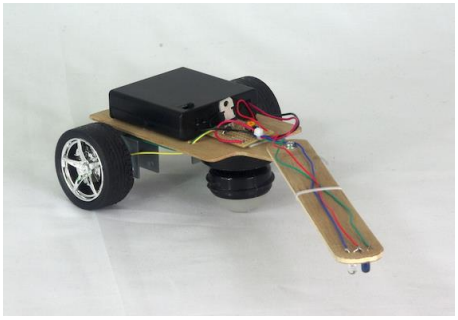
AMAZER - Table Top Vehicle (a Protoboard Project)

DESCRIPTION

The *AMAZER* project is a vehicle that moves around a table top and avoids falling off by sensing the table top edge and turning the vehicle away from the edge. It uses an Infra Red LED and an Infra Red Photo Transistor to control the operation of the vehicle.



SECTION 1: PROJECT REQUIREMENTS

1.1 COMPONENTS REQUIRED

The following components are required and are available from Scorpio Technology (item codes in brackets). Before starting we suggest that you check you have all the components using the checklist below – tick off each component as you identify it.

☐ 1 x Protoboard	(PCB-PROTO)	
☐ 1 x Battery Holder – 6V	(BH4AAF)	
☐ 2 x Wheels – 52mm	(W52C2)	
☐ 1 x Diode – 1N4004	(DIO1N4004)	
☐ 1 x Transistor – TIP122	(TIP122)	
☐ 1 x Vertical Trimpot – 10K (103)	(TRIM10V)	
☐ 1 x Infra Red LED – 5mm (Blue)	(LEDIRRT5)	
☐ 1 x Infra Red Photo Transistor – 5mm (Clear)	(PHOTOIR5)	
☐ 1 x Resistor – 39 Ohm	(RES39)	(O-W-Blk-G)
☐ 1 x Resistor – 220 Ohm	(RES220)	(R-R-Br-G)
☐ Length Tinned copper wire (for wire links)	(TCW	
☐ 2 x Versatile Gearbox Kit	(GVERS6)	
☐ 5 x M3 x12mm Bolts	(BOLT12)	
☐ 4 x M3 Nuts	(NUTM3)	
☐ 1 x M3 Nylock Nut	(NUTNYL)	
☐ 2 x M3 Washers	(WASHER)	

NOTE: The Infra Red LED and the Infrared Photo Transistor look almost the same. The Infra Red LED's body is coloured blue. The Infrared Photo Transistor's body is clear.

1.2 ADDITIONAL REQUIREMENTS

The following items are required and are available from Scorpio Technology, but need to be ordered separately if required:

☐ 4 x Battery – AA (BATTALK or BATTALK40)
☐ Multi strand hook-up wire – in a variety of colours (WIREHU10)
☐ Cable ties (CABTIE100A) or twist ties to hold wires in place.

The following material is to be supplied by the student / designer:

☐ The material for the vehicles base. The prototype used 3mm plywood.
☐ Roller from a plastic deodorant stick (See text)
☐ Adhesive/double sided tape to hold the Battery Holder and Protoboard in place.
☐ Block of wood to support gear case at the assembly stage. At least 25mm thick, that holes can be drilled into.

1.3 TOOLS REQUIRED

The following tools are required. A number of these are available from Scorpio Technology, and can be ordered separately if required (item codes in brackets):

- ☐ Soldering Iron: a good quality soldering iron, with a fine tip (SOLDIRN) and Soldering Iron Stand (SOLDIRNSTD) or Soldering Station (SOLDSTN)
- ☐ Solder: the use of 0.71mm 60/40 solder is recommended (SOLD500)
- ☐ Phillips screwdriver #1 point (SCREWDRPH1/80)
- ☐ Small hammer (HAMMERCP)
- ☐ A small spanner (MULTITOOL)
- ☐ Mini bolt cutters (BOLTCUTM)
- ☐ Wire strippers (WIRESTR)
- ☐ Side cutters (SIDECUT or SIDECUTM)
- ☐ Hot glue gun (GLUEGUN or GLUEGUNMIN) and Hot glue (GLUESTK or GLUESTK7)
- ☐ Assorted hand tools and cutting tools – depending on the choice of materials to be used, such as:
    - Scroll saw or hand saw
    - Ruler / square and pen / marker
    - Scriber or pin punch
    - Sanding block and sandpaper
- ☐ Drill and drill bits:
    - 3mm drill bit
    - 1mm drill bit (DB1.0)

SECTION 2: DESIGN

The design stage is crucial. At this stage the locations of all the components on the vehicle are to be worked out. Additionally, the answers to some of the questions posed in the previous section, in Items For Investigation (e.g. Shorter or longer platform), should be taken into account at this stage.

NOTES:

- ☐ Each student is able to, and should, design and build their own unique vehicle. Before starting construction, the size and shape need to be developed on paper (or on a CAD program).
- ☐ For the vehicle's optimum functionality, the designer must look at the vehicle as a complete unit, and not just as separate parts. The layout of all the components affects the size and shape of the vehicle's platform, as well as the ease of assembly – different placement of components will change the platform's size and shape.

The designer has to make a variety of decisions and determine the following:

- ☐ The size, design and shape of the base.
- ☐ The type of material to be used for the base.
- ☐ The length of the neck

THE BODY

The body of the *AMAZER* is in two parts.

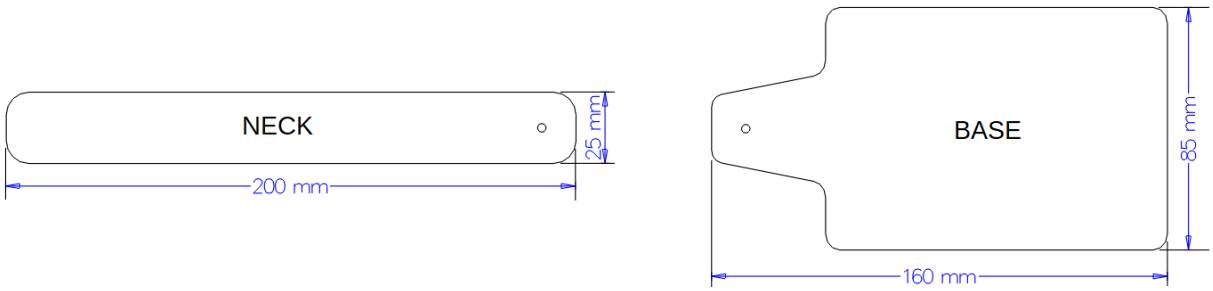
- The Base has the motor gearboxes and ball roller (made from a plastic roll-on deodorant bottle) mounted underneath. On top are mounted the battery holder and protoboard.
- The Neck which has the IR LED and Photo transistor mounted underneath.

The *AMAZER* images that follow, show one possible design and can be modified.

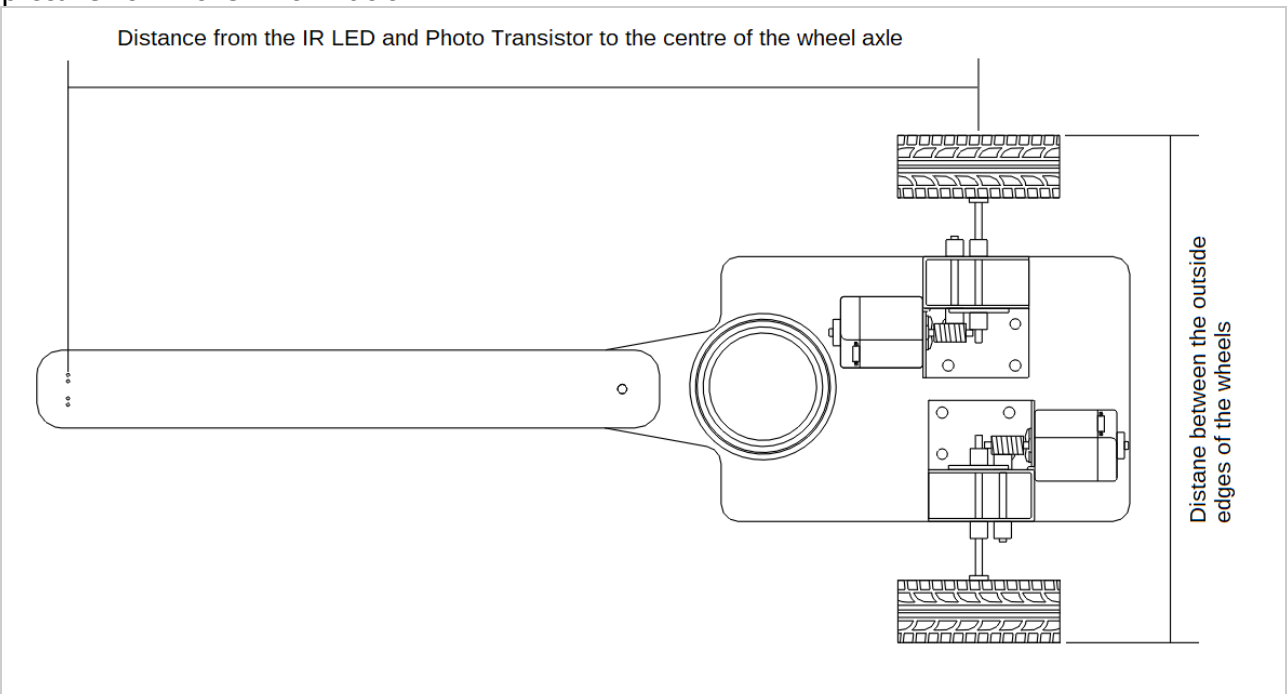
You can make the *AMAZER* a different size to the one shown. The 85mm width of the

base was chose because it allows mounting the two motor gearboxes next to each other.
NOTE: The absolute minimum width is 82mm, that is the minimum width that can be achieved by mounting the two motor gearboxes up against each other.

If you design and construct a body for your *AMAZER* and use a different width for the base, you will have to change the length of the neck. This is to ensure that the *AMAZER*'s turning circle is able to turn correctly and avoid falling off the table top.



In the following picture you can see the measurements mentioned. The distance between the IR LED and Photo Transistor and the centre of the Wheel axle MUST be at least TWICE the distance between the outsides of the wheels. Refer to the following picture for more information.

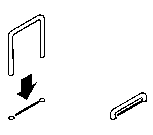


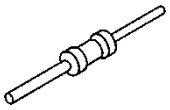
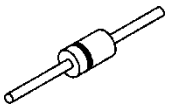
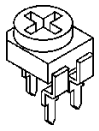
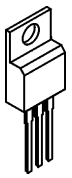
The distance between the IR LED and Photo Transistor and the centre of the Wheel axle **MUST** be at least **TWICE** the distance between the outsides of the wheels.

SECTION 3: THE ELECTRONIC COMPONENTS

The components required are:

☐ **Making and mounting the Wire Link**
Wire links are shown by a line and the words "Wire Link". Take the supplied length of tinned copper wire and bend it into the shape of a staple.



Mount the Resistors (R1 to R2) in place. ☐ Resistor – 220 Ohm (Red-Red-Brown-Gold) R1 ☐ Resistor – 39 Ohm (Orange-White-Black-Gold) R2 *Resistors are non-polarised components and do not need to be placed in any particular direction. However, the convention is that horizontal resistors are mounted with the tolerance band to the right or to the bottom of the board*	
Mount the Diode (D1). ☐ Diode – 1N4004 (DIO1N4004) *When mounting diodes ensure that the negative end, with the band, is facing in the correct direction as shown on the Protoboard layout.* *WARNING: if diodes are inserted in the wrong direction the microcontroller will NOT work.*	
☐ **Mount the Trimpots (VR1)** Mount the trimpot in place. • The mounting direction is defined by the mounting holes, and can only be mounted in the direction shown in the Protoboard layout Adjustment is made from the top	
☐ **Insert the Transistor T1** *It is very important to ensure that this is mounted in the correct direction (as shown on the layout drawing). The metal side of the Transistor MUST face the same direction as shown in the Protoboard layout.* *The transistor has 3 leads (legs): the Emitter (E), Base (B) and the Collector (C).*	

SECTION 4: ASSEMBLING THE PROTOBOARD

4.1 MOUNTING THE COMPONENTS

The picture shown later in Section 4.3 shows the location of the components on the Protoboard.

- ☐ Face the Protoboard so that you can see the component side.
- ☐ Begin with the components that sit lowest on the Protoboard. In this case it will be the wire links, resistors, diode, trimpot and lastly the transistor.
- ☐ Refer to Section 4.3 for detailed information on locating component mounting positions.

4.2 SOLDERING THE COMPONENTS IN PLACE

NOTE: Check that all the components are in their correct positions: it pays to spend some time doing this before soldering components in place. It can prevent wasted time later on, trying to find out why the circuit is not working and unsoldering and replacing damaged or wrongly positioned components.

4.2.1. GENERAL PRINCIPLES

- ☐ Turn over the Protoboard to the side that has the copper tracks and slightly bend the leads of the components outwards, to prevent the components slipping out.
- ☐ Apply the soldering iron's tip to the lead and track pad at the same time. Heat the joint for 2-3 seconds and then apply the solder to the heated lead and pad on the opposite side to the soldering iron tip. Melt the solder onto the hot pad and lead, not onto the soldering iron.

☐ Once all the components have been soldered, use a pair of side cutters to cut off the ends of the leads – as close as possible to the solder

4.3 PROTOBOARD LAYOUT

Carefully follow the layout of the following picture:
- Every component and wire MUST be in the exact location shown.
- Any variations will prevent the circuit from working.

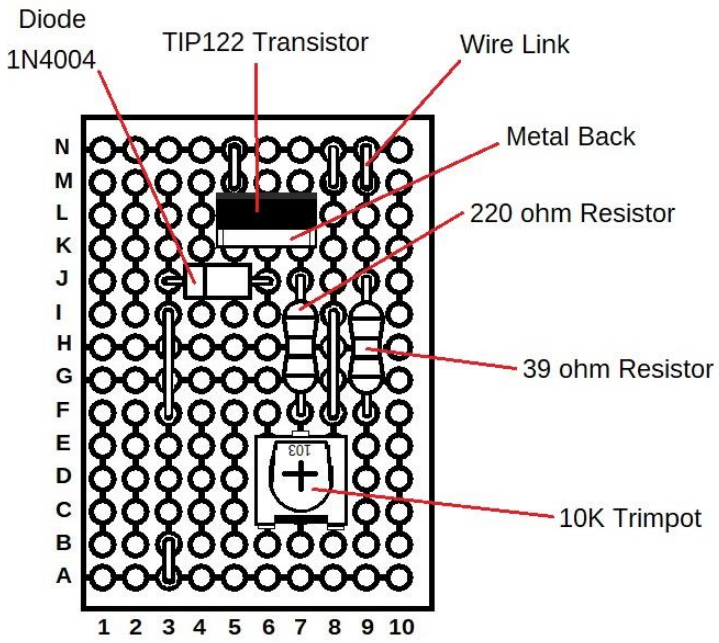
If your circuit does not work make sure the components and wires are connected as shown. Any components and links MUST be positioned correctly. The Transistor, Diode and Trimpot must face in the direction shown or the circuit will not work.

☐ Use the following picture to help you correctly locate the component leads and wire links.

The rows are marked by letters and columns are marked by numbers. A1 would identify the hole in the bottom left hand corner of the Protoboard.

The information shown below works like this:

- 220 ohm Resistor, F7-J7 indicates that the 220 ohm resistor's leads fit into holes J7 and F7.
- For the wire links A3-B3 indicates a wire link that fits into holes A3 and B3.



Protoboard - Shortened to 10 holes long.

Components

☐ **220 ohm Resistor -** J7-K7
☐ **39 ohm Resistor -** J9-F9
☐ **1N4004 Diode**, J3-J6
☐ **TIP122 Transistor -** Emitter L5 - Collector L6, - Base L5
☐ **10K Trimpot** - E6, E8, C7.
☐ **Wire Links -** B3-A3, I3-F3, I8-F8, N5-M5, N8-M8, N9-M8

NOTES:

The voltage connected to this circuit is 6 volts.

- The diode is used protect the circuit components from damage by a phenomenon called "Back EMF", a large voltage that can be produced by an operating motor.
- Without the diode it is possible to permanently damage the transistor preventing the circuit from ever working again. Make sure it is facing in the correct direction before soldering.
- The 39 ohm resistor is used to limit the maximum current that can be drawn from the battery to a safe level for the IR LED to operate.

SECTION 5: THEORY - HOW THE CIRCUIT WORKS

5.1 CIRCUIT OPERATION

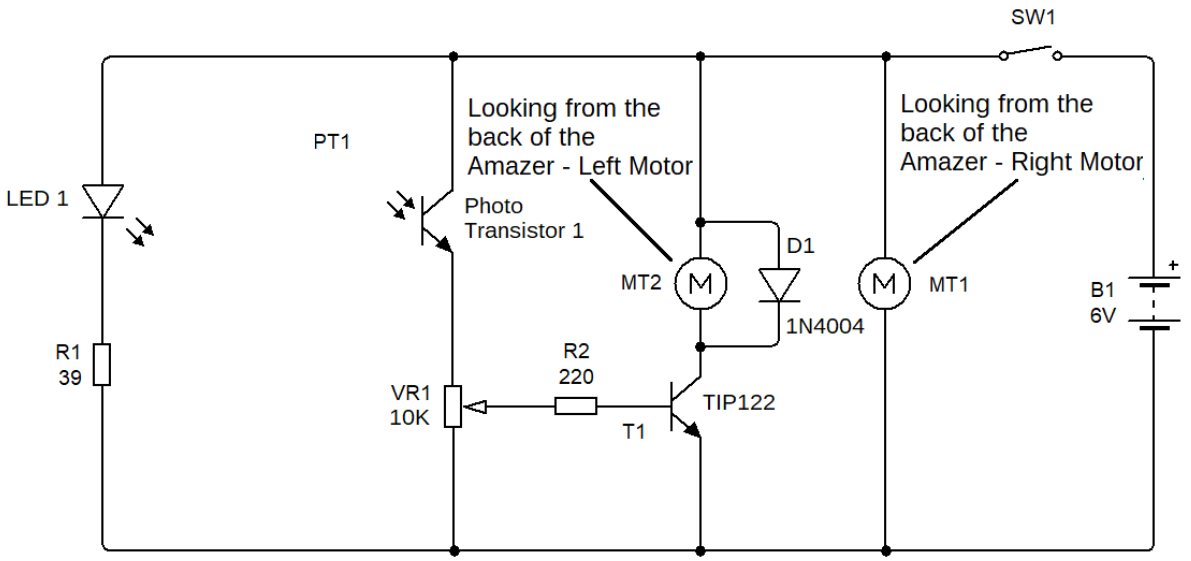
The circuit operation is fairly simple.

When the circuit is turned on current flows through the IR LED.

- The amount of current that flows through the IR LED is limited to a safe amount by the 39 ohm resistor (R1).

The IR signal is reflected off the table top to the Photo Transistor.

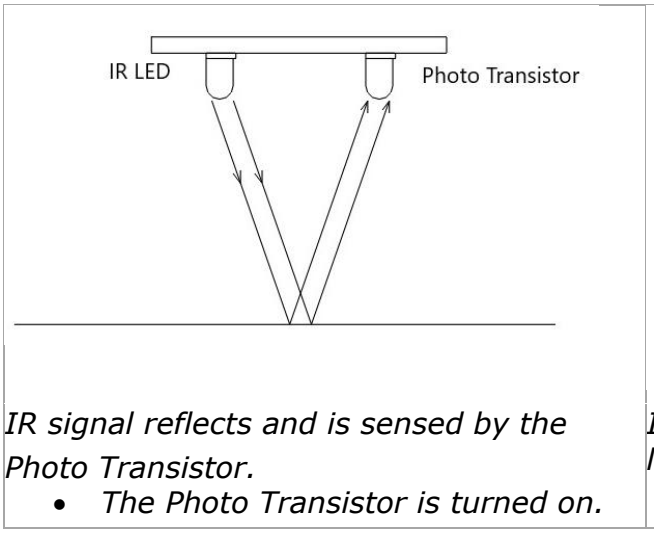
- This causes the Photo Transistor to turn on, connecting 6 volts to the 10K Trimpot (VR1) and the 220 Ohm resistor (R2).
- Current will now flow through the 220 ohm resistor to the base of the TIP122 Transistor, causing it to turn on.
- This allows current to flow through motor (MT2) causing the motor to turn.
- At the same time current flows through the other motor (MT1) and begins to turn. Motor (MT1) remains operating at all times until the circuit is turned off.



AMAZER Circuit Diagram

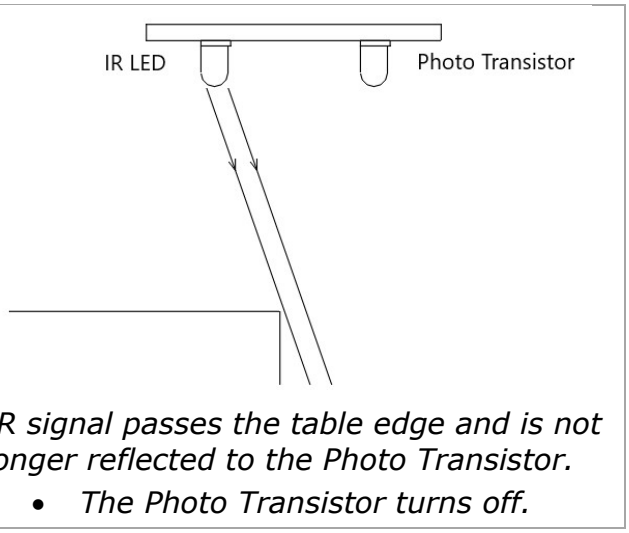
If the IR LED's signal passes the edge of the table it will no longer be reflected to the Photo Transistor.

- The Photo Transistor will turn off disconnecting the 6 volts to the 10K Trimpot (VR1) and the 220 Ohm resistor (R2).
- Current ceases flowing through the 220 ohm resistor to the base of the TIP122 Transistor causing the Transistor to turn off.
- Motor (MT2) will stop turning.



IR signal reflects and is sensed by the Photo Transistor.

- *The Photo Transistor is turned on.*



IR signal passes the table edge and is not longer reflected to the Photo Transistor.

- *The Photo Transistor turns off.*

- Motor (MT2) stops turning while motor (MT1) continues to turn.

This causes the *AMAZER* to turn to the left and steer the *AMAZER* back on to the table top.
The Photo Transistor senses the IR signal again causing motor (MT2) to turn.
The *AMAZER* continues on its way until it encounters the table's edge again, losing the reflected signal and the process repeats.

SECTION 6: CONSTRUCTION NOTES

6.1 ASSEMBLING THE GEARBOXES

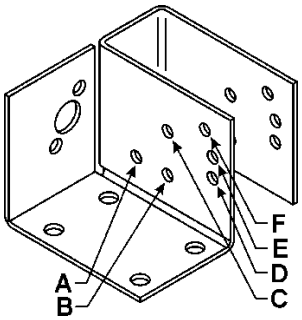
While this Gearbox can be assembled in a number of different speeds, the following assembly instructions (Ratio 1:88) are for the best operating speed of the *AMAZER*. This is the fastest configuration possible that ensures that the *AMAZER* stays on the table top.
NOTE: the next ratio down (1:192) is much slower)

6.1.1 GENERAL ASSEMBLY INFORMATION

The assembly sequence consists of assembling the outer gear and shaft first, followed by the inner shaft and gear. The last item to be assembled is the motor and worm gear.

NOTES:

- ☐ When assembling the second gear to any shaft ensure that there is about 1/2mm CLEARANCE, so that the shafts can turn freely.
- ☐ The 40mm long 3.0mm inside diameter white PVC tube is to assist in assembling gears onto the shafts, but it is not part of the gearbox.



OUTPUT SHAFT HOLE LOCATIONS

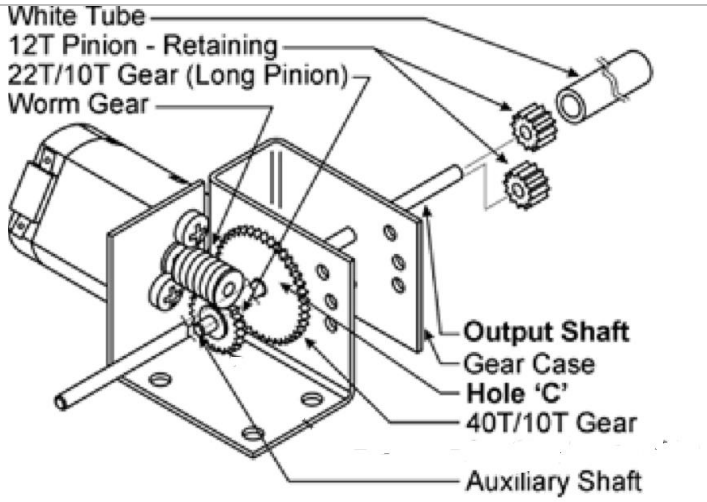
1:88 VERSION

PARTS REQUIRED:

- ☐ *1 x Gear case (Versatile)*
- ☐ *1 x Shaft – Steel – 2.5x70mm*
- ☐ *1 x Shaft – Steel – 2.5x120mm*
- ☐ *2 x Pinion gear 12T – 2.4mm hole*
- ☐ *1 x Spur gear 22T/10T – white 2.4mm hole (pinion gear is 7.25mm long)*
- ☐ *1 x Spur gear 40T/10T – white 2.4mm hole*

For this gearbox you will need two shafts:

- ☐ One long shaft - up to 120mm long (this is the output shaft).
- ☐ One shaft 35mm long (cut from the 70mm shaft).



THE OUTPUT SHAFT

- ☐ Place one 12T pinion gear on the bench. Place the long 2.5mm dia. steel shaft into the gear's hole.
  - Use a small hammer to tap the shaft into the gear hole until the shaft reaches the other side of the gear.
  - Place this shaft (with the 12T pinion gear) through hole "C".
- ☐ Place the 40T/10T gear with the 10T gear facing downwards on the bench and insert the other end of the shaft into the gear's hole.
  - Use a small hammer to tap the shaft into the gear hole until the shaft reaches the other side of the gear.
- ☐ Place the 40mm white tube on the top of the shaft with the 40T/10T gear and use it to tap down the 40T/10T gear to the gear case.

THE SHORTER SHAFT

☐ Place a 22T/10T gear on the bench with the 10T gear facing upwards. Place the 35mm long steel shaft into the gear's hole and repeat the process as for the previously described gear and shaft.
- ☐ Place the 12T gear on top of the 25mm thick block of wood.
- ☐ Place the shaft through Hole "A".
  - Repeat the process described previously to locate the 12T pinion gear

NOTE: Ensure that the 12T pinion gear meshes with the 40T/10T gear.

6.2 THE BODY

The body of the *AMAZER* is in two parts.

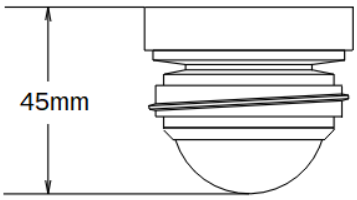
- The Base has the motor gearboxes and ball roller (made from a plastic roll-on deodorant bottle) mounted underneath. On top are mounted the battery holder and protoboard.
- The Neck which has the IR LED and Photo transistor mounted underneath.

☐ The holes on the Base and Neck used to fix them together are 3mm.

☐ The Neck is fixed to the base using one of the M3 x12mm Bolts, 2 washers, one washer underneath the head of the bolt and the other washer between the Base and the M3 Nylock Nut. It should be done up tight enough so that when the neck is moved it remains in place.

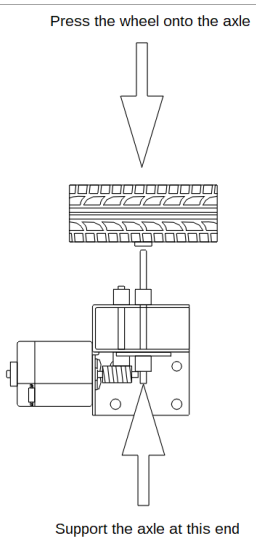
6.3 ASSEMBLING THE BASE

You will need to find a suitable empty plastic roll-on deodorant bottle. Measure 45mm from the ball and carefully cut off the end section.
You can either glue this directly to the Base or to make it more rigid, cut out a disk from suitably thick material to fit inside the top lip, then glue it to the Base.



Place the motor/gearboxes on the Base. Make sure the axles on both are in line. Mark two diagonally opposite holes on each motor/gearbox. Drill these holes with a 3mm drill.

Cut axles of the motor/gearboxes to the appropriate length. Use a file to chamfer the end of the axle. This will make it fit better into the wheel. Support the bottom end of the axle and then either use a drill press to press the wheel onto the axle or use a hammer and carefully tap the wheel onto the axle.
Use 2 x M3 bolts and nuts to fix each of the motor/gearboxes to the base. Work out where you can place the roller ball and then glue it in place.



6.4 THE NECK

Remember that when you cut the neck out, it must be long enough so that the distance from axles to the IR LED and the Photo Transistor is at least twice the distance between the outside of the two wheels (see previous section).

Once the neck has been cut out measure where the 3mm hole will be drilled at one end and then mark out where the IR LED and Photo Transistor will be mounted. The 4 holes are all 1mm and the spacing can be seen in the picture below.

☐ **Mount the Infra Red LED (Blue body)**

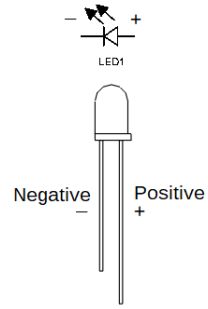
LEDs are polarised components and must be mounted correctly.

The negative lead can be identified in different ways:

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

2.The short leg is negative

3. A flat on the ridge, around the base of the LED is on the negative side.



☐ **Mount the Infra Photo Transistor (Clear body)**

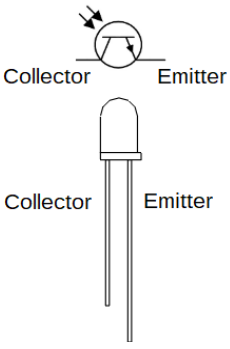
This is a special type of transistor and although it looks like a LED it has different connections. It only has two leads. The collector and the emitter. The usual 3rd lead of a transistor, the base is not present and the base connection for this type of transistor is operated by light. An appropriate light level will enable the current to flow through the photo transistor.

The Collector is identified using the following methods.

1. The flag (the larger connection inside the body) identifies the Collect lead. This is visible when the LED is held up to the light.

2. The short lead is the Collector.

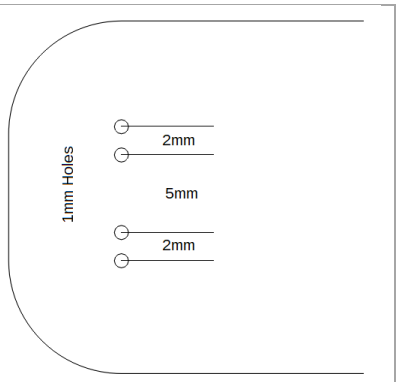
3. A flat on the ridge, around the base of the Photo Transistor is next to the Collector lead.



The IR LED and Photo Transistor are mounted underneath and the leads pass through the holes to the top and are soldered to the wires from the Protoboard.

The neck is fixed to the base using one of the M3 x12mm Bolts, 2 washers, (one washer underneath the head of the bolt and the other washer between the Base) and the M3 Nylock Nut.

To do this you will need a screwdriver and spanner to hold the nut when tightening.



- Do up the nut and bolt. It should be done up tight enough so that when the neck is moved it remains in place.

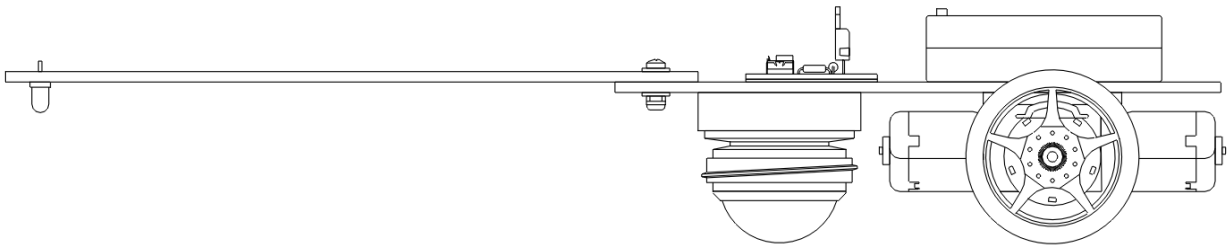
6.5 THE AMAZER ASSEMBLED

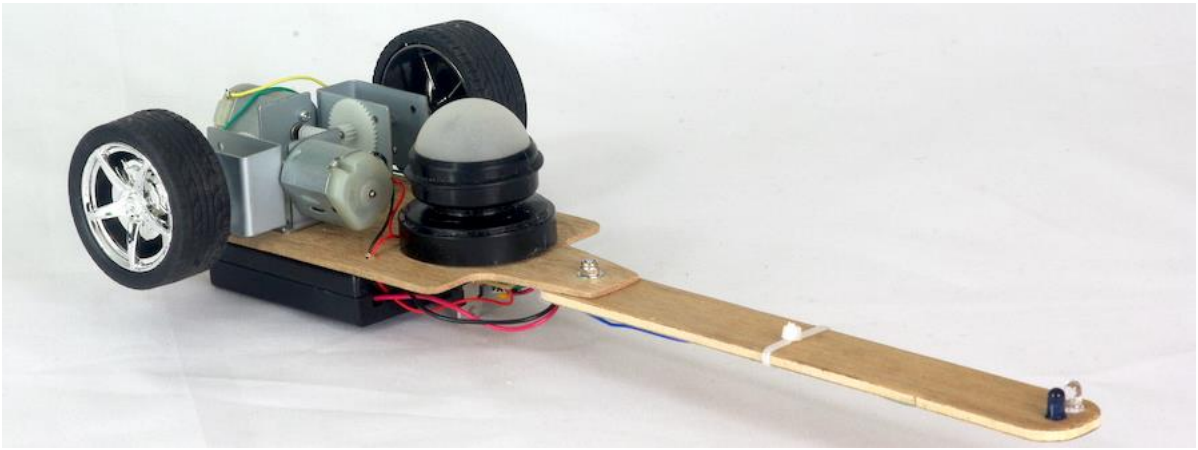
☐ To complete the assembly of the *AMAZER* the battery holder must be positioned on the base.

- It will make wiring easier if the wires and switch are at the end facing the Protoboard.
- Use either hot glue or double sided tape to attach it to the base. HINT: Double sided tape will adhere to plywood much better if the plywood is varnished.

AFTER all the wiring has been completed, use double sided tape to hold the Protoboard in position.

This picture shows the *AMAZER* with all the parts in their positions.

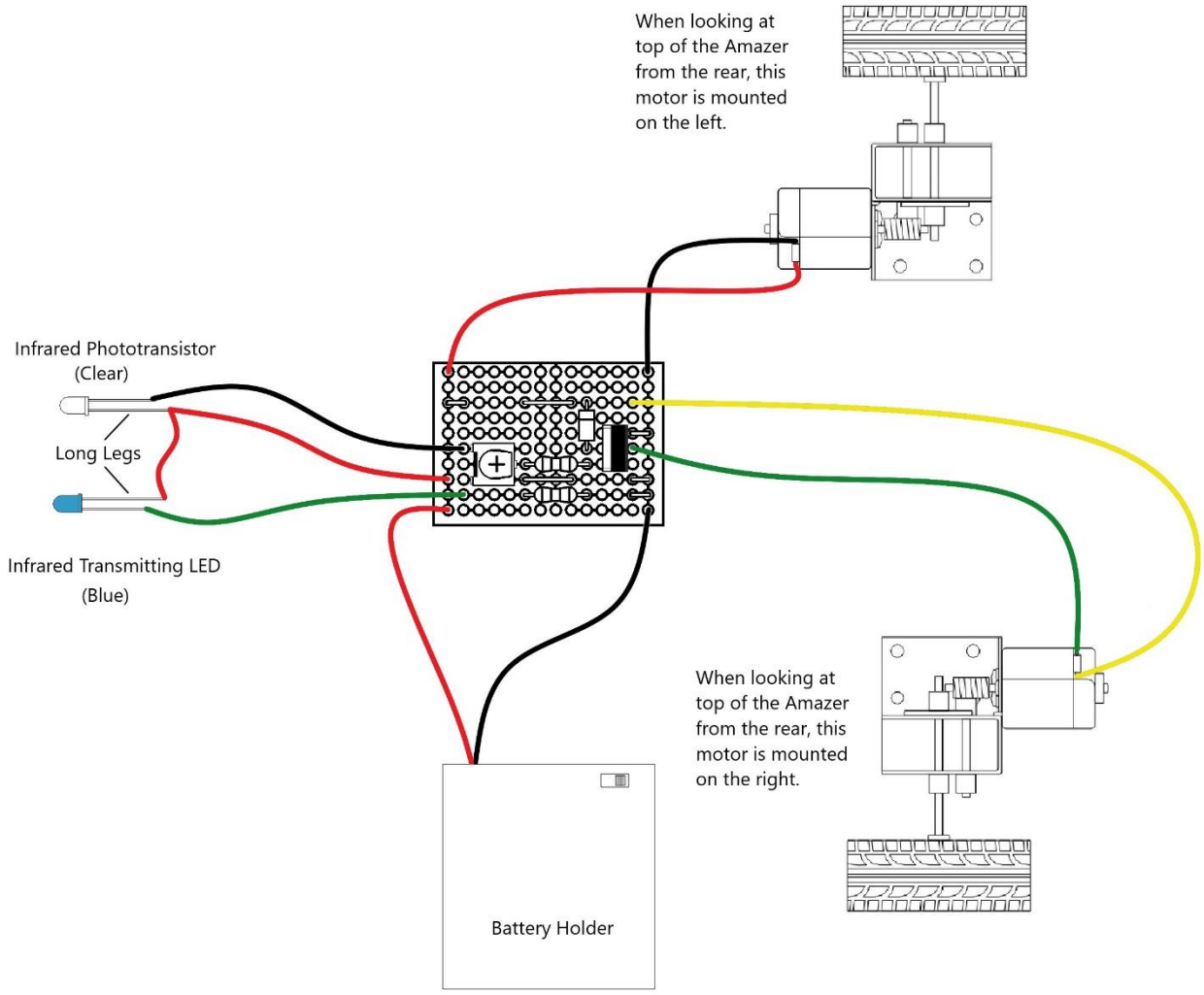




6.6 WIRING THE AMAZER

Use this wiring diagram to wire up the *AMAZER*. Follow the diagram carefully, any

errors will prevent the *AMAZER* from working.



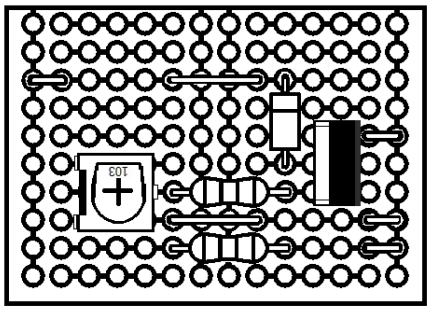
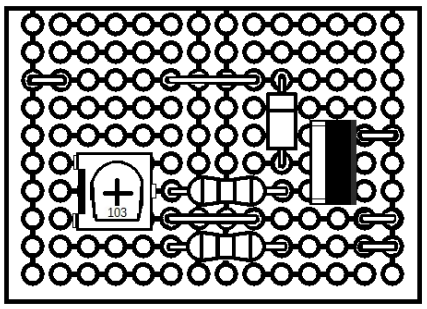
SECTION 7: TESTING AND ADJUSTMENT

- ☐ Once you have completed the construction of your *AMAZER* and you have checked everything and are satisfied it is correct, you will then need to insert the batteries.
- ☐ Adjust the Trimpot to mid position.
    - Hold the *AMAZER* in your hand.
    - Turn on the switch.
    - When looking from the back of the *AMAZER* the right motor will operate continually.
    - Move the IR LED and Photo Transistor over a flat surface. The left motor should begin to operate. If this is what is happening then you need to move the IR LED and Photo Transistor past the table edge. When you do that the left motor should stop.
    - The trimpot is used to adjust the sensitivity of the *AMAZER*'s response to the table top and edge.

You can adjust the sensitivity of *AMAZER* to respond to different coloured table tops and table edges.

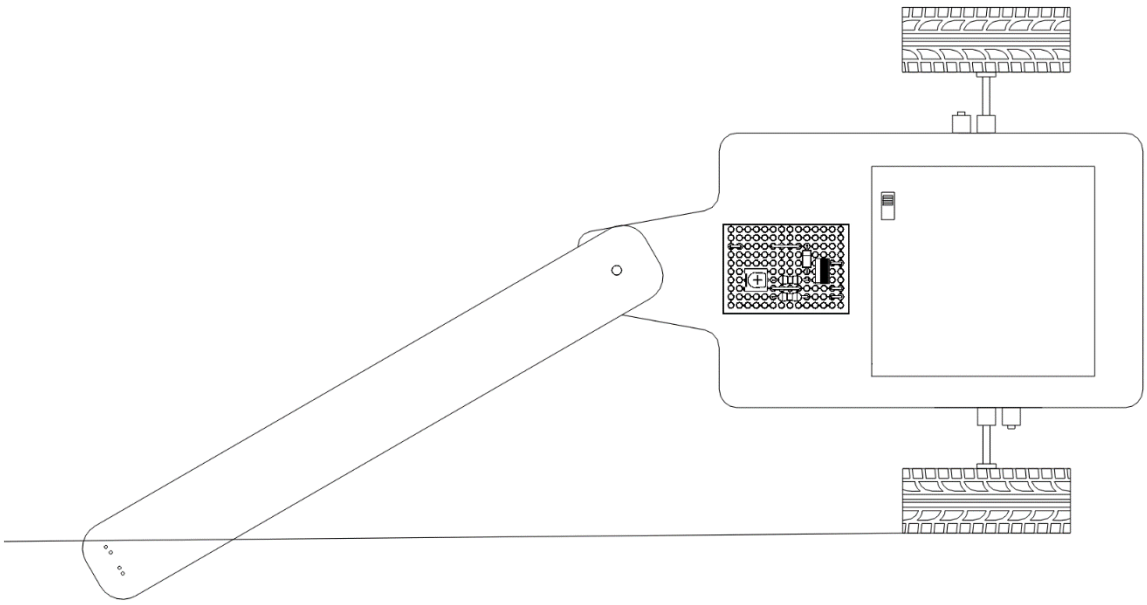
- For a darker table top and to adjust for the height of IR LED and Photo Transistor above the table surface the sensitivity will need to be increased.
- For a lighter surface and lower height of the IR LED and Photo Transistor above the surface the sensitivity will need to be decreased.

- See the following pictures.

	
To increase sensitivity turn the Trimpot Anti-Clockwise	*To decrease sensitivity turn the Trimpot Clockwise*

☐ The neck needs to be angled so that the IR LED and Photo Transistor are past the outside the edge of the *AMAZER* s left wheel, as shown in the picture below.
☐ Experiment with different angles to see what angle works best.

DIRECTION OF TRAVEL
The *AMAZER* will travel in a clockwise direction around the table top. If for some reason you wish to make the *AMAZER* travel around the table top in an anti-clockwise direction then all you need to do is swap over the wiring of the two motors and angle the neck in the opposite direction to what is shown below.



NOTE: For the correct angle of the neck it must be past the outside edge of the table edge motor.

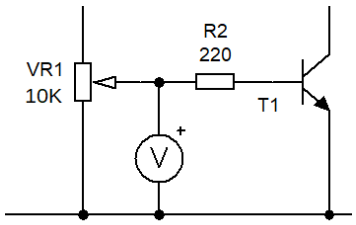
SECTION 8: TROUBLE SHOOTING

TROUBLESHOOTING:

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

☐ Check battery voltage. It should be around 6 Volts.

- ☐ Check the orientation of the Battery leads connected to the Protoboard. Red is positive and Black is Negative.
- ☐ Check the position of components on the Protoboard against the drawing. Even one hole position different will probably mean it is a problem.
- ☐ Check that bare wire ends do not touch
- ☐ Check that bare wire ends do not touch.
- ☐ Check for short circuits (solder bridges), these can occur more easily between close components.
- ☐ Make sure there are no dry joints (they can look "frosty") - 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)
- ☐ Check that the IR LED and the Photo Transistor are facing in the correct direction.
- ☐ Check that the leads from the IR LED and the Photo Transistor are not short circuited by a solder bridge or wires touching (shorting).
- ☐ Check that Transistor T1 is facing in the correct direction.
- ☐ Check the values of resistor R1 and R2 are correct.
- ☐ Check the direction of diode, D1. Check that D1 has its positive and negative leads in the correct direction. If the diode is inserted the wrong way round the circuit will not work.
- ☐ A motor or motors are turning in the wrong direction. Reverse the wires connected to the terminals of the motor.
- ☐ Compare your project to a working one and look for differences in component placing, orientation, component values and soldering.

☐ If the right motor (looking from the rear) does not turn on and off in response to the table surface and edge, check that the IR LED and the Photo Transistor are working. To check this you need to place a voltmeter between the junction of the 220 ohm resistor and the Trimpot and negative. If you adjust the Trimpot between minimum and maximum you should see a meter reading between zero and a couple of volts.	

- ☐ If you get a reading of a couple of volts and the motor does not operate check the orientation, placement and soldering of the Transistor.
- ☐ Use a Transistor Tester to check that the Transistor is operating correctly. Replace the Transistor if the transistor Tester shows it is faulty.
- ☐ If this still does not enable the *AMAZER* to operate, check diode D1. If it is facing in the wrong direction the motor will not work.
- ☐ Lastly if everything has been and the motor still does not turn, disconnect the motor and apply 6 volts to its terminals. If it does not turn there are two possibilities, either:
    - The gears are fitted too tightly and the gearbox cannot turn
    - The motor is faulty.
- ☐ After determining which it is, either:
    - Loosen up the gears (see Section 6.1.1).
    - If the motor is faulty, replace it.

ENJOY YOUR PROJECT.