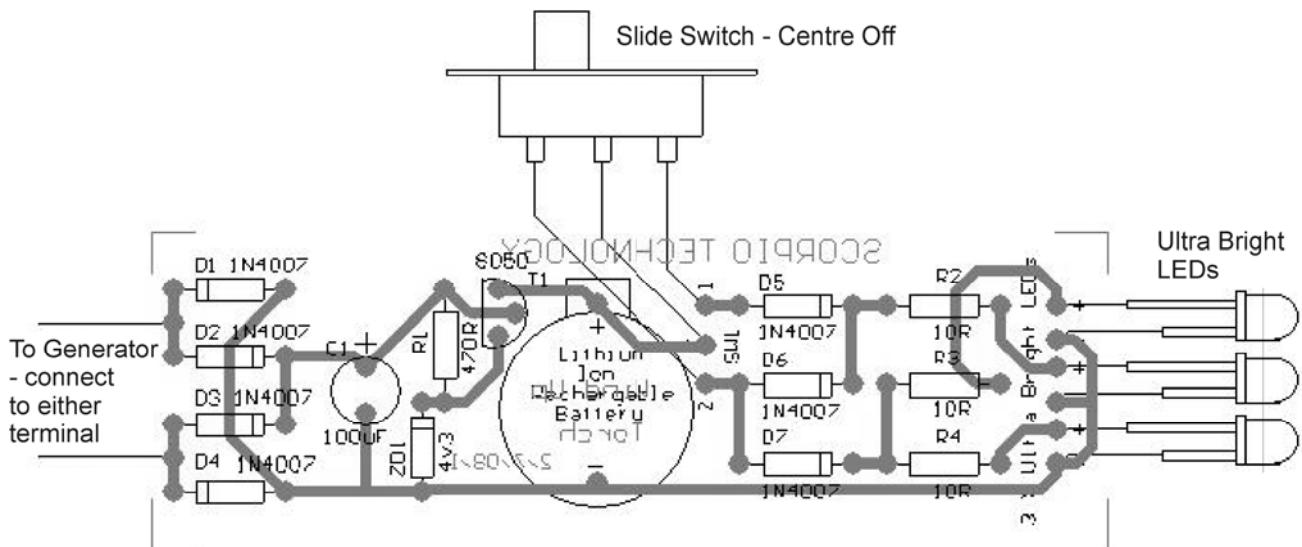
- When all the components are in place, check them carefully against the Printed Circuit Board. **DO NOT SOLDER ANY COMPONENTS UNTIL ALL HAVE BEEN PLACED ON THE PCB.**

**Note:** it's much better to spend time now, making sure all the components are in the correct position, than to waste time later on, trying to figure out why the torch doesn't work. If required, unsoldering and replacing damaged or wrongly positioned components will waste considerable time.

- Once all the components are correctly located, turn the PCB over and bend the component leads outwards, away from the component's body (about 15 degrees from vertical). This prevents the components from slipping down while being soldered in position. (Don't bend them too far or you'll have considerable trouble removing them if it becomes necessary later on.)

### 5.2 ASSEMBLY INSTRUCTIONS

Begin the assembly of the components to the PCB, by placing the components that sit lowest on to the PCB.

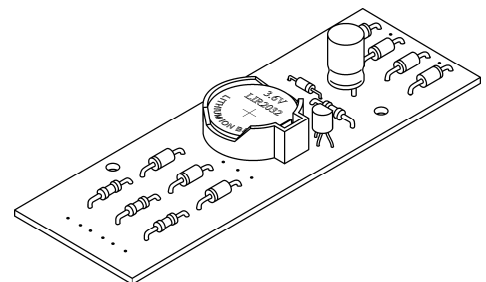


*Printed Circuit Board Overlay & Wiring diagram*

- Mount all the resistors in place. Resistors are non-polarised components and don't need to be placed in any particular direction. However, the convention is that horizontal resistors are mounted with the gold band to the right and vertical resistors with the gold band to the bottom.

- Make sure the Diodes D1 to D7 (black body, white band) have the negative end (the one with the band) facing in the same direction as shown on the PCB.

- The battery holder is mounted next: make sure that positive and negative terminals on the socket face in the same direction as indicated on the PCB.



- Make sure the Zener Diode (ZD1 - grey body, black band) has the negative end (the one with the band) facing in the same direction as shown on the PCB.
- Mount the Capacitor in its location on the PCB.
- The last component to be mounted before soldering is the Transistor (8050). Make sure that the transistor faces in the direction shown on the PCB.

**Warning:** If you connect power to the PCB and the transistor is facing in the wrong direction, then the transistor will almost certainly be damaged.

### 5.3.1 FINAL ASSEMBLY OF THE ELECTRONICS

#### 5.3.1 THE PCB

- Carefully solder all the component leads.
 

**Hint:** If you find it difficult to get to all the leads, cut off any that are in the way and continue soldering.
- When all the soldering is complete, cut the leads as close to the solder as possible.
- Check the soldering for any poor joints or solder bridges between the tracks. Solder bridges are most likely to occur between tracks that are close together, so pay careful attention to the solder tracks where the transistor is mounted.
 

**Warning:** Solder bridges must be removed before connecting power to the PCB. Failure to do so may result in damage to the circuit.

#### 5.3.2 THE WIRING

**Hints:**

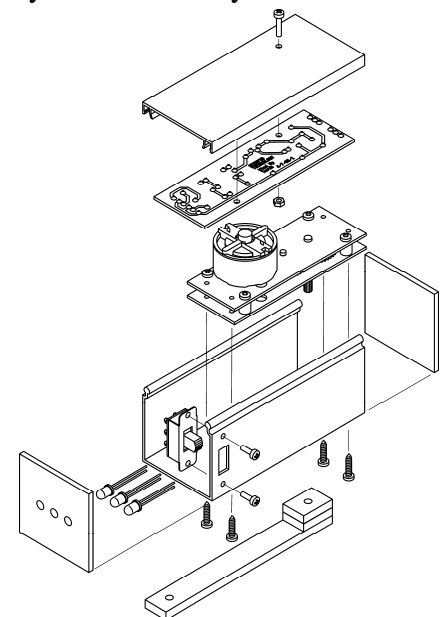
1. When soldering wires, strip a short piece of insulation from the end of the wire, twist the strands and “tin” them. This is done by using a hot soldering iron to apply solder to the ends.
  2. Use different colour wires so it is easier to follow the wiring connections, and to fault find any problems (if they occur).
- Work out the length of the wires that connect the generator and the three LED’s to the PCB – connect and solder them. The wires connecting to the LED’s must have positive and negative connected correctly or the LED’s will not light up. See the wiring diagram for details.
  - Connect and solder the three wires to the slide switch. Make sure that they connect to the tabs along one side of the switch. Note: the Generator has its positive (+) terminal marked, but because the PCB has a bridge rectifier the Generator can be wired in either direction, and it will still work correctly.
  - When all the wiring has been completed, slide the Lithium ion Battery into the battery holder. Make sure the positive (+) side of the battery faces upwards.

## 6. MAKING THE TORCH

### THE PROTOTYPE’S CASE:

The original case was made from 50mm x 50mm PVC Cable Duct Tubing with a clip on lid:

- The lid was clipped in place and the duct measured and cut to be 165mm long. The ends were then sanded to be clean and square.
- Two end pieces of 3mm thick PVC were cut to size and PVC glue used to glue them to the duct. When gluing the ends in place, care was taken to ensure that no glue was put on the duct lid, to allow the lid to be removed later. The 5mm holes for the 3 LEDs were drilled prior to the ends being glued on.
- After the glue had dried, the edges of the end pieces were cleaned up, to finish flush with the duct.



### 6.1 CONSTRUCTING THE CASE

If using a different material than PVC Cable duct for the case and lid, decide on the size, shape, material and colour to be used before doing any wiring.

**Note:** if a different material/size/shape is used, some of the instructions that follow may need to be modified to suit your torch's case and lid.

## 6.2 ASSEMBLING THE COMPONENTS IN THE CASE

The Gear box assembly is installed in the bottom of the case, and the PCB is attached to the inside of the lid.

- Position the gear box and generator assembly in the case.
- Use the 2.6 x 12mm screws to secure the gear box to the torch's case (the holes were marked and drilled prior to the gearbox being assembled).
- Measure the distance between the slide switch's mounting holes. Mark and drill 2 off 3mm holes in the case.
- Cut out a hole for the switch's slide lever – make sure that the hole allows the slide lever movement for the whole distance.
- Mount the switch to the case using 2 off M3x8 bolts.
- Drill a 3mm hole in the PCB, above component C1 and between D1 and R1.
- Slide the PCB in between the grooves on the inside of the lid. Position the PCB so that it is clear of the generator when the lid is in place. Mark the position of the PCB's 3mm hole and slide the PCB clear
- Drill a 3mm hole in the lid. Slide the PCB into place and fit the 3x8mm screw in place. Use the nut to hold the PCB onto the lid.
- Push the LEDs into the holes - they should fit tightly. After checking that the LEDs work properly, a small amount of hot glue can be used to hold them in place.

## 6.3 THE HANDLE AND KNOB

6.3.1 To make the *WIND-UP TORCH's* handle:

- Cut a rectangular section of 3mm PVC 110mm x 12mm.
- Next cut 2 sections, each 25mm long. Glue these to one end as shown in the diagram (with PVC glue).

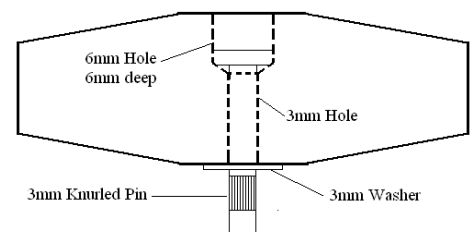
Note: This is necessary to give extra grip for the knurled shaft, as a single or double thickness section will strip out the shaft hole when turning the handle.

- When the glue is dry, drill a 3.9 mm hole all the way through the centre of the thick end.
- At the other end of the handle, and about 12mm from the end, drill a 2.9mm hole for the knob.
- After the gear box is installed in the torch's case (in Section 6.2), the handle can be pressed onto the 4mm shaft.

6.3.2 To make the knob for the handle:

The knob can be made from a piece of wood or plastic (ours was 45mm x 15mm x 9mm), and shaped as seen in the drawing.

- Drill a 3mm hole all the way through the centre.
- Drill a 6mm hole, 6mm deep.
- Fit the 3mm Knurled pin into the hole. Place a 3mm washer onto the pin's end. Using a nail punch on the head of the knurled pin, tap the pin into the 2.9mm hole in the handle's end. Make sure that there is enough space so that the knob can spin freely on the handle.



6.3.3 Attaching the Torch's handle

- Place the Torch's handle on the edge of a solid bench, making sure that the side with the extra sections glued onto it is facing upwards. Put the handle shaft in place on the torch handle's 3.9mm hole. Tap firmly on the end of the shaft projecting from the other side of the gearbox until the shaft is flush with the handle's top surface.

Now that all the parts are inside the torch case, and the handle is installed, the last stage is to clip the lid onto the case. Now your *WIND-UP TORCH* is completed, and ready for testing.

## **7. TESTING**

### **7.1 MECHANICAL TESTING**

Check that the handle can turn freely in both directions

### **7.2 TESTING THE GENERATOR**

When the gearbox is completed, connect a DC Voltmeter to the output terminals. When wound the generator will produce about 30 volts. This may seem to be far too high considering that we expect the generator to produce 6 volts. The generator produces 6 volts only when the generator is connected to some sort of load. A load is a component that consumes power, such as a light globe. When a 6 volt torch globe is connected to the terminals you should measure close to 6 volts.

### **7.3 ELECTRICAL TESTING**

7.3.1 Insert the battery and turn the handle for one minute to charge the battery. Then:

- move the sliding switch from the middle position (Off) to the upward position. Check that the 3 LEDs light up
- move the sliding switch from the middle position (Off) to the downward position. Check that the single LED lights up

7.3.2 When you turn the handle you should be able to measure about 6 volts across the Capacitor.

- If it measures 6 volts, you should now be able to measure 4.3 volts between negative and the junction of R1, the Zener diode and the base of T1. The voltage between negative and the emitter of transistor T1 should measure 3.6 volts.

## **8. TROUBLESHOOTING**

If nothing happens while testing the *WIND-UP TORCH*:

- turn the torch off immediately
- check that all the components are in the right position and facing in the correct direction (check against the diagram and information in section 5.2).
- Check the diodes to ensure that they are facing in the correct direction.
- Check that the transistor is facing as shown on the PCB.
- Check the orientation of C1 to make sure that the positive and negative leads are the correct way round.
- Check the orientation of the wiring for the three Ultra Bright LEDs. If they are connected the wrong way, they will not light up.
- If the components are correctly placed and orientated, double-check your soldering.
- Make sure there are no dry joints: the soldering may look dry or lumpy, or you may notice the solder around a lead does not actually connect to the lead. This will look like a dark ring around the lead, try pulling the component up to see if the lead comes out or moves.
- Check for short circuits (solder bridges) where solder connects across from one track to another track.

Now that the torch works properly, you have successfully made your *WIND-UP TORCH*!!!

*WELL DONE!*