WOMBAT

DESCRIPTION

The ***WOMBAT*** is a black-line-following vehicle. An electronic circuit senses the line position and changes the speed of each driven wheel, keeping the *WOMBAT* on track.

The following tasks need to be performed to build and complete the *WOMBAT*:

- Design the mechanical components.
- Assemble and solder the Printed Circuit Board (PCB).
- Fabricate and assemble the components.
- Test, diagnose and adjust the completed *WOMBAT*.

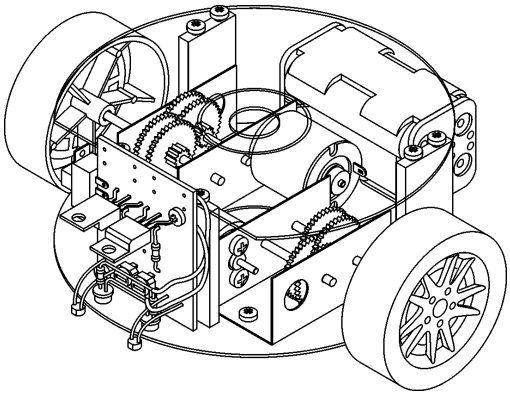


Figure 1 Wombat Assembly

INVESTIGATION

This project provides a number of different aspects for investigation. Some ideas are listed below.

- Investigate alternate materials, such as Aluminium, PVC, Perspex and CD/DVD. What are the advantages and disadvantages of each material?
- Investigate converting *WOMBAT* to follow a white line on a black background.
- Investigate the minimum taped corner radius that it can negotiate.
- Investigate different LED and LDR locations and the effect on the line tracking ability.
- Investigate other vehicles that use different guidance systems.
- Calculate the speeds that could be expected if using different gear ratios, such as the Triple or Quadruple reductions (refer the section on Assembling the Gearbox for more information).

1. COMPONENTS REQUIRED

1.1. COMPONENTS SUPPLIED.

The following components are supplied in the kit:

- 2 x 52mm Wheel
- 1 x 5.5mm Pulley
- 3 x M2.6x4 Self-tapping Screw
- 12 x 2.6x12mm Self-tapping Screw
- 1 x 4 "AA" Battery Holder
- 1 x Sliding Switch (small)
- 2 x Diode 1N4004
- 1 x Printed Circuit Board (PCB) - *ROBOBUG*
- 2 x Transistor TIP122
- 2 x Light Dependant Resistor (LDR)
- 2 x LED - 5mm White (high intensity)
- 2 x Resistor - 220 Ohm (Red-Red-Brown-Gold)
- 2 x Resistor - 10k Ohm (Brown-Black-Orange-Gold)
- 2 x Trimpot - 5k Ohm (horizontal - "502") – V1, V2

2 x Intermediate Gearbox kits, in each:

- 1 x Intermediate Gearbox Case
- 1 x 4.5V Electric Motor (round)
- 2 x 2.5 dia x 100-150 long steel rod
- 1 x 3mm ID 1.0 thick Washer
- 1 x 100mm long ID PVC Guide Tube (white)
- 4 x M2.6x4 Self-tapping Screw
- 4 x 40/10T Spur Gears (white)
- 4 x 12T Pinion 2.4mm Hole
- 1 x 10T Pinion 1.9mm Hole

1.2. ADDITIONAL REQUIREMENTS

- The following are available from us, and need to be ordered separately: 2.3mm, 2.6mm and 3.5mm diameter drill bits; and the 4 AA batteries.
- Additional requirements are: fine, multi-strand electric hook-up wire (assorted colours); black PVC insulation tape; material for the various body components (PVC or acrylic sheet; CDs).

2. HOW THE CIRCUIT WORKS (THEORY)

The electronics consists of two electronic systems: illumination and motor control.

- LEDs provide illumination of the tape, for the LDRs to follow.
- The change of *WOMBAT's* direction is controlled by the difference between the speed of the two motors. The speed of each motor is proportional to the amount of light which is reflected by the tape, and detected by its LDR.

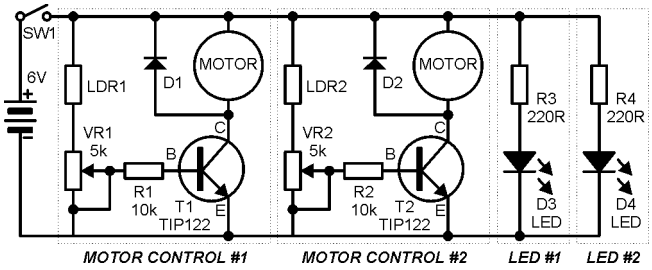


Figure 2 Circuit Diagram

2.1. ILLUMINATION

- Both illumination circuits are the same.
- The illumination circuit consists of a white LED (D3, D4) and a 220 Ohm current limiting resistor (R3, R4).

2.2. MOTOR CONTROL

- Both motor control circuits are the same.
- The LDR (LDR1, LDR2) and the 5k variable resistor (VR1, VR2) form a voltage divider. The voltage at their junction is proportional to the light intensity detected by the LDR.
- The output of the voltage divider passes through a current limiting resistor (R1, R2) to the base of the TIP122 transistor (T1, T2).
- The transistor passes current to the motor in proportion to the current passing from the base (B) to the emitter (E).
- The 1N4004 diode (D1, D2) eliminates EMF (electrical noise) that is generated by the motor from being fed back into the circuit.
- To further reduce electrical noise, a 0.1uF capacitor is soldered across each motor's terminals.

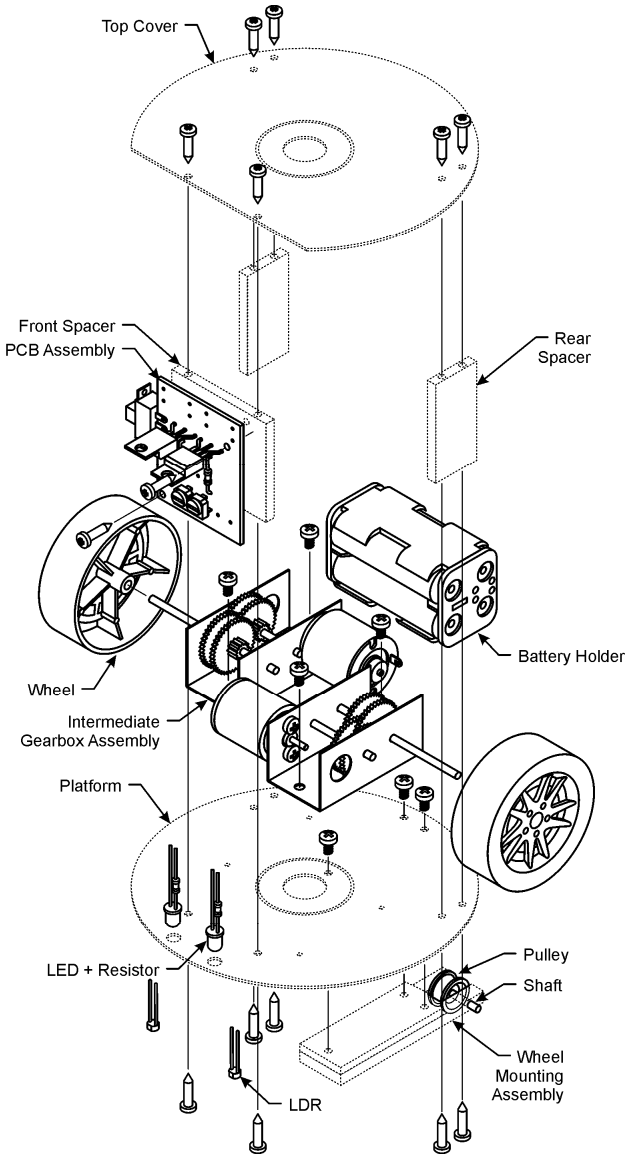


Figure 3 Exploded View

3. DESIGN AND PLANNING

3.1. PLANNING

The student needs to plan the size and shape of the *WOMBAT,* by laying out all of the components, using a suitable program or making full size drawings on paper.

Plan the most effective and compact shape and size, by looking at your *WOMBAT* as a complete unit, and not just as a collection of separate parts.
Hint. It is worth reading this entire unit before starting the design, to understand the requirements of each section.

3.2. DESIGN

- The assembly should be light and robust. However, to increase the device's rigidity, we suggest you use a top cover. You should design spacers to attach the top cover to the platform.
- Both of the gearbox output shafts should be in line.
- Design the trailing wheel assembly (using the pulley) so that the *WOMBAT* is stable when running, and the platform is parallel with the ground.
- For stability, position heaviest components (the batteries) between the three wheels.
- Determine the positions for the LEDs and LDRs. These should be placed so that each pair (ie one LED & one LDR) is near the edge of the black tape which will be used. Note: the width of the tape determines the spacing between the LDR and LED pairs (refer the Assembly section for more detail)
- Locate the PCB so that the Trimpots can be easily adjusted.

4. ASSEMBLING THE PCB

NOTE: the values of various components differ from the values printed on the PCB. To ensure correct assembly, please read the instructions carefully, and refer to the Circuit overlay and the Wiring diagram.

- Insert two 10k Ohm resistors (R1 and R2). On the printed overlay, these are marked with the value "1k". The resistors can be inserted either way.
- Insert two 1N4004 diodes (D1 and D2). Insert the end with the white/silver band as shown on the printed overlay.

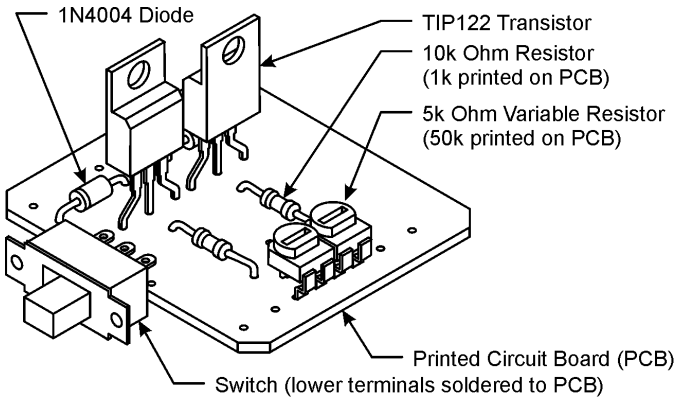


Figure 4 PCB Component Terminology

- Insert two TIP122 transistors (T1 and T2). Bend the legs to fit the holes. These components could be tight in the PCB holes.

WARNING: It is very important to ensure that the Transistors are mounted in the correct direction. If they are not mounted in the correct direction the transistors will be damaged when power is connected to the circuit board.

- Turn over the PCB and slightly bend the component leads to prevent them slipping out.
- Solder the components to the PCB. When soldering, place the soldering iron tip to the lead and track pad, heat the joint for 2 to 3 seconds and then apply the solder to the lead and pad. Do not overheat the PCB or other components.
- Use a pair of side cutters to cut the ends of the leads close to the solder. The cut ends should be about 2mm from the PCB.
- Position the switch on to the PCB, with the PCB between the two rows of the switch's pins. Solder the switch's lower pins to the PCBs tracks.

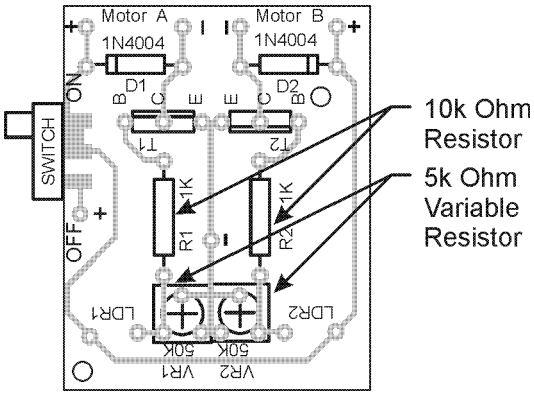


Figure 5 Circuit Overlay

5. ASSEMBLING THE GEARBOXES

The *INTERMEDIATE GEAR BOX* kit provides a choice of 4 gear ratios. Before starting, the desired ratio must be determined, as this defines the gears to be used, and the assembly procedure. For the *WOMBAT*, we used the Quadruple reduction ratio, to ensure the *WOMBAT* went slow enough to follow the taped line.

However, if a designer chooses to use a different ratio, we have supplied information for both the Triple and Quadruple reduction options (information on the first and second can be found on our website).

Note: The choice of ratios available at the „Output" shaft are:

Single Reduction	Double Reduction	Triple Reduction	Quadruple Reduction
1:4	1:13.33	1:44.44	1:148.148

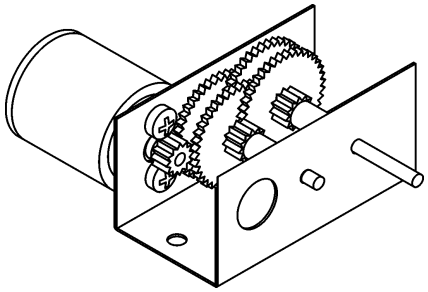


Figure 6 Intermediate Gear Box

Under load, the motor speed is approximately:

- At 3 Volts (i.e. 2xAA batteries) 6,500 RPM
- At 6 Volts (i.e. 4xAA batteries) 12,600 RPM

5.1 PRELIMINARY TASKS

5.1.1. Determine the required ratio, as this will affect the component and rework requirements (for rework instructions, refer to Section 5.3, for the Triple or Quadruple reduction gearbox section).

5.1.2 based on the gearbox reduction ratio, cut appropriate length spacers / retainers from the PVC tube. Make sure that the ends are flat (ie at right angles to the tube) and de-burred.

5.1.3 Determine the required length of the gearbox shafts, cut and de-burr them (with a file).

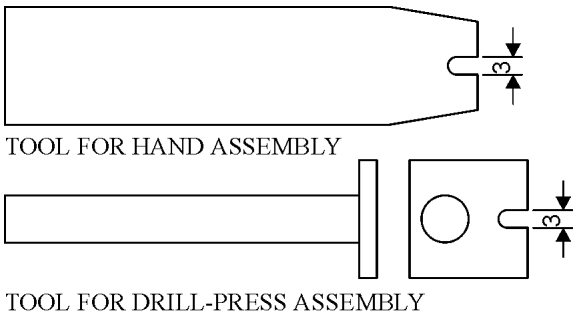
- Use sidecutters to cut the steel rods to the required lengths. Use a file to round off the ends.

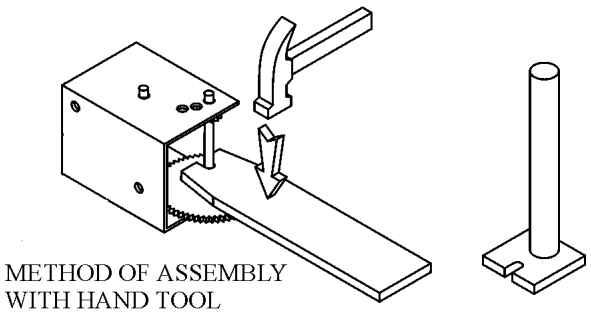
5.2 ASSEMBLY

5.2.1 ASSEMBLY HINTS AND TOOLS

The following will aid your assembly work.

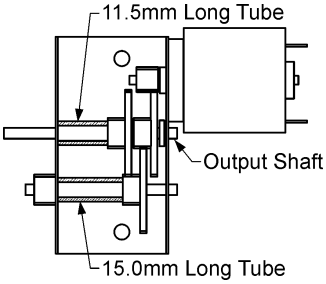
- As a jig, a piece of hardwood 40x60x150, with 3.0 dia holes drilled to varying depths is useful.
- Further, when the shaft starts to penetrate through the gear, a 1 mm thick plastic sheet can be placed, temporarily, between the gear and case to prevent damage.
- For pushing the gears along the shaft, the following tool should be constructed. The tool on the right is used with the drill press. The tool shown on the left is used (gently) with the hammer.



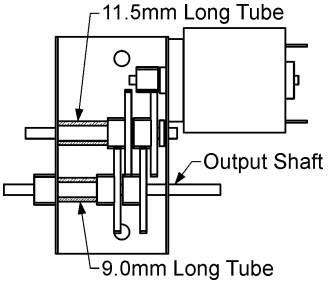


5.2.2 ASSEMBLING THE GEARBOX

- Assemble the steel rods, and all the gears, to the gearcase, as shown in the drawings.
- Use 12T pinion gears to retain the steel shafts in position.
- The gears can be assembled onto the shaft/s with a help of small hammer.



Triple Reduction
Ratio = 1:44



Quadruple Reduction
Ratio =1:148

TRIPLE REDUCTION GEARBOXES

Note: for the Triple reduction gearbox, the first spur gear (closest to the gear case wall) must have the central hole drilled out with a 2.6mm drill bit. This will allow the gear to freewheel on the shaft.

- Start with the shaft nearest the motor. Insert the steel rod thru the gear case wall, the 1.0mm washer (keeping the washer between the gear case and the spur gear), and a modified spur gear.
- Add the 2nd shaft, PVC tube, an unmodified spur gear and 12T pinion gear (locator).
- Assemble an unmodified spur gear to the first shaft, together with a PVC tube

QUADRUPLE REDUCTION GEARBOXES *(RECOMMENDED)*

Note: for the Quadruple reduction gearbox, the first two spur gears (the first to be added onto each shaft, and closest to the gear case) must have the central holes drilled out with a 2.6mm drill bit. This will allow these gears to freewheel on the shafts.

- Start with the shaft nearest the motor. Insert the steel rod thru the gear case wall, the 1.0mm washer (keeping the washer between the gear case and the spur gear), and a modified spur gear.
- Add the 2nd shaft, with a modified (2.6mm hole) spur gear.
- Assemble an unmodified spur gear to the first shaft, together with a PVC tube
- Assemble an unmodified spur gear to the second shaft, together with a PVC tube

5.2.3 ASSEMBLING THE MOTOR

- Press the 10T pinion (1.9mm hole) onto the motor shaft. To do this, place the gear on the bench, insert the motor shaft into the pinion's hole and gently tap the shaft's end (where it exits the motor) with a small hammer. Stop when the pinion gear is 1mm from the motor's body. WARNING: Don't just push the motor down by hand as this can push the motor armature out of its bearings and jam the motor.
- Solder a suitable length of wire to each of the motor's terminals.
- Secure the motor to the gearbox case using two self-tapping screws.

6. ASSEMBLY

6.1 ASSEMBLY OF THE LED / LDR PAIRS

- Determine the position for the LEDs and LDRs. The LEDs should be pushed through from the top.

NOTES::

- Proper location of the LDRs is critical for the satisfactory tracking of the vehicle.
- The tape width, that the *WOMBAT* will follow, must be selected before the LDRs are installed.

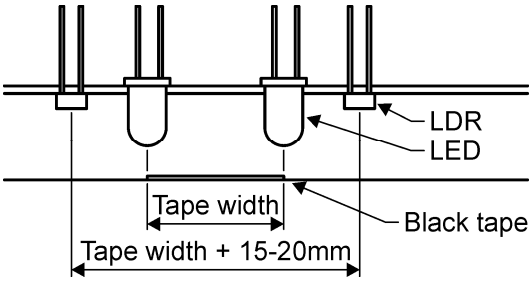
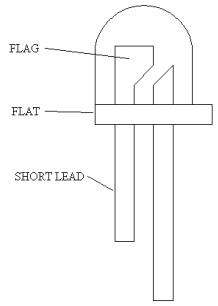


Figure 7 LED & LDR placement

- The LDR's should be located on the vehicle about 2-3 mm outside either edge of the tape. For example, if using 18 mm wide tape, the LDRs should be spaced approximately 22 to 24 mm apart.
- Allow room on the platform, for the LDRs to be re-positioned or adjusted if required. This will be determined by the *WOMBAT's* performance during testing and adjusting.

NOTE**:** LED's are commonly used as indicators to show whether something is turned on or adjusted properly. For example, the stereo light used on an FM radio is a LED.



LED's may use one or more of three methods to identify the negative lead. All types use method 1. However, not all LED's use methods 2 & 3. These methods are:

Method 1: The Flag (the larger connection inside the body) identifies the negative lead. This is visible when the LED is held up to the light.
Method 2: The shortest leg is negative
Method 3: A flat on the ridge around the base of the LED is on the negative side.

6.2 MECHANICAL ASSEMBLY

- Make the platform and top cover from CDs or other suitable material (PVC? Perspex?).
- Make all other needs – spacers for the top cover and mounting for the trailing wheel (pulley).
- Enlarge the pulley's hole to 2.6mm diameter, using a drill.
- Mount the trailing wheel.
- Insert the gearbox's steel axle into one of the wheels. Using a hammer gently tap the steel axle down into the wheel hole. Repeat for the other wheel and gearbox.
- Attach both gearboxes to the platform, using two 2.6x4mm self-tapping screws (diagonally).
- Make and attach top cover spacers to the platform.
- Attach the PCB to the front spacer.
- Attach the battery holder to the platform. Hook-and-loop tape was used on the prototype.

6.3 WIRING

When soldering wires, strip a short piece of insulation from the end of the wire, twist the strands and "tin" them with solder.

- Connect the battery holder (positive = red, negative = black) to the PCB.
- Attach white LEDs. Solder insulated wire between the negative battery terminal and the leg on the LEDs closest to the flat. Solder the LEDs other leg to the 220 Ohm resistor. Solder insulated wire between the resistors and the motor "+" (positive) terminal.
- Attach the LDRs. Solder insulated wire between the LDRs and the PCB.
- Attach insulated wires between the motor terminals and the PCB.

Note: these wires should only be soldered after completion of the Testing and adjusting stage. During the Testing stage, the wires may need to be swapped, to achieve the required direction of rotation for both wheels.

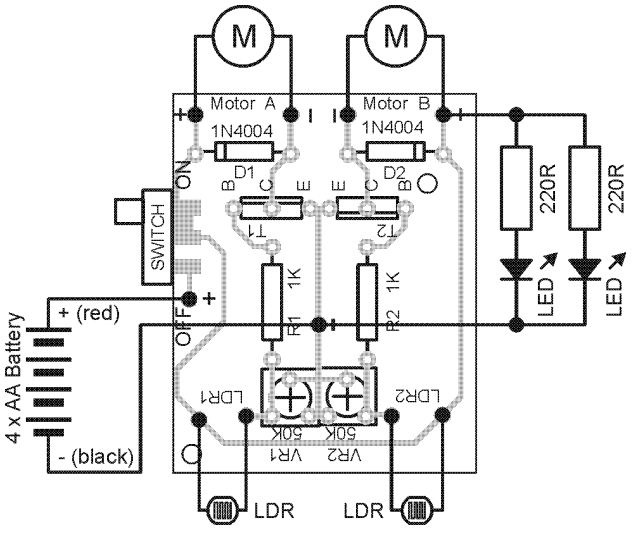


Figure 8 Wiring Diagram

7. TESTING AND ADJUSTING

7.1 ADJUSTING THE *WOMBAT*

- Adjust VR1 and VR2 about halfway.
- Insert four 1.5Volt AA batteries into the battery holder. Switch on the *WOMBAT*. Both LEDs should light up. Note that the LEDs can vary in brightness during operation.
- Hold the *WOMBAT* so that the LDRs point away from light sources. Adjust VR1 and VR2 (in opposite directions) so that both motors are at the point where they stop turning.
- Move a piece of white paper towards an LDR. The motor on the same side as the LDR should rotate. If required, swap the wiring to both motors. Both motors should rotate to move the *WOMBAT* forwards. If required, swap the wires on motor(s) that turn backwards.
- Adjust VR1 and VR2 so that the motors stop (or rotate slowly) when the LDRs are above a black surface and rotate faster (and at the same speed) when they are on a white surface.
- Fine tune your adjustment of VR1 and VR2 so that your *WOMBAT* follows your taped path.

7.2 TROUBLESHOOTING:

If any of the above are not achieved, turn off the power **immediately** and check the following:

- that the batteries have adequate charge
- that the +ve (red) and –ve (black) leads from the battery connectors go to the correct positions on the P.C.B.
- that bare wire ends do not touch
- check that there are no solder bridges between the terminals
- check that components are installed in the PCB, in the correct orientation.
- that the wiring is connected as per instructions
- Make sure there are no dry joints - the soldering may look dry or lumpy or you may notice the solder does not actually connect to the wire. This will look like a dark ring around the wire: try pulling the wire to see if the lead comes out or moves (a magnifying glass will help)

8. FURTHER DEVELOPMENT

Congratulations on successfully building and customising your own *WOMBAT*.

HAVE FUN WITH YOUR WOMBAT!