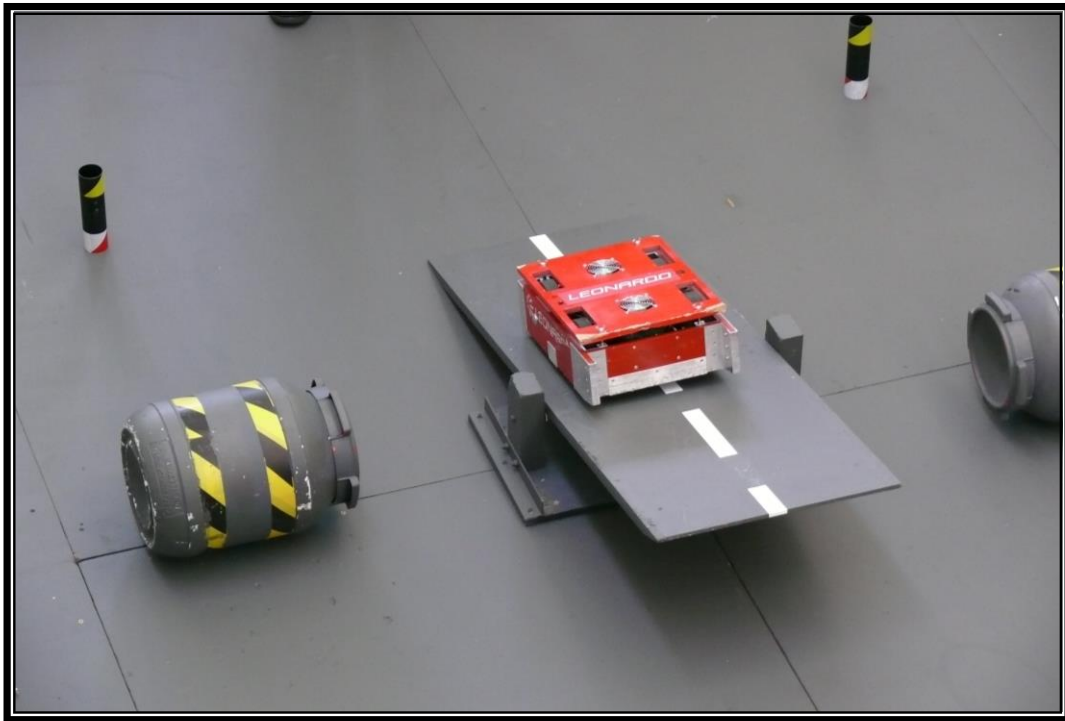




# Construction of a Rampaging Chariot



Instructions on how to make a powerful featherweight sporting robot  
to compete in the

**Assault Course, Sumo and 2-a-Side Football Competitions  
at the Rampaging Chariots Robotic Games.**

by

**Rampaging Chariots Guild**

**BBC Technogames Assault Course World Record Holders  
UK Robot Wars Lightweight, Middleweight and Heavyweight Grand Champions  
World RobOlympics Silver Medallist (Typhoon 2)**

In partnership with



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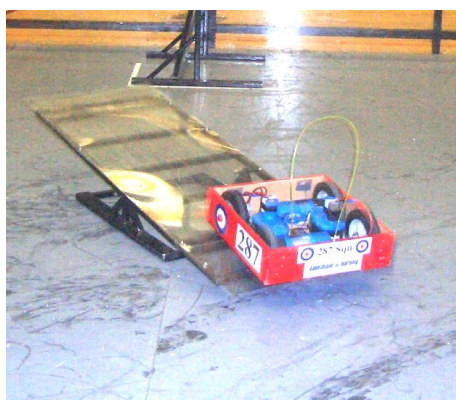
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# Robotics Challenge

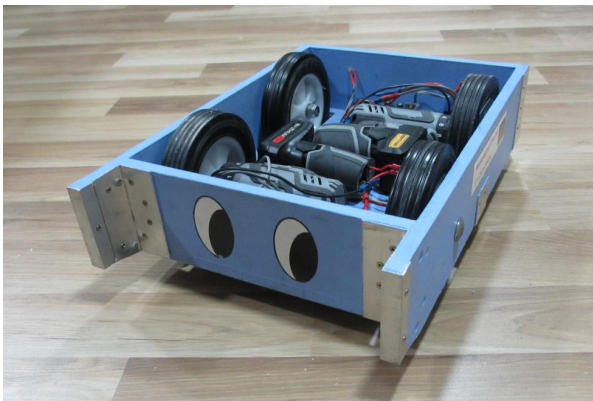
**Your team's mission is to design and construct a powerful robot to compete in an Assault Course competition and to play in a two-a-side Football Tournament.**

## Theory 1. Introduction

Teams have to construct a radio controlled robot to:

- Race head to head through a series of obstacles including a see-saw and score a penalty goal. Time penalties will be awarded for obstacles knocked over. The quickest time will win.
- In conjunction with other teams play two-a-side football for 3 minutes. In the event of a draw, 1 minute of extra time is allowed and the first team to score a 'golden' goal is the winner. If there is still no score at the end of 4 minutes, a simultaneous penalty shoot-out will decide the winner.
- Undertake Sumo and Tug-of-War events which test agility and strength.

This project is challenging, but hugely rewarding. Students will work as a team to produce a robot that has **a very sporty performance and is not a toy**. Safety is therefore a prime consideration. The assault course and football tournament will provide a major challenge and an exciting climax to the project.



The construction task is to

- Build a chassis to a standard design from a kit of wood, plastic and metal parts.
- Construct two electronic motor controllers from a kit (requiring soldering skills).
- Dismantle two cordless electric drills
- Install in the chassis: two drill motors, four wheels, two batteries, radio receiver and aerial.
- Wire up the components.
- Test

Teams of four or five students will build a standard Rampaging Chariot. Two or three students should work on the chassis and two students make the two electronics boards. The team will then install the components, wire up and test their robotic creation. If the electronics boards are made in parallel with the chassis, our experience is that a Rampaging Chariot can be finished within six or seven periods of 90 minutes each.

Having achieved a working robot and fully tested its capabilities, the team should consider the design and brainstorm improving its performance. If they wish, they can then construct an improved personalised chassis and transfer the main components into it.

A robot combines a number of technologies and at the end of the project students will have gained a general appreciation of materials, motors, power controllers, electronics, radio control, ergonomics, artistic design, safety considerations and test techniques.

**"Far better it is to dare mighty things, to win glorious triumphs, even though chequered by failure, than to take rank with those poor spirits who neither enjoy much nor suffer much, because they live in the grey twilight that knows not victory nor defeat."**

**Teddy Roosevelt**



### **Main Components**

4 channel 2.4GHz digital radio transmitter  
 Radio receiver  
 2 Cordless electric drills with batteries and chargers  
 2 Motor controller electronics kits  
 4 Wheels and axles  
 12mm MDF chassis parts  
 Miscellaneous aluminium angle parts  
 Nuts, bolts and screws.  
 Velcro

A full list of components is at Appendix C



### **Tools**

You will need the following basic tools  
 Small & Medium Posidrive Screwdrivers  
 Pointed Nose Pliers  
 17mm Open-ended Spanner  
 Coping Saw  
 Hacksaw  
 Flat and Round Files

Scissors  
 Wire Cutters  
 Hand or Power Drill  
 Set of Drill Bits including 7mm and 10mm  
 Countersink  
 Soldering Iron with a small Bit  
 Solder  
 Electrical Test Meter

### **Rules for the Rampaging Chariots Robotic Games**

The full rules of the Rampaging Chariots Robotic Games are available at [www.rampagingchariots.org.uk](http://www.rampagingchariots.org.uk)

The full rules take precedence over the following summary:

No weapons of any kind may be fitted and dangerous projections will be disallowed.

Robots must not have any device that can physically hold the ball, but may have 2 guides fitted to the front of the machine, with a maximum projection of 50mm in front of the main chassis, to gather and control a small football (Ball diameter is approximately 125mm)

There must be easy access to a switch or the push-on battery connectors so that in the event of a run-away the robot can be inhibited easily.

Maximum overall dimensions: 600mm (length) x 450mm (width).

Maximum Mass: 12 kg.

Electric power only. Maximum battery voltage: Nominal 18 volts

Radio control - 2.4 GHz band.

All team members must be under 18 years of age on the day of the competition, although adult supervision is permitted.

Robots will be examined to ensure their build is consistent with that anticipated from an under 18 team.

### **Design**

A good design is always a compromise, but by careful thought students can produce (using the standard parts supplied) a very high performance robot that is unique.

Keep the design simple and easy to construct using the KISS (Keep It Simple Stupid) principle. You must allocate your construction time to allow for a reasonable period of testing. This may be followed by some design changes.

This is not a combat robot, but your creation may fall off the ramp and minor collisions are inevitable during the football competition. Your construction should therefore be reasonably robust and easy to dismantle service and repair.

The project is split into sections with an introduction to the technology, design considerations, construction hints, photos and advice. A basic robot design is described and this should be constructed first.

Students should then be encouraged to think of ideas (within the rules) that will improve upon the standard design and thereby gain a possible advantage over their opponents.



**Basic Robot Example**

## Theory 2 - Safety

### **Soldering Irons**

Irons are hot and will burn you if they touch your skin. Be careful.

Molten solder can splash so wear eye protection.

Soldering should be done in a well ventilated room and you should avoid breathing in the fumes.

### **Sharp Edges**

Any sharp edges should be filed smooth and spikes such as the top of the aerial wire should be bent over at the top to avoid injury to eyes.

### **Batteries**

If you short the battery wires together there will be a bang and a flash. The leads may melt and fuse together and you may start a fire or burn yourself.

Battery connectors must be accessible at all times so that in the event of a runaway robot they can be removed easily to immobilise the robot very quickly.

### **Electric Shock**

Maximum battery and charging voltage is 22 volts. You should not get an electric shock from this voltage.

Chargers plug into the mains and should be treated as a normal mains electrical appliance. Do not switch on at the mains until the charger is connected and switch off when disconnected from the batteries.

Standard charge rate is 1500 mA.

### **Testing at your Bench**

A runaway robot is highly dangerous. Batteries must therefore only be connected on the bench when the robot wheels are off the ground and free to rotate.

Batteries must not be connected if the robot is unattended or if the transmitter is not physically in your possession. Radio interference or another team operating on your frequency could cause your robot to move.

### **Testing in the Arena**

Dynamic robot testing must only be undertaken in an arena.

The person connecting the battery should do so slowly and stand to the side of the robot so that the battery can be disconnected immediately if any movement occurs.

### **Radio Control**

The 2.4 GHz digital proportional radio transmitter is paired to its receiver and should not interfere with other robots.

Transmitters have an audible beep to indicate a low battery which should be recharged before a competition. Switch off transmitters when they are not in use.

To ensure good reception mount the receiver aerial away from sources of electrical noise such as the motor control boards and the drill motors.

### **Loose Clothing**

Electric drills are powerful. Keep loose clothing away from the robots and do not wear a tie to avoid it getting caught in the mechanism and strangling you.

### **Weapons and Aggression**

Robots may not be fitted with weapons of any description.

The Assault Course and Football competitions are not a war. Teams will be yellow carded (one warning) and red carded (banished to a sin bin) if they employ aggressive or dangerous tactics.

A risk assessment example for the specific robot activities is included at Annex B.



## Theory 3 - General Theory

### Motive power

The robot could be powered by either electric motors or an internal combustion (petrol) engine.

A **petrol engine** has very little power at low revs which is why it is easy to stall a car engine. It requires a clutch to start off from rest and needs a gear mechanism to reverse.

**Electric motors** have high torque (turning power) at low speed and do not require a clutch. The forward speed can either be varied by a simple three position switch commanding Forward-Off-Reverse (where the robot proceeds in a series of accelerating and decelerating steps) or by a more sophisticated electronic device which allows a smooth and precise speed to be demanded.

We have chosen to use electric motors from cordless electric drills and build electronic speed controllers to give smooth and precise control via a radio link. Either a normal drill or a hammer drill will work (provided the hammer action is removed or not selected).

Cordless electric drills are excellent for motive power as they have compact epicyclic gearboxes to provide a rotation speed that is ideal for robots of this nature. There are, however, a few snags to be addressed:

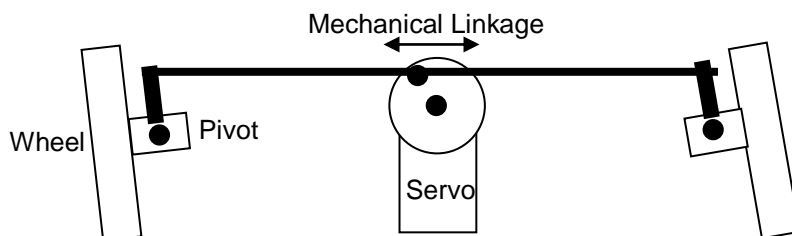
- We need the robot to be able to reverse under radio control. Unfortunately the normal variable speed control selected by the drill trigger works in one direction only and the drill motor must be stopped and a reversing switch operated mechanically before the motor will turn in the opposite direction.
- Electric drills have a torque limiting mechanism. This can be locked by selecting the screwdriver position, but some backlash remains that can cause huge stress on the gearbox when power is reversed from full forward to full reverse. We incorporate a software filter to reduce this reversal shock to acceptable limits.
- Most modern electric drills have a mechanical brake which stops rotation as soon as power is reduced or reversed. The drills we supply have had this feature removed.

### Steering

There are two main choices: 'car type' or 'tank type' steering.

**Car type steering** is very precise and involves moving the front wheels left and right. This requires an electric motor, mechanical linkages and hinged wheels. Turning on the 'spot' (also known as a zero turning circle) is achieved by shunting backwards and forwards (a three point turn). It is therefore difficult to manoeuvre or park in a confined space.

Steering control can be a simple but crude Left-Off-Right switch (called 'bang-bang' control) as in some cheap model cars, or alternatively a more sophisticated radio control servo (called 'proportional' control). A servo contains an electric motor that rotates a lever to a position that is proportional to the movement of a control lever on the transmitter. A potentiometer within the servo senses the angle achieved by the servo, compares this with the angle demanded and stops the motor when the correct angle is reached.



**Car Type Steering Mechanism**

**Tank type steering** (also known as differential skid steering) involves driving the wheels on one side faster than the wheels on the other side. An electrical device for controlling the current to the individual motors is required. Turning on the spot is achieved by turning the wheels on opposite sides in opposite directions. The wheels skid sideways over the ground during the turn.

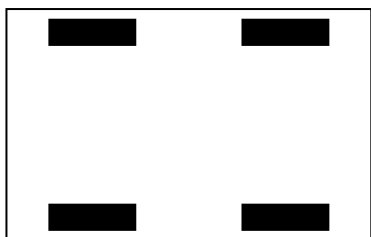
Steering control can again be a simple, such as a crude Forward-Off-Reverse switch (bang-bang) for each motor, or alternatively a more sophisticated (proportional) control using electronic speed controllers to vary the current to each motor and thereby achieve the individual wheel speed (and direction) demanded.

For ease of construction, reliability and robustness Rampaging Chariots use 'tank type' steering and two electronic speed controllers are constructed by pupils to achieve proportional control of the motor speeds and direction.

## Wheels

For stability 4 wheels are generally better than 3 wheels.

If you mount two drill motors in line back to back to provide a classic front wheel drive or rear wheel drive configuration the chassis will be very wide and you will have difficulty negotiating the obstacle course. Rampaging Chariots therefore use diagonal drive (one front wheel and the opposite rear wheel). This has proved quite satisfactory provided the two drive wheels are always in contact with ground and take almost all the weight of the robot. The other two wheels are purely to balance the robot and should be mounted higher than the drive wheels. The robot will rock slightly when stationary, but this is not a problem and is hardly noticeable when driving.



The wheelbase (the distance between the front and rear wheels) is important and has to be a compromise. Increasing the wheelbase increases straight line stability (minimise the tendency to move in a curve). It will also prevent the robot tending to tip up when it starts or stops quickly. Also, the nearer the wheels are to the front and back the easier it is to negotiate obstacles such as a ramp. Unfortunately, if we make the wheelbase longer, the robot requires more power to turn, as the wheels have to skid more sideways. If the wheelbase is too long the robot may not have enough power to turn on the spot.

With no turn demanded we want the robot to travel in a straight line both forward and backwards. We also want it to change direction quickly and precisely. To drive the left and right wheels forward one motor is driving clockwise and one motor is driving anticlockwise. The batteries may have slightly different charge states and one motor may turn faster than the other. This may cause the robot to move in a slight curve.

## Axles

One option is to fit a 10mm bolt through the wheel hub and tighten up a nut to grip the wheel. The thread of the bolt can then be gripped firmly in the drill chuck. (see photo above)

Experience has shown this method to be unsatisfactory as the axle can come loose in the drill chuck during spirited manoeuvring and the bolt can come loose in the wheel hub. We have therefore designed and supplied a special axle which screws directly onto the threaded motor shaft and is locked in the same way as the original chuck using a central screw with a left hand thread. Drill chucks are now no longer included in the kit as several schools had difficulty removing them from the drill.



**Wheel and Axle held in Drill Chuck**



**Direct Attachment To Motor**

## Maximum Horizontal Speed.

Speed is Distance / Time.

For one revolution of the wheels the robot moves forward by the circumference of a wheel.

The horizontal speed of the robot is the circumference of the wheel times its speed of rotation.

Wheels are 75mm radius. The circumference of the wheel is  $2\pi \times \text{radius} = 0.47 \text{ m}$

Motors turn at over 20000 rpm and our two gear selections give approximately 0 to 400rpm or 0 to 1400rpm = 3.1 or 11.0 metres per second.

Maximum horizontal speed = **6.9 or 24.6 miles per hour**

In practice, friction will reduce this top speed and because our motor drive boards allow you to select full reverse from full forward, we limit and smooth the power demand to avoid the gearboxes from disintegrating. We recommend you use the slower gear 1 as this is quite fast and gives much better precise control.

## **Batteries**

**Voltage.** Your cordless electric drill batteries are rechargeable Li-ion batteries providing a nominal output of 18 volts. As a general rule the power from a cordless electric drill is proportional to the voltage and the price also increases with higher voltage as more battery cells are required. The motor controllers require at least 9 volts to function and for safety the electronic circuit will shut down below this voltage. As 2 volts is lost across the voltage regulators the minimum battery voltage is therefore 11volts. Battery voltage reduces when supplying a large current and also reduces as the battery becomes discharged in use. A 12V or 14V battery will probably work when it is fully charged, but the boards will soon shut down if a large current is demanded. If you use a battery with a voltage in excess of the drill motor specification the motors may overheat and sparks from the commutator may cause radio interference and speed glitches. We have found that 18V batteries provide the best compromise and value for money. Look after your Li-ion batteries, always charge them with the charger supplied, and if they get damaged do not use them as they might catch fire.

**Capacity.** The capacity of the drill batteries is 1300 mAh each which means the battery will deliver a current of 1.3 Amps for one hour. The battery will also deliver twice this current for half the time or four times the current for a quarter of the time. The current required depends on how aggressive you are with the controls. When accelerating from rest and turning on the spot about 10 amps per motor is required and even more if you select reverse from full forward speed. When travelling at a constant speed, only about 3 amps per motor is required. Assuming you use two batteries (one for each motor) and do average manoeuvring, the batteries will probably last for about 20 minutes. If you stall the motors (prevent the wheels turning) a huge current will be demanded (almost the same as a direct short circuit between the battery terminals) which can only be sustained for a few seconds before the motor windings, battery, electronic speed controllers and even the main interconnection wires heat up and melt.

Use of low gear (if available) will use less power from the batteries as you are less likely to stall the motors and they use much less power when rotating quickly. (This is due to a phenomenon called 'back emf').

**Fixing.** Batteries can be fixed to the chassis with Velcro. There must be easy access to the battery connectors so that in the event of a run-away the robot can be inhibited easily. Alternatively a double pole ON-OFF switch can be fitted that switches both red wires from the two batteries.



## **Charging**

The mains chargers supplied will recharge the batteries from zero charge to maximum in about an hour. Always charge batteries on a bench in your workshop or garage. Never use the charger in your home. The red light will illuminate to indicate charging is in progress. The green light indicates the battery is charged.

The batteries heat up when charged and should never be allowed to exceed 40 degrees C.

Do not exceed the recommended charging time (e.g. by leaving them on charge over night) or you may damage the batteries and charger.

Do not dispose of the battery by incineration, as the battery will explode.

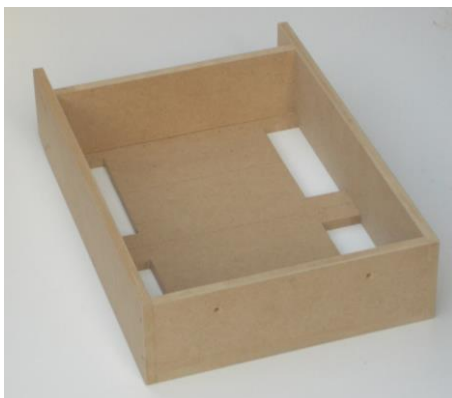


## Chassis

**Size.** The interior of the chassis must be large enough to contain all the components, but not too large or it will be heavy, sluggish and difficult to control on the ramp. The prototype example is 400mm long (excluding ball guides) and 310mm wide, but these dimensions can be altered provided you keep within the maximum dimensions and mass allowed (see design rules). A narrow robot is better for the assault course where you have to negotiate obstacles with a fixed width. For football a wider chassis can be an advantage.

**Materials** for the chassis are your personal choice. MDF is generally a good material for the base with MDF, plastic sheet or aluminium for the sides and superstructure. If you use a metal chassis you will have to **put insulating material between the printed circuit boards and the metal chassis to prevent short circuits.**

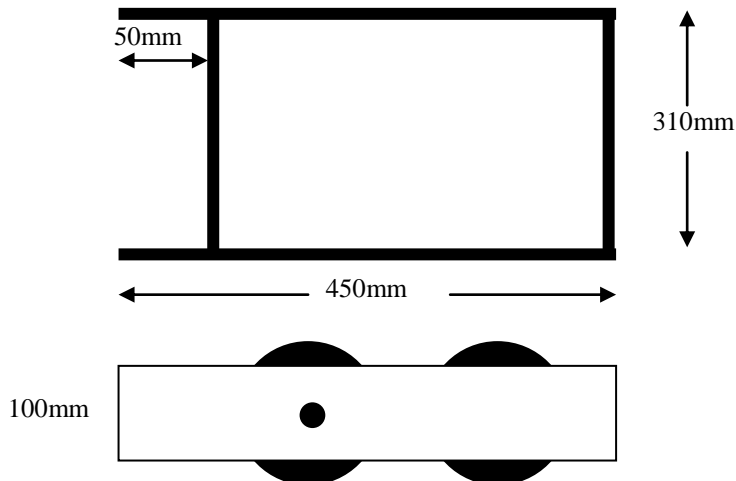
Your construction should be reasonably robust and easy to dismantle service and repair.



**Chassis Made of MDF**

## Ball Guides

Robots must not have any device that can physically hold the ball, but may have a pair of ball guides which project no more than 50mm from the front of the machine to gather and control a ball (Ball diameter is approximately 125mm).



## Aerial

To avoid interference and poor reception keep the aerial away from the electronic motor control boards and the electric motors.

No not change the length of the aerial as this is very important for good radio control reception.

## Artistic design

You can improve the appearance of your robot by adding a simple superstructure and by some imaginative design and colour. Some hints are given later in this manual.

## Theory 4 - Electronic Motor Controllers

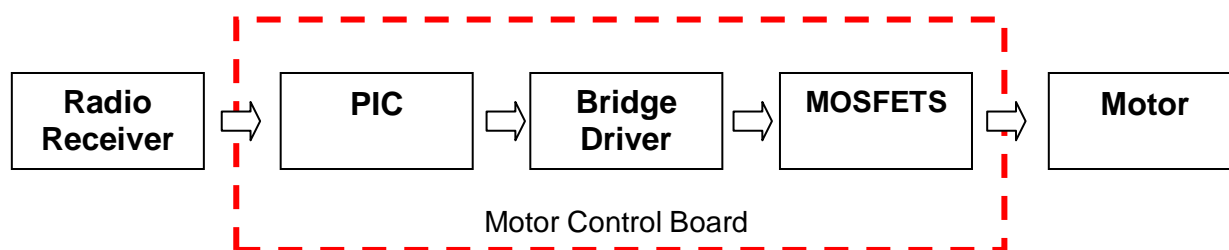
Most cheap toy cars have a 'bang-bang' control system. This has only two selections: Zero or full speed. For precise control you need a proportional control system. You will build two motor controllers that give you full electronic control of forward, reverse and proportional speed via radio control.



### What The Motor Controller Does

The motor controller takes the separate left and right channel low voltage control signals from the radio receiver and switches the main battery power to the motor (Up to 40 Amps). Not only does it control the speed by varying the current to the motor, but it also swaps round the connections to make the motor go in reverse. Note: A cordless electric drill uses a mechanical lever and a mechanical switch to swap over the connections to make it rotate in reverse.

The three main components in the controller are the PIC (Programmable Interface Controller), Bridge driver and MOSFETS.



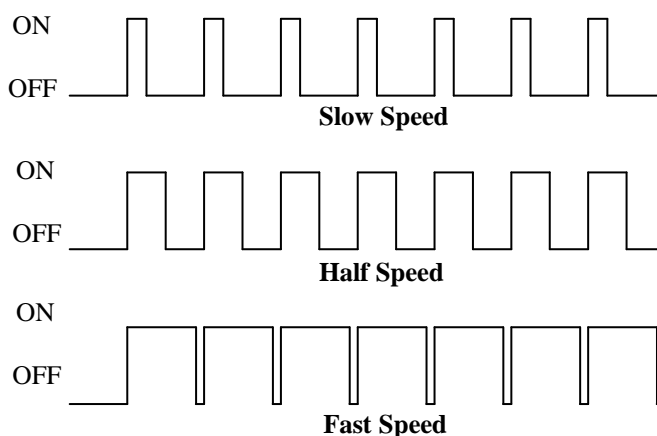
- The Radio Receiver outputs pulses. The width of these pulses determines the required speed and direction.
- A Programmable Interface Controller (PIC) decodes the pulses and checks that a valid control signal is being received. If not, it shuts down the controller and stops the motors. The PIC also mixes the left, right, forward and back demands into the correct outputs for the left and right motors. These outputs of direction and speed are sent as pulses from the PIC to the bridge driver.
- The Bridge Driver electronically switches the correct MOSFET on and off to control the motor direction. MOSFETS are transistors that can switch high power on and off very quickly.
- The Motor receives a series of pulses of current which it averages to give the required speed

### PIC

A PIC can be considered as a small computer on a single chip that is designed to interface with sensors & controls and provide a variety of outputs. There are several different types of PIC and the one we use can be programmed with 2000 commands and has a special Pulse Width Modulated (PWM) output. The software commands are held inside the PIC and can be modified by downloading a programme into it from a normal home computer. The PIC has been programmed by the Rampaging Chariot Guild on your behalf.

### How A Motor Controller Works

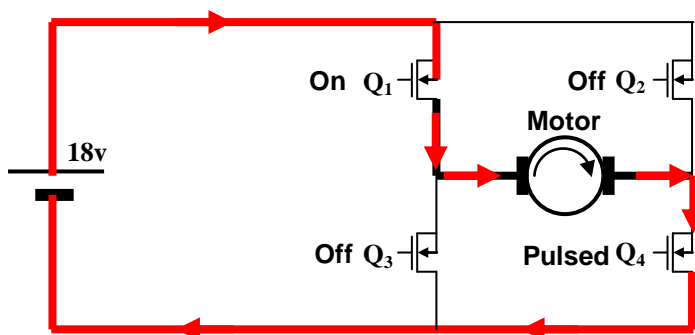
A motor speed controller takes the signal representing the demanded speed and drives a motor at that speed in the correct direction. It works by varying the average voltage sent to the motor. The most efficient way to do this is to switch the full 18 volt supply voltage on and off again very quickly in a succession of pulses. If the switch is on for the same amount of time that it is off the motor will see an average of 9 volts and run at half speed. If the switch is on for longer than it is off the motor will see a higher average voltage and run faster.



### MOSFET Bridge

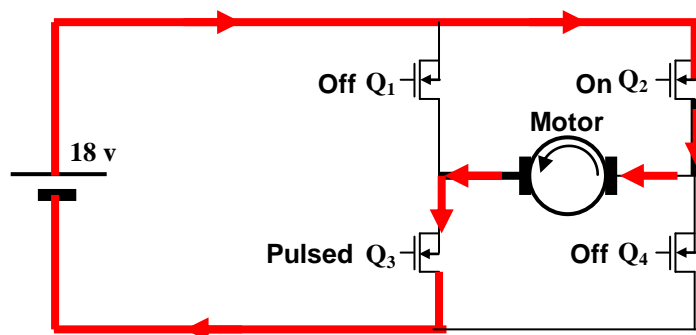
Devices known as MOSFETS (Metal Oxide Semiconductor Field Effect Transistors) can turn very large currents on and off under the control of a low signal level voltage. MOSFETS have a small resistance and therefore heat up when controlling large currents.

To drive a motor, a minimum of four MOSFETS  $Q_1$   $Q_2$   $Q_3$   $Q_4$  are arranged in what is called a full bridge circuit. To make the motor go forwards  $Q_1$  is turned on and  $Q_4$  is pulsed on and off. The current flows through the motor from left to right.



**MOSFET Bridge – Motor Turning Forwards**

To make the motor go backwards  $Q_2$  is turned on and  $Q_3$  is pulsed on and off. The current then reverses direction through the motor and it turns in reverse.



**MOSFET Bridge – Motor Turning Backwards**

### For Geeks

The circuit diagram of the motor speed controller and a more detailed explanation of how it works is at Appendix A.

### Stall Current

The motor requires maximum current at slow speed and much less current when it is turning fast. If you stall the motor and demand full speed, the motor and MOSFETS will heat up quickly and burn out. This results in expensive blue smoke and a horrible smell. Do not therefore keep full power applied if the wheels and motor are stalled and not turning. This is particularly important in the Sumo and tug-of-war events.

### Protection Diodes

Each MOSFET has an internal protection diode to bypass a large back emf from the motor; e.g. when you demand a quick change from forward to reverse. **Take care not to connect the battery the wrong way round or a large current will flow immediately through the protection diodes and destroy them.** The MOSFETS might still work until the moment you demand a sudden speed reversal. They will then burn out – Kaput!

## Theory 5 – Radio Control

### How It Works

Radio Control (RC) is the use of radio signals to remotely control a device such as a model aircraft or robot. For ground vehicles the transmitter (Tx) transmits a radio carrier wave in the 40 MHz or 2.4 GHz bands. (35MHz band is reserved for model aircraft).

The 40 MHz band has 34 channels. Each unique channel frequency is controlled by a crystal in the transmitter and a matching crystal in the receiver. This is very awkward for a large number of robots at a games, as robots will interfere with each other. The 2.4 GHz band has several thousand discrete channels.

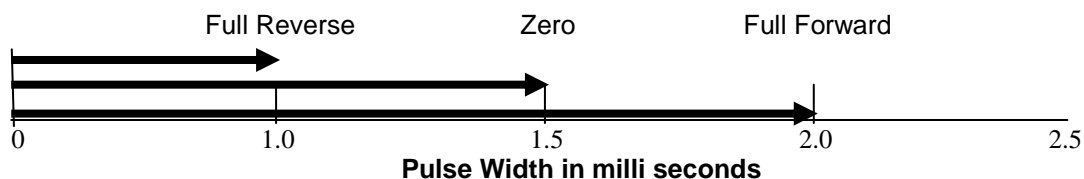
The transmitter looks at the position of each control stick and sends this information by radio to a receiver which is tuned to the same frequency. There are 3 methods used by the transmitter to superimpose the control stick information onto the carrier wave:

- Amplitude Modulation (AM). This suffers from interference and is seldom used today.
- Frequency Modulation (FM). This suffers much less from interference, but is more expensive. To prevent interference between robots, crystals must be fitted to provide discrete radio channels.
- Digital Pulses which are encoded to give proportional control  
(Your new Rampaging Chariot contains a 2.4 GHz digital radio transmitter and matched receiver).

Control position is superimposed onto a carrier wave by modulation. The positions of the four axis controls (channels) are read and transmitted in sequence. In the Transmitter the stick position for Channel 1 is read and the information sent to the Receiver. Immediately afterwards the stick position for Channel 2 is read and that information is sent. This repeats for all of the channels, one after the other followed by a longer gap. The sequence is repeated about 60 times a second so that it appears that the servos instantly know you have moved a control stick.

The Saturn 2.4 GHz radio control system supplied uses a Frequency Hopping Spread Spectrum (FHSS) technique to minimise interference. Under normal circumstances the system hops between a fixed number of channels (frequencies) in a repeating random sequence.

The receiver converts the digitally coded signal into Pulse Width Modulated (PWM) outputs to individual servos, or in the case of the Rampaging Chariot, to the electronic motor control boards. The way the stick position is conveyed from the receiver is by varying the width of a pulse. Typically, a pulse width of 1.5ms (milliseconds) will centre the servo or keep the motor stationary. If the pulse is reduced to 1.0ms, maximum reverse speed is demanded and if it is increased to 2.0ms, maximum forward speed is demanded with intermediate positions available.



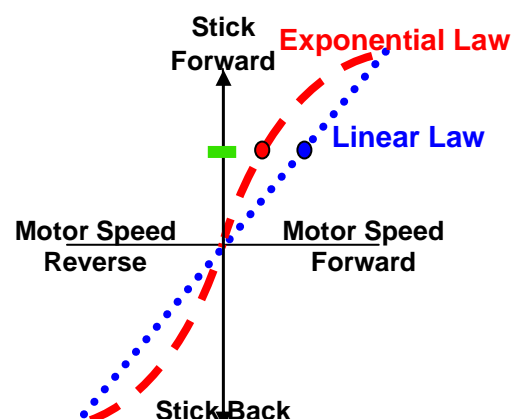
In a Rampaging Chariot the motor control boards convert these PWM signals into the motor speed and direction of rotation.

In a model aircraft the PWM Signal drives servo motors that mechanically move the control surfaces

### Exponential Control Law

To provide precise control at slow speed for accurate manoeuvring it is useful to have the control sticks more sensitive around the central position. This can be achieved by having an 'exponential control law' which allows the sensitivity around zero to be adjusted according to an exponential curve. To minimise the cost of the radio control equipment we have incorporated an exponential control law for both input channels within the motor control boards provided.

From the diagram you will see that moving the stick half way forward (Green Line) will demand half speed with the linear law (Blue Spot), but only quarter speed with the exponential law (Red Spot). At full stick movement both laws demand full speed.



**Control.**

We have decided to use differential skid steering which is also known as 'tank type' steering. This means that the robot is turned by varying the speed of wheel rotation on each side of the robot. If the left wheel is going forward and the right wheel is in reverse, the robot will turn on the spot. (This is known as a zero turning circle).

**Method 1 – No Mixing:**

The speed and direction of the two motors can be controlled independently from the left and right control sticks, but this requires considerable skill to demand precise turns. To go in a straight line you must move both sticks forward exactly the same amount

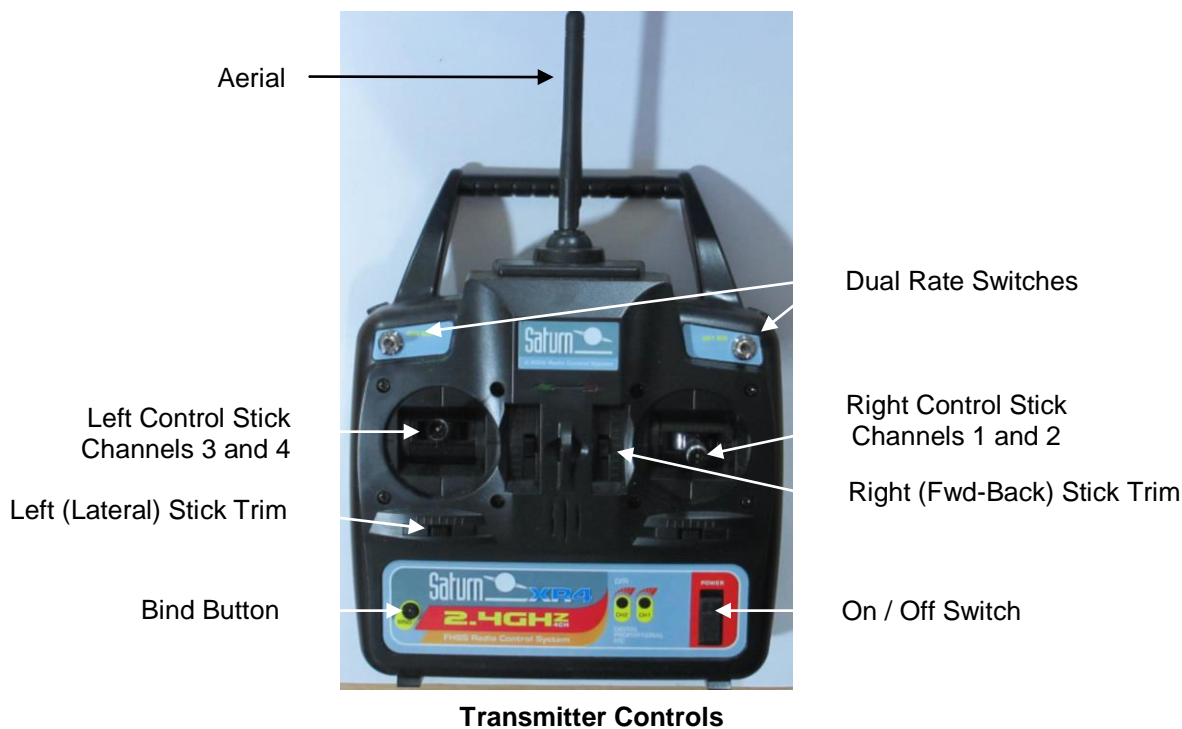
**Left stick controls left motor,      Right stick controls right motor**

**Method 2 – Control Mixing:**

Your transmitter and receiver have four separate functions (or channels) controlled by two sticks. Your Rampaging Chariot uses two of the available control functions and which ones you use is a matter of preference. Note that the left stick up-down movement is normally used as a model aircraft engine throttle and does not spring back to the central position. This is not suitable for forward-back robot movement as the stationary zero speed position is very difficult to select quickly.

It is easier to mix the channels such that one control demands straight line speed from both motors equally, and the second control modifies the straight line demand such that one motor goes faster than the other in order to turn. Moving one control lever on the transmitter forward commands both motors to run forward at the same speed. Moving the other lever sideways causes one motor to go forward and one to go in reverse. If selections are made at the same time the robot will turn whilst moving forward or in reverse. The turn demand is added to the straight line demand to provide the required mixed command to each motor. The robot then turns in the direction of the slower wheel.

You can implement control mixing by using two separate sticks, or one stick moved in two directions. Most drivers prefer that speed and direction are controlled by separate control sticks. We have chosen to use the right control stick forward/back (channel 2) to demand forward speed and the left control stick left/right (channel 4) to demand turn rate. You can easily implement single stick control by moving the lead plugged into the receiver channel 4 slot to the receiver channel 1 slot. (See receiver picture on next page)







### Receiver Binding

The Saturn Radio Transmitter comes already bound as a pair. If it is ever necessary to bind the receiver to another transmitter, first turn off the transmitter and receiver. Press and hold the bind button on the receiver and then power up the receiver in the robot. The LED on the receiver should flash to indicate the binding mode is active. Now release the receiver bind button. Turn on the transmitter power and after the beeps press the transmitter bind button. The green LED should flash at the top of the transmitter. After a few seconds your receiver should bind and be ready for use. If the bind procedure fails then turn everything off and try again.

### Servo Reversing

The transmitter control channels should work in the correct direction if you have the master motor drive board fitted at the front of the chassis connected to the right front motor. If you ever need to reverse the output channels 1-4 you need to start with the transmitter turned off and only reverse one channel at a time. Hold the relevant trim for the channel you wish to reverse to its end in either direction. You should hear a small click. With the trim in that position turn the transmitter ON. The green LED on the transmitter will flash and then turn solid to indicate the channel has been reversed. Repeat this procedure for other channels if required.

### Dual Rates

To enable new drivers to practice at a lower power and speed, two separate power settings can be selected on channels 1 and 2. You will probably only alter the forward power channel 2.

The switches to activate the dual rates are located on the top of the transmitter and are labelled to show each channel. With the switches in the top position each channel has the ability to move 100% of its control range. When the switch is in the lower position the range can be limited. To limit the range, move the relevant switch to the lower position and move the relevant control to its extreme in either direction. Then insert a small flat headed screwdriver into the relevant hole (located to the left of the power switch) and there is an adjuster that can be turned 180 degrees to adjust the range of movement.

### Burning Rubber

**Static Friction** is the force that prevents motion between two surfaces such as a tyre and the floor. It is parallel to the surface, in a direction opposite to the applied force.

The magnitude of the friction force ( $F$ ) is the product of the mass of the object ( $m$ ), the acceleration due to gravity ( $g$ ), and the coefficient of friction ( $\mu$ ) (which depends on the material of the tyre and floor).

$$F = mg\mu$$

This means that the force of friction is directly proportional to the weight ( $mg$ ) which is vertically downwards and should be independent of the apparent area of contact between the rubber tyre and the floor.

The mass of the Rampaging Chariot is supported mainly by the two drive wheels. Very little mass is supported by the two balancing wheels. Cordless electric drill motors are quite powerful and it is easy to overcome the static friction between the wheels and ground and 'burn rubber'. If you select full speed from a standing start the wheels will slip. This is a useful feature as it prevents the motors stalling and heating up.

Static friction is generally greater than dynamic (moving) friction so if the wheels start to slip it should be most beneficial to reduce power to regain traction and then increase power again. Theory indicates that the most efficient way to accelerate is to apply the maximum power possible without the wheels slipping and then increase power gradually as the robot starts to move.

You should experiment yourselves as Rampaging Chariots seem to defy accepted theory.

When you wear off the tread of the two drive wheels does the friction increase? In Formula 1 motor racing, tyres without tread (slicks) give better grip in dry conditions!

As a mere human you have no control over gravity, but what other factor in the friction force equation above could you alter easily to improve your performance in the Sumo and Tug-of-War events?

## Practice 6 - Soldering

Soldering is a delicate manual skill that only comes with practice. Remember that your ability to solder effectively will determine directly how well your motor control boards function. Bad soldering technique can be a cause of major disappointment which damages your confidence. It needn't be like that: soldering is really easy to learn, and like learning to ride a bike, once mastered is never forgotten!

You should be given a small piece of stripboard and some gash components to practice soldering.

### Tools

As well as a soldering iron (ideally temperature controlled) you will need a pair of pliers to bend component leads, a pair of wire cutters to cut the leads to length and a screwdriver to attach the heat sink.

### Solder Joints

Solder joints should possess some degree of mechanical strength. The components' wires are bent to fit through the holes in the board until the component is flush against the board's surface. Use some masking tape to hold the component flush with the board whilst you turn it over. It's generally better to snip the surplus wire leads off before you solder to make the joint more accessible. Leave about 3mm of wire poking through the board.



**Component Ready for Soldering**

The perfectly soldered joint will be nice and shiny looking, and will prove reliable in service. The key factors affecting the quality of the joint are:

- **Cleanliness**
- **Temperature**
- **Time**
- **Adequate solder coverage**



**A Good Solder Joint**

A little effort spent now in soldering the perfect joint may save you - or somebody else - a considerable amount of time in troubleshooting a defective joint in the future. It only takes a few seconds to make the perfect joint, which should be nice and shiny.

### Cleanliness

Firstly, and without exception, all parts - including the iron tip itself - must be **clean** and **free from contamination**. Solder just will not "take" to dirty parts! It will "bead" into globules, going everywhere except where you need it. *Dirt is the enemy of a good quality soldered joint!* Hence, it is an absolute necessity to ensure that parts are free from grease, fingerprints, oxidation and other contamination.

Before using the iron to make a joint, it should be "tinned" (coated with solder) by applying a few millimetres of solder, then wiped on a damp sponge preparing it for use. Then re-apply a very small amount of solder again, mainly to improve the thermal contact between the iron and the joint, so that the solder will flow more quickly and easily.

Traditional electronics grade solder is usually 60% lead - 40% tin or 40/60, and **it already contains cores of "flux"** which helps the molten solder to flow more easily over the joint. Flux removes oxides which arise during heating, and is seen as a brown fluid bubbling away on the joint. Note: Lead free solder is more difficult to use as it has a higher melting point.

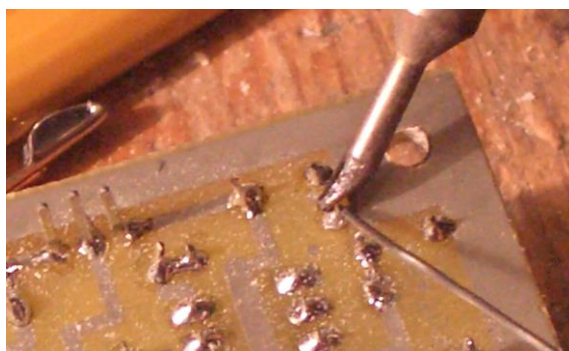
### Temperature

Another step to successful soldering is to ensure that the component lead and the PCB track are heated **QUICKLY** and **SIMULTANEOUSLY** to roughly the same temperature. **Press the chisel or conical tip of the soldering iron against both the PCB track and the component lead and apply a few millimetres of solder until it melts and flows readily over the joint onto the track. Then remove the iron and allow the joint to cool naturally. This should take only a few seconds. Do not move parts until the solder has cooled.**

Heating one part but not the other gives a far less satisfactory joint, so strive to ensure that the iron is in contact with *all* the components first, before touching the solder to it. The melting point of most solder is in the region of 188°C and the iron tip temperature is typically 330-350°C.

Inexperienced solderers often use a small clip-on heat-shunt, which resembles a pair of aluminium tweezers. In the case of, say, a transistor, the shunt is attached to one of the leads near to the transistor's body. Any excess heat then diverts up the heat shunt instead of into the transistor junction, thereby saving the device from over-heating.

Remember that the tip of the iron must be 'tinned' first to improve the thermal contact between the iron and the joint.



**Applying Both Heat and Solder**

### Time

It only takes a few seconds to solder the average PCB joint. Aim for less than 4 seconds. Excessive heating time will damage the component and perhaps the circuit board copper foil too! The heating period depends on the temperature of your iron and size of the joint. Larger components and large areas of copper need more heat than smaller ones - but some parts such as semiconductor diodes, transistors and integrated circuits (ICs), are sensitive to heat and should not be heated for more than a few seconds.

### Soldering Horrors 1 – The Dry Solder Joint

A well soldered joint will be nice and shiny looking. If it looks dull and crystalline you have made what is called a 'dry joint' and you should reheat the joint until the solder flows. A "dry joint" usually results from dirt or grease preventing the solder from melting onto the parts properly and is often noticeable because of the tendency of the solder not to "spread" but to form beads or globules instead, perhaps partially. Alternatively, if it seems to take a very long time for the solder to spread, this is another sign of possible dirt and that the joint may potentially be a dry one. Solder should cover the joint completely. If you can see the hole through which the component lead passes, or if the solder forms a round bead, the joint is likely to be dodgy.

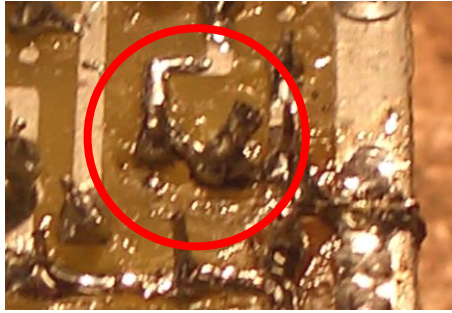


**A 'dry joint' - the solder failed to flow and instead formed globules around the wire.**

*Remedy. Sometimes it's enough to simply remelt the existing solder. If this doesn't produce visible results, remove solder and remake joint.*

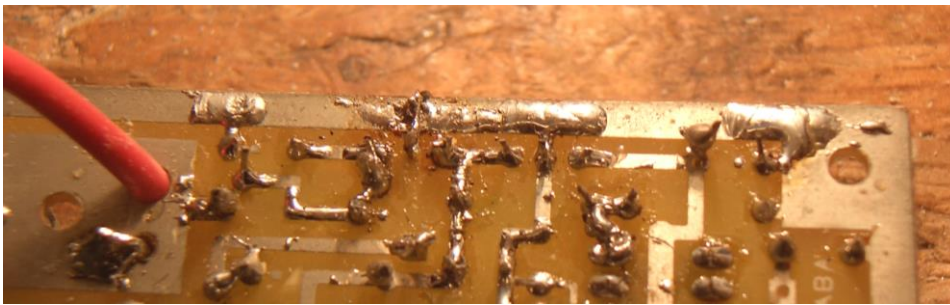
## Soldering Horrors 2 - Solder Bridges

The final key to a successful solder joint is to apply an appropriate amount of solder. **Too much solder** is an unnecessary waste and may cause a solder 'bridge' which short circuits adjacent tracks.



**A Solder Bridge Between Two Tracks Causing A Short**

*Remedy. A bridge can usually be got rid of by melting it with the soldering iron and then wiping the soldering iron along the copper track at right angles to the bridge. If it's a massive blob of solder, use a desoldering pump (sometimes called a solder sucker).*



**Too Much Solder**

**Too little solder** and it may not support the component properly, or may not fully form a working joint. How much to apply, only really comes with practice. A few millimetres of solder is enough for an "average" joint.

A soldered joint that is improperly made will be electrically "noisy", unreliable and is likely to get worse in time. It may even have made no electrical connection at all, or could work initially and then cause the equipment to fail at a later date!

## Removing and Resoldering Components

There will undoubtedly come a time when you need to *remove* the solder from a joint: possibly to replace a faulty component, to fix a dry joint or remove a solder bridge. The usual way is to use a **desoldering pump** which works like a small spring-loaded bicycle pump, only in reverse! A spring-loaded plunger is released at the push of a button and the molten solder is then drawn up into the pump by suction. The pump has a P.T.F.E. nozzle which is heat proof.



**Using a Desoldering Pump**

## Troubleshooting Guide

- Solder won't "take" - grease or dirt present - desolder and clean up the parts. Or, material may not be suitable for soldering with lead/tin solder (e.g. aluminium).
- Joint is crystalline or grainy-looking - has been moved before being allowed to cool, or joint was not heated adequately - too small an iron/ too large a joint.
- Solder joint forms a "spike" - probably overheated, burning away the flux.

Intentionally blank



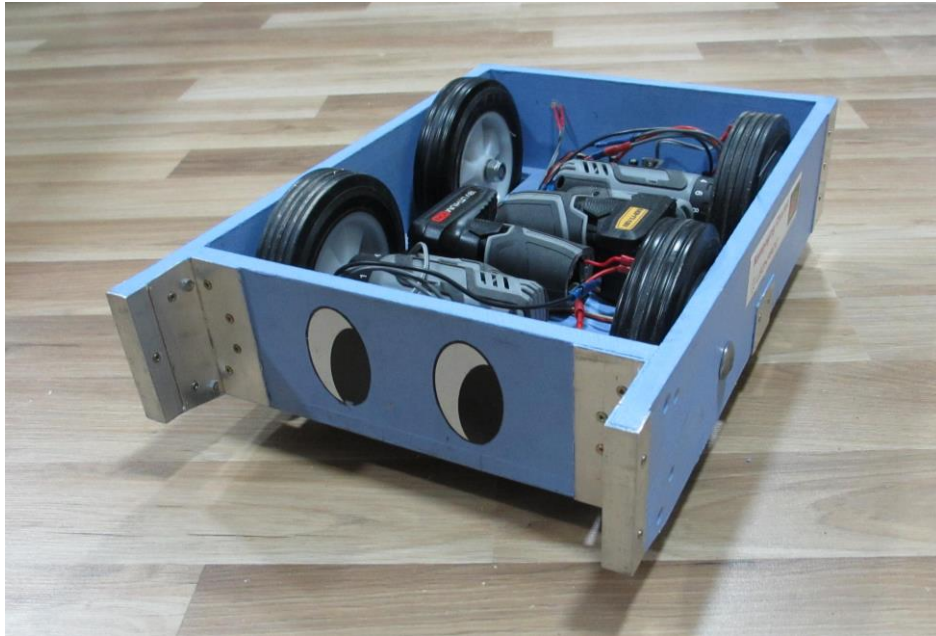
# START OF CONSTRUCTION

## Build 7 – Constructing The Chassis

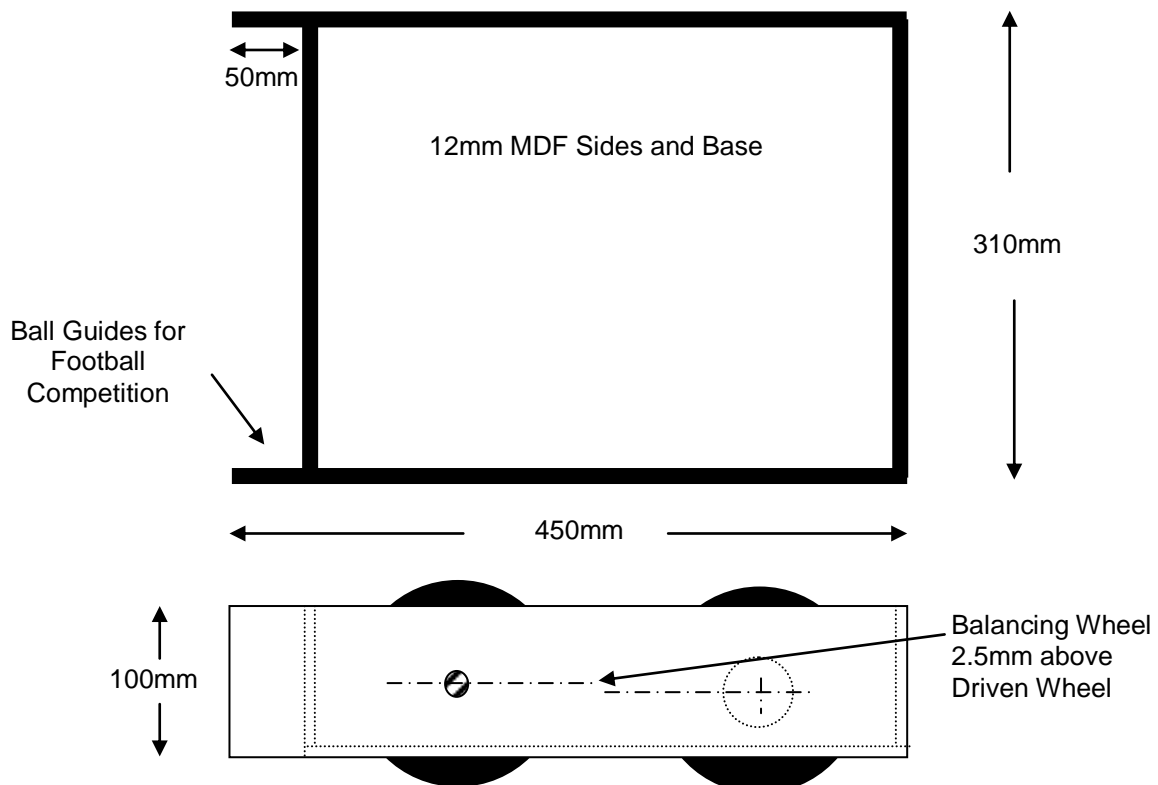
**Read and understand all the instructions before you start construction. You can make extra copies.**

Most of the problems experienced by teams constructing Rampaging Chariots are because the team has not read the instructions.

A basic robot design is described and we recommend you construct this first. Once you have a working robot you can test it and formulate ideas (within the rules) that will improve upon the standard design and thereby gain a possible advantage over your opponents. You can then, if you wish, make a replacement chassis and transfer the working and tested components into it.



**What Your Finished Rampaging Chariot Should Look Like**



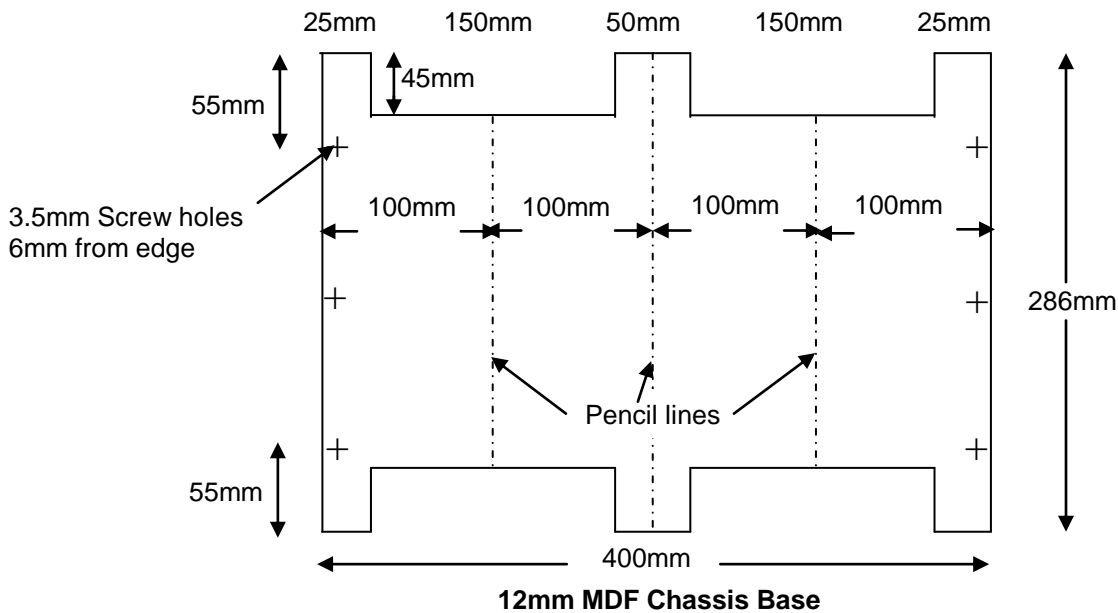
**General Arrangement of the Base and Sides**

## Chassis Base - Working with wood – Marking out – Drilling Holes

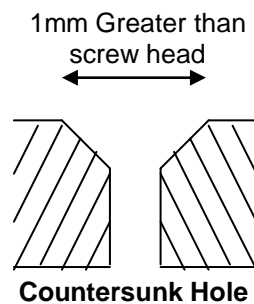
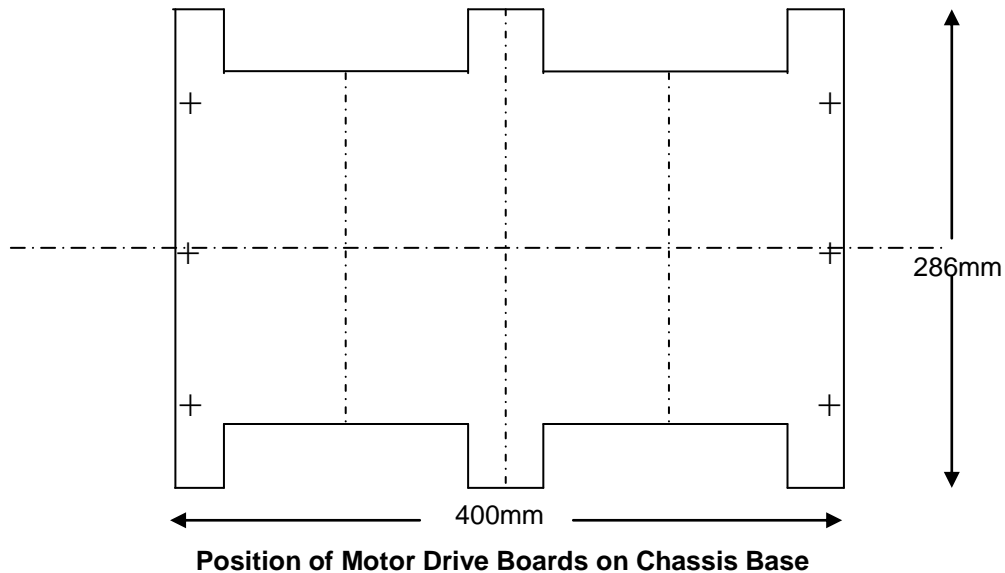
The more accurately you layout the pattern on the base and cut to it, the easier it will be to assemble the robot later.

1. Mark out the base with a pencil and cut out the four wheel holes using a coping saw or jig saw

**Hint:** Clearly identify the pieces to be cut out to avoid cutting the wrong line.



2. Drill six clearance holes 3.5 mm diameter in the base for the screws at the positions of the black crosses. Countersink these holes on the bottom.

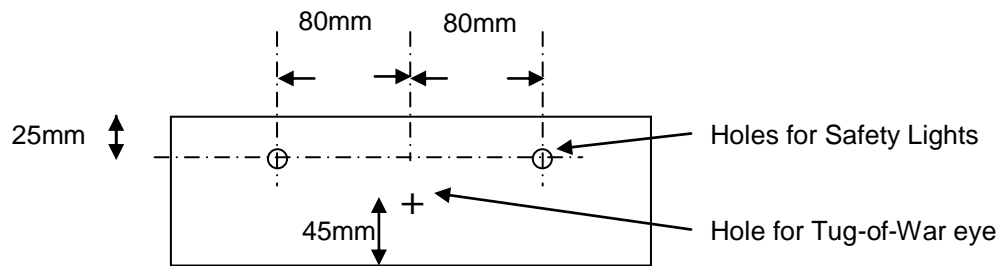




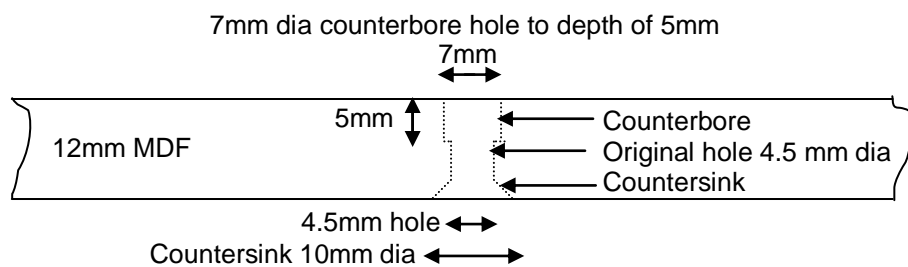
### Holes For Rear Safety Lights

7. Drill two 4.5mm diameter holes completely through the back of the chassis for the Red LED (Light Emitting Diode) Safety Lights. Counterbore from the inside with a 7mm drill to a depth of 5mm. Countersink the outside to increase the angle of view of the LED.

**Hint:** Wrap some masking tape round the 7mm drill bit 5mm from the end to tell you when you have reached the correct depth from the inside.



**Chassis Back**



**Plan View**

**Section Through Hole for LED in Rear of Chassis**

8. Drill a 2.5 mm diameter hole through the back in the position shown for the Tug-of-War rope attachment eye.

### Assembling the Chassis

We recommend that you initially assemble the base and sides of the chassis with screws and glue the joints later.

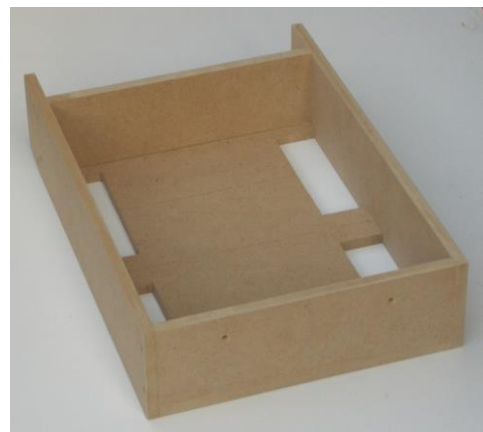
9. Grip the chassis front in a wood vice with one long edge about 5mm above the bench top. Place on the chassis base (upside down) and insert three 3.5 x 30mm wood screws in the holes. Line up the base and front **exactly** and when **absolutely happy**, tap each screw lightly with a hammer sufficient to make a small indentation in the edge of the MDF. Lift off the base and drill 2.5mm pilot holes into the edge of the chassis front to a depth of about 18mm. Screw the two pieces together.

**Hint:** The pilot holes should stop the edges of the MDF splitting when you insert the screws but you could also grip the sides of the MDF either side of the pilot hole (using the jaws of a wood vice or with a G Cramp, whilst you insert the screw. Once the screw has been inserted once, the MDF is unlikely to split when you insert it again later.

10. Repeat this procedure for the chassis rear ensuring you have it the correct way round.
11. Fit one side onto the chassis the correct way round and using the technique above, screw in place using five 3.5 x 30mm wood screws. Fit the other side in the same way.

**Hint:** Remember to drill pilot holes 2.5 mm diameter to stop the MDF splitting

12. When you are happy with the fit, remove the front, back and sides, glue the joints (we use a PVA adhesive from B&Q) and reassemble using the screws to hold the joints together.



**MDF Chassis**

**Chassis Protection and Strengthening** – *Working with Metal – Cutting, Drilling holes, Countersinking*  
 - *Why strengthening is necessary*

**Front of Football Guides**

13. To protect the ends of the football guides, cut the two 12mm aluminum channels to a length of 90 mm. Drill two holes 3mm dia through one side near the top and bottom and one hole 3mm dia through the other side in the centre. Countersink these screw holes.
14. Fit the aluminum channels over the ends of the MDF and use a rubber mallet (or hammer with a scrap piece of wood) to make sure they are fully seated and in the correct position. Screw in place using three 3 x 12mm screws.



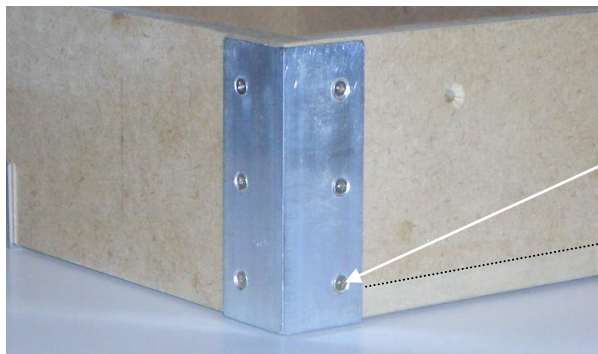
Reverse side shown in  
picture on next page

**Football Guide Protection Channel**

**Rear Corners**

15. To protect the MDF rear corners and to strengthen the chassis, cut four 35mm x 35mm aluminum angle plates to a length of 100mm. Fit two of these to the rear corners of your robot with six 3 x 12mm screws. Countersink the holes in the aluminum on the outside of the angle.

**Hint:** Think about the best positions for these screws: They should not be too near the ends of the MDF or they will pull out under stress. They must also miss the existing screws fixing the chassis together.



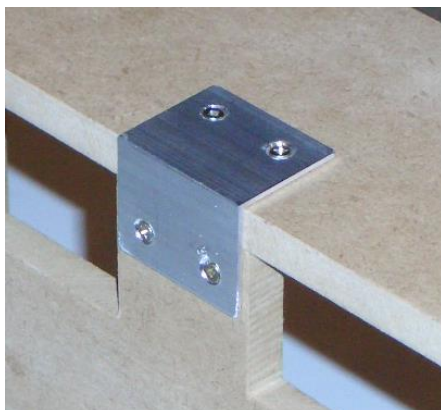
**Mistake.** This screw is positioned much too close to edge of MDF

**Rear Protection and Strengthening Plate**

**Centre Strengthening**

16. To strengthen the chassis in the centre cut two 35mm x 35mm aluminum angle plates to a length of 45mm (from the 90mm piece) and fit these to the centre of each side of your robot with four 3 x 12mm screws. Countersink the holes in the aluminum on the outside of the angle.

**Hint:** Drill the holes in the aluminum protection plates in places where the screws will not be too near the edge of the MDF sides and will also miss the existing screw fixing the chassis together.



**Centre Strengthening Plate**

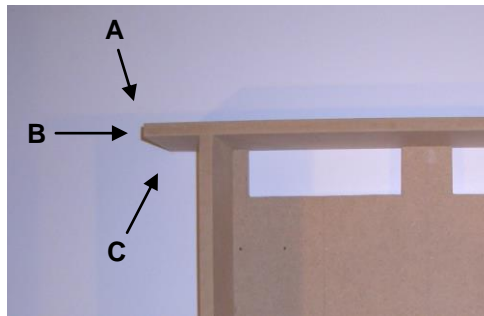


## Front Corners

17. To strengthen the chassis and football guides, cut two 35mm x 35mm aluminum angle plates to a length of 100mm and fit each of these to the front corners of your chariot with six 3 x 12mm screws.

**Hint:** Again think about the best position for these screws. Like the rear protection plates they should be well away from the ends of the MDF and miss the existing screws.

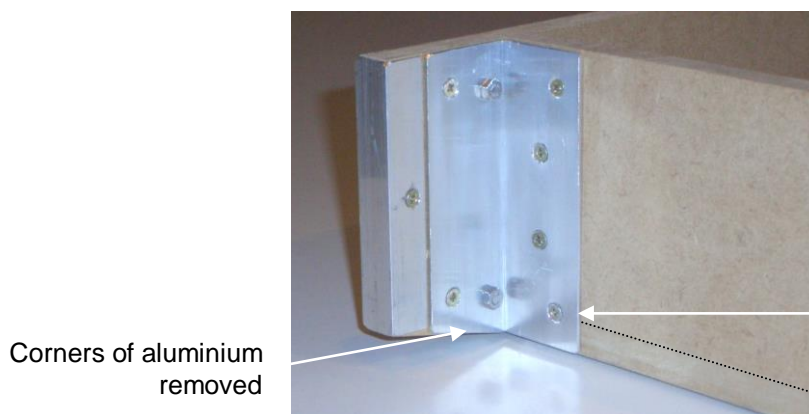
During a football match, the protruding football guides will be hit in three directions:



**Direction 'A'** will cause the side to pivot about the front of the chassis and pull away at the center and rear. (This is solved by the rear and center strengthening plates).

**Direction 'B'** will push the side rearwards and the front bracket will be in compression against the chassis front.

**Direction 'C'** will push the side away from the rest of the chassis and is likely to cause the most damage. It will try to pull out the screws from the side and will also try to bend the aluminum angle away from a true right angle. It is therefore important to hold the aluminum angle firmly to the MDF side with 4mm bolts positioned as close as possible to the bend in the aluminum.



**Mistake.** This screw is positioned much too close to edge of the MDF

### Football Guide and Front Corner Strengthening Plates

18. From the outside, insert a 4mm drill in each of the two 4mm holes in the side and drill through the aluminum angle. Insert two 4 x 20mm countersink bolts and tighten the nuts securely.
- Hint:** If you wish, you can cut off surplus thread on the inside and put a spot of Loctite glue on the nuts to prevent them vibrating loose.
19. Cut off the corners of the aluminum in line with the MDF chassis corners that have already been removed.

## Painting

20. Paint the inside and outside of the chassis with a white undercoat paint before installing the motors.
21. Redraw the two drill centerlines across the base 88mm from the inside of the front MDF and 88mm from the inside of the back MDF. Check that there is a distance of 200mm between these two centerlines.

At this point your basic chassis is complete and the two cordless electric drills can be dismantled and converted to provide the motive power for your Rampaging Chariot.

### **Dismantling The Drills** - Conversion of a commercial item to a new purpose

There should be sufficient charge in the battery to allow you to test that the cordless electric drill rotates clockwise and anticlockwise before you start to dismantle it. The two drills require exactly the same modifications so you may wish two team members to do the following sequence of actions simultaneously.

**Note:** Put all the pieces you remove in a container or plastic bag and keep them safe.

**Remember that there is a magnet in the motor and if you put metal nuts and bolts close to the motor they will disappear inside and jam the motor.**

**Never throw any parts away until you have a fully working robot.**

22. Remove the battery and check its fuel gauge. If required, put the battery on charge for up to an hour to achieve a full charge.

### **Replacing the chuck with a wheel**

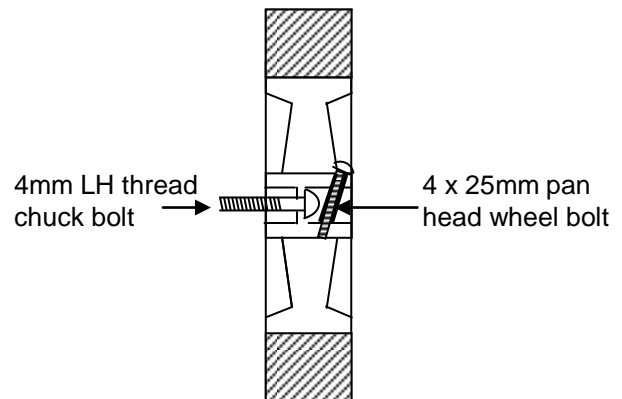
The Neilsen CT0153 18V Li-ion Cordless Electric drills are ordered without drill chucks and with the internal mechanical brake removed. The two drive wheels have an aluminium axle inserted which screws onto the standard drill shaft. To avoid the wheel coming loose when you operate the drill in reverse it also has a special bolt in the centre of the chuck that has a reverse (or left hand) thread. This ensures that which-ever way the drill is rotating the chuck or wheel should not come loose.

**Note:** If you lose this special left hand thread screw it is very unlikely that you, or we, will be able to get a replacement.

23. Turn the torque selector at the front of the drill fully clockwise until the drill symbol is in line with the arrow at the top of the outer plastic drill casing.
24. Move the gear selector on top of the drill rearwards to position 1.
25. Remove the left hand thread bolt by twisting it in a clockwise direction viewed from the front.
26. Insert a pan head M4 x 25mm bolt sideways through the white plastic wheel hub and into the wheel axle. This will stop the axle rotating inside the wheel whilst you screw the wheel onto the drill shaft.



**Wheel Fitted to Drill**



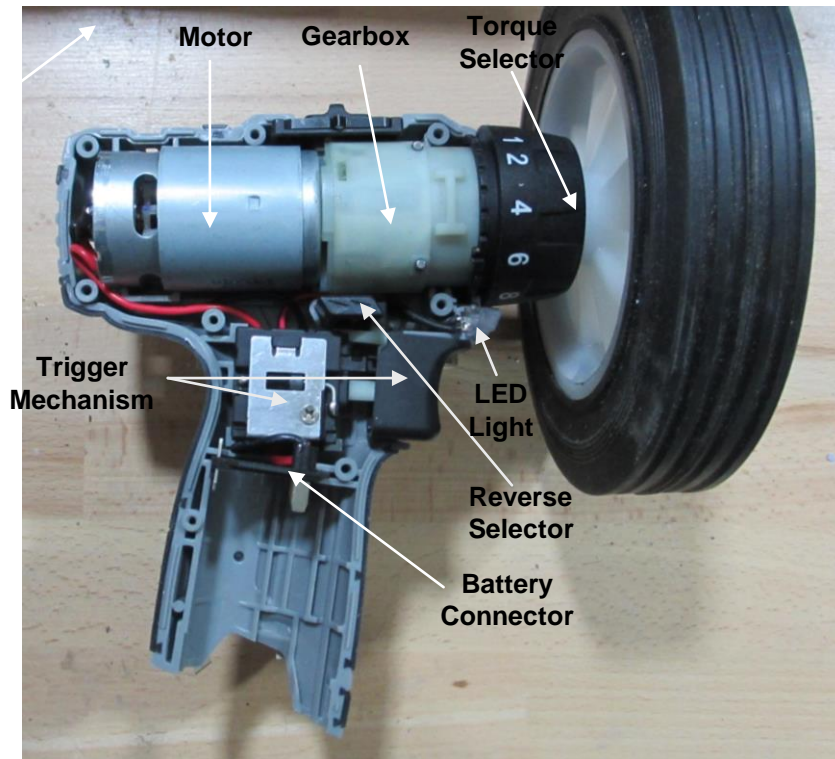
**Section Through Wheel  
Showing Retaining Screws**

27. Screw the wheel onto the drill shaft and jerk it the last quarter turn to ensure it is as tight as possible.
28. Withdraw the M4 cross bolt so that it is just through the first side of the aluminium wheel axle. This will give you enough clearance to Insert the left hand thread screw into the wheel hub and tighten it by twisting in an anticlockwise direction.  
Finish screwing the M4 x 25 cross bolt fully into the wheel Hub.

**Note:** Attaching the wheel to the drill motor at this stage is intended to stop the torque mechanism detaching from the drill motor during the following stages. If this were to happen you will have to carefully slide the cover back on checking that the top arrow still aligns with the screw symbol.

## Drill Casing

29. Place the drill on a block of wood on a clean table or bench as there is a good chance some loose parts may drop out.
30. Remove the two silver U shaped metal clips from the bottom of the drill handle by inserting a small flat blade screwdriver at the bottom of the clips and levering them up.
31. Turn the casing so that the heads of the eight case securing screws face upwards. Unscrew the eight identical self tapping screws and very carefully lift off the top half of the grey plastic casing starting at the bottom of the handle.

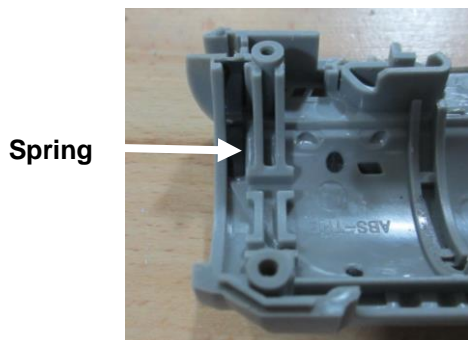


Drill With Top Half of Casing Removed

**Note:** Carefully store all the parts you remove, but NEVER put the motor in the same bag as other metal parts such as springs, bolts or nuts. These and metal filings will be attracted by the powerful magnets inside the motor, disappear into the ventilation holes and jam the motor.

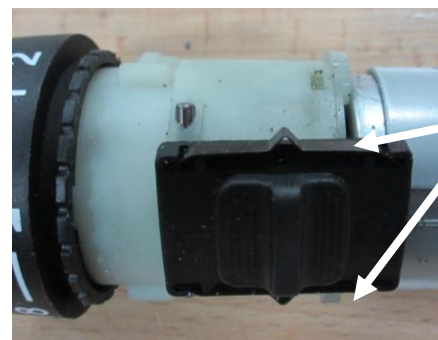
32. Remove the Reverse Selector beside the trigger and the clear plastic LED housing. Try to keep the black plastic gear selector attached to the drill motor

**Note:** A flatish black locator spring (left photo below) will probably fall out of the lower plastic motor casing. This should be kept safely until you have finished bolting the bottom casing to the chassis. If a similar flatish black locator spring detaches from the side of the black plastic gear selector reinsert it by referring to the right photo below.



Spring

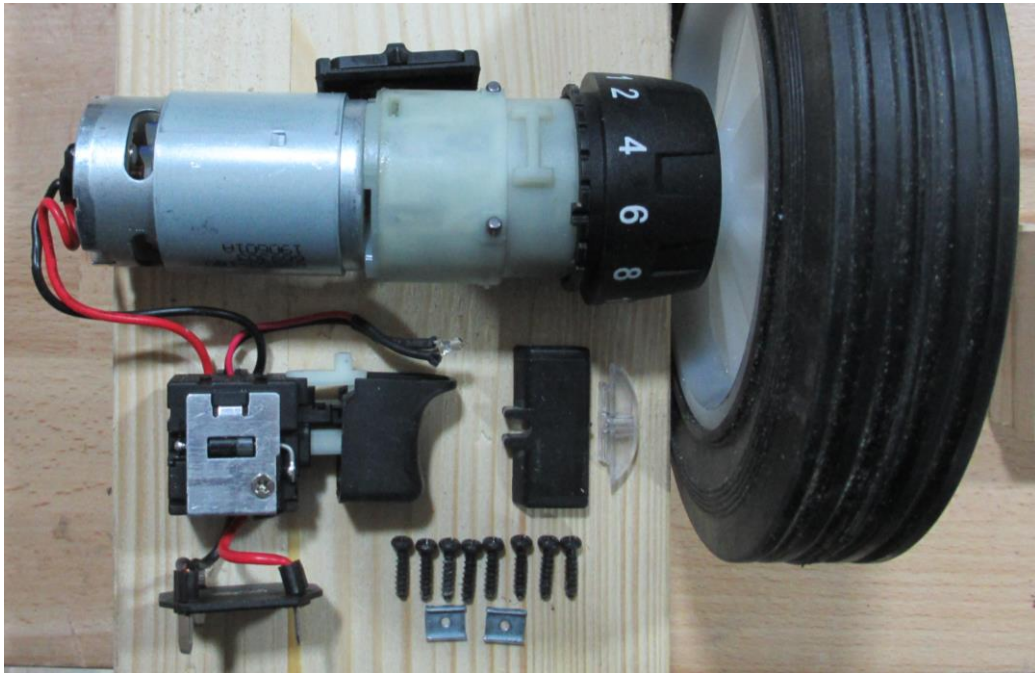
Torque Mechanism Spring In Lower Casing



Springs

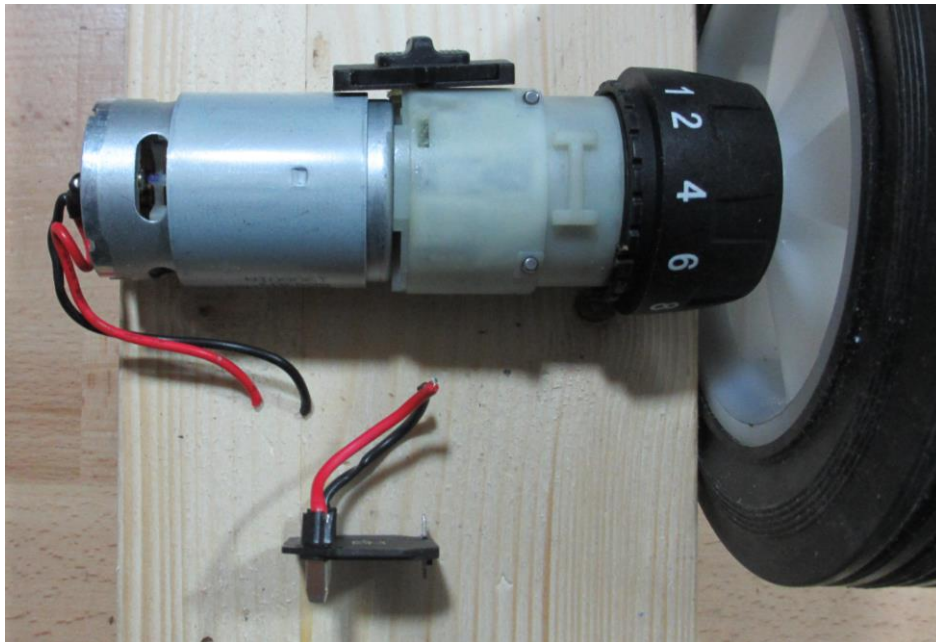
Springs on Side of Gear Selector

33. Lift up the wheel, torque selector, gear selector, gearbox, motor, trigger mechanism, LED light and battery connector plate as a single unit and place on the bench.



**Parts Removed from Drill Casing**

34. Using a pair of wire cutters cut off the wires coming from the motor and also from the battery connector as close as you can to where they are soldered to the trigger mechanism. The Trigger mechanism is no longer required.

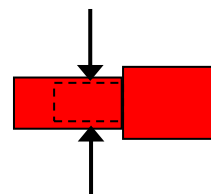
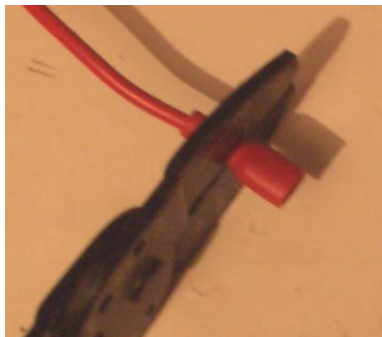


**Motor and Battery Connector After Disconnection**

**Warning: Do Not Connect the battery until you have fitted the crimp terminals, or the bare leads may short and weld together resulting in a major bang and fireworks display.**



35. Remove 10mm of plastic insulation from the ends of the four cut wires. Be careful not to cut the wire itself. Twist the ends of the exposed wires.
  36. Crimp a red and blue **female** crimp connector to the red and black wires coming from the battery connector using the special crimp tool provided and a lot of squeeze.
- Hint:** Ensure the wire is fully inserted and the part of the terminal you crimp is within 5mm of the spade or you will just be squeezing plastic!
37. Crimp blue **Male** spade connectors to both of the red and black wires connected to the motor using the special crimping tool provided and a lot of squeeze.

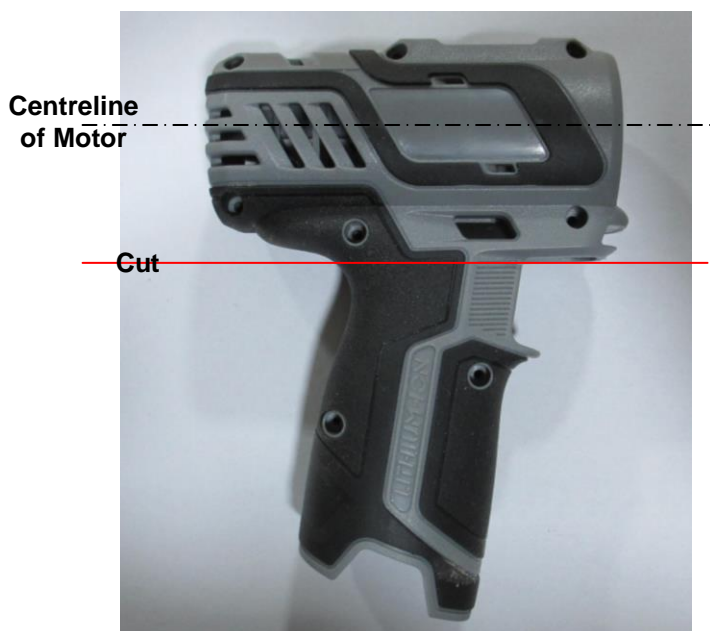


#### Where to Crimp the Spade Terminals

38. Give each spade connector a tug to ensure it is not loose

#### Cutting The Motor Casings

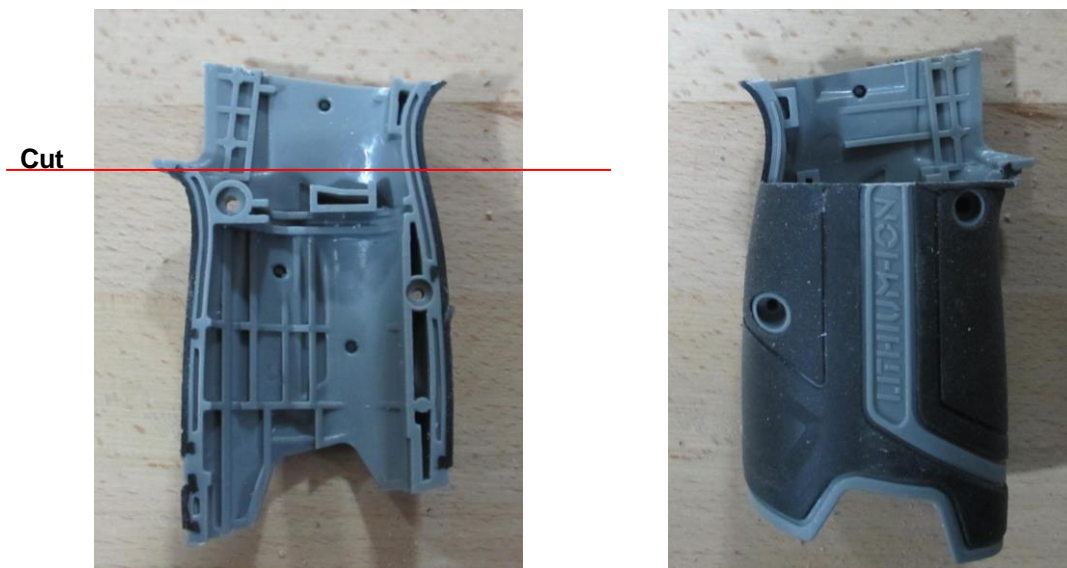
39. Take the top drill casing (The one with the eight screw holes) and use a pen to mark exactly where you are to cut off the plastic handles (see top left photo). The upper cut is parallel with the drill centreline and it is easier to do the first top cut from the outside of the half casing (Photo below). Carefully remove the handle section with a hacksaw.
40. Fit the first cut off motor casing onto the mating part of the lower drill casing and continue the hacksaw cut through the lower casing.



**Position and Angle to Cut  
Top Part of the Drill Handle**



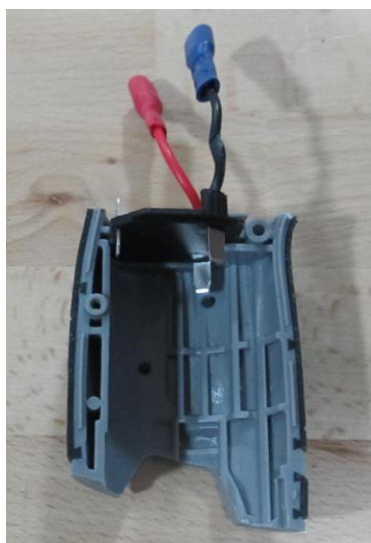
41. The lower cut is above the handle screw holes and parallel with the battery connector plate. It is easier to do the lower cut from the inside of the half casing. Carefully remove the lower handle section with a hacksaw.
42. In the same way place the cut off handle part of the handle casing onto the mating part of the lower casing and continue the hacksaw cut through the lower casing.
43. Remove the burrs from the cut faces using a file, knife or sandpaper to make it look good. The two small half sections between the two cuts are not used.



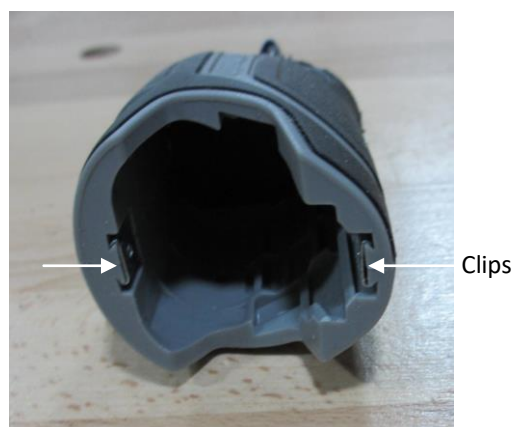
**Position and Angle to Cut  
Lower Part of the Drill Handle**

#### Refitting the Battery Connector

44. Slide the battery connector into its groove in the lower half of the handle housing.
45. Fit the upper and lower housings together and if they are mating correctly without gaps, insert the two self tapping screws.
50. Refit the two silver U shaped clips to the bottom of the handle.



**Battery Connector**



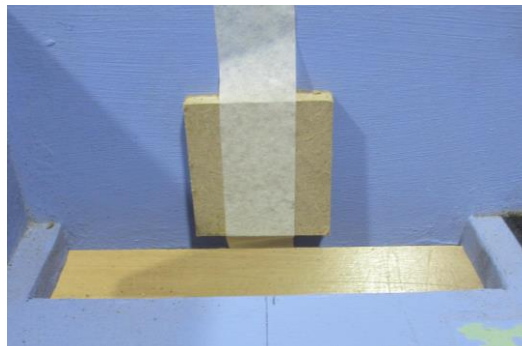
**Handle Clips**

51. Insert the battery and use a voltmeter to check the battery voltage across the red and blue female spade connectors is approximately 18 volts and the positive voltage is at the red spade connector.
52. Repeat actions 39 to 52 for the other drill.

### Fitting The Motor Assembly

The two drive wheels are the left rear wheel and the front right wheel.

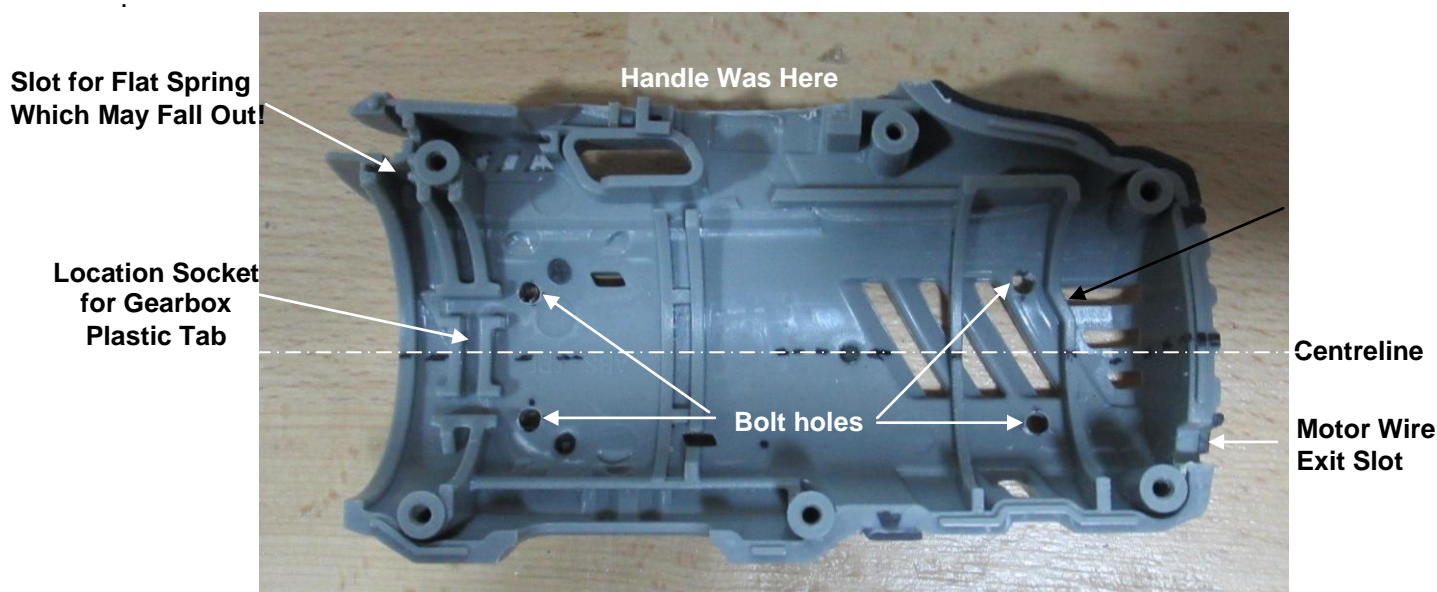
53. Temporarily tape the 50mm x 50mm piece of 6mm thick MDF to the inside of the chassis in line with the motor shaft. This is to ensure the correct distance of the motor and wheel from the side of the chassis.
54. Make sure the two drill centrelines are clearly marked on the inside base of the chassis



**6mm MDF Used As a Temporary Spacer**

### **Plastic Casing**

55. The bottom half of the grey plastic casing that bolts to the MDF chassis is the half that the six black self tapping screws that join the two halves together screw into. The motor plastic casings are fitted with the position of the handle (which you cut off earlier) facing towards the centre of the chassis.
56. Using the edge of a flat file make a slot about 4mm deep in the back of the motor casing to allow the red and black motor wires to exit (see photo below).
57. Mark the positions of the four holes required to bolt the lower drill casing to the MDF chassis. Make sure the holes are far enough away from the moulded obstructions to allow the head of the screw to fit in.
58. Drill four 3mm diameter holes in the lower half of the plastic casing in the positions shown below. You can start drilling the hole at right angles to the inside of the plastic casing, but when the hole is established move the drill bit gently to a vertical position so that the bolts will enter straight into the MDF chassis. Be as accurate in positioning these holes as you can.



**Position of Four Fixing Holes in Lower Plastic Casing and Rear Slot in Rear for Motor Wires to Exit**

59. Insert the motor and gearbox assembly into the lower half of the plastic casing and ensure the motor is correctly seated.

**Hint:** The protruding plastic tab under the gearbox locates into a socket in the lower plastic casing to stop the motor casing rotating. When lined up, the motor and gearbox should drop vertically into the plastic case with no forcing required.

60. Fit the motor and wheel into the chassis checking the following:

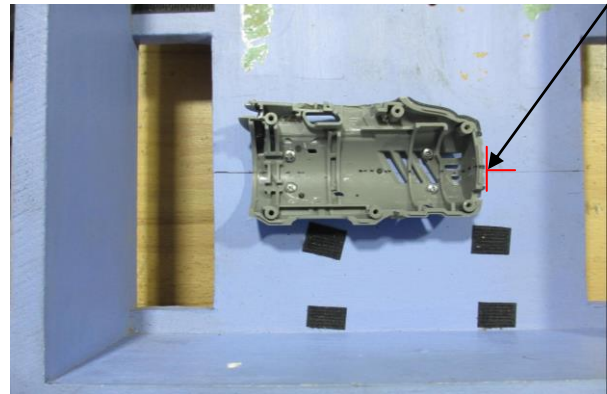
**Is the wheel firmly against the temporary MDF spacer?**

**Is the wheel parallel to the side of the chassis?**

**Is the wheel positioned centrally in its cut out hole in the bottom of the chassis?**

**Is the drill body on its centreline and parallel with the ends of the chassis?**

When you are absolutely happy, mark the exact position of the rear of the casing onto the chassis.



**Position of Wheel, Motor and Casing in Chassis**

61. Remove the motor, gearbox and wheel from the bottom half of the plastic casing. Remove the MDF spacer from the side of the chassis.
62. Place the lower casing back in the chassis and locate it in the correct position on the drill centreline with the rear of the casing lined up with your mark.

**Hint:** You will find that the casing tries to rotate whilst you are trying to position it and will rock lengthwise when placed on a flat surface. You can prevent this annoying movement and also give a firmer flat seating of the casing by using a file to file down the central piece of rubber going across the outside of the casing. You only need to take off about a millimetre, but this will prevent the casing rocking.

63. Position your 3mm drill bit in one of the four holes you have made in the drill casing. Check the casing has not moved, and get a friend to hold it firmly whilst you drill completely through the chassis. Insert a M3 x 25mm countersink head bolt and loosely tighten the nut. Check the drill casing is still correctly positioned and drill the next hole. Insert the other three bolts in turn after each hole is drilled. Do not tighten the four bolts/nuts too tight or you may distort the lower casing and the top half will not fit.

**Note:** Inserting a bolt after each hole is drilled and rechecking the drill casing is still correctly aligned will ensure that all four bolts will line up with the chassis holes.

64. Refit the flatish spring for the torque selector that probably fell out of the front of the lower casing when you dismantled the drills (see photo on previous page). Route the two motor wires out of the rear groove you previously filed. Replace the motor, gearbox and wheel assembly back in the lower casing.

65. Carefully fit the upper plastic drill casing using the six black screws. You may need to rotate/adjust the position of the motor to line up the plastic housing and correctly fit the torque selector. There should be a satisfying click when the casings fit together and you should not try to tighten the four bolts until the two casings halves are fitting together without a gap.

**Hint:** If the upper casing does not fit easily, **do not over-tighten** the six black upper casing screws or you may crack the casing. Try the following five engineering possibilities and solutions:

Wiggle both halves of the casings whilst applying a little downwards force.

Check that the protruding plastic tab under the gearbox locates correctly into a socket in the lower plastic casing.

Check the motor wires are routed correctly and not trapped between the lower and upper casings.

Check the lower casing is not distorted caused by tightening the casing to chassis bolts too tight.

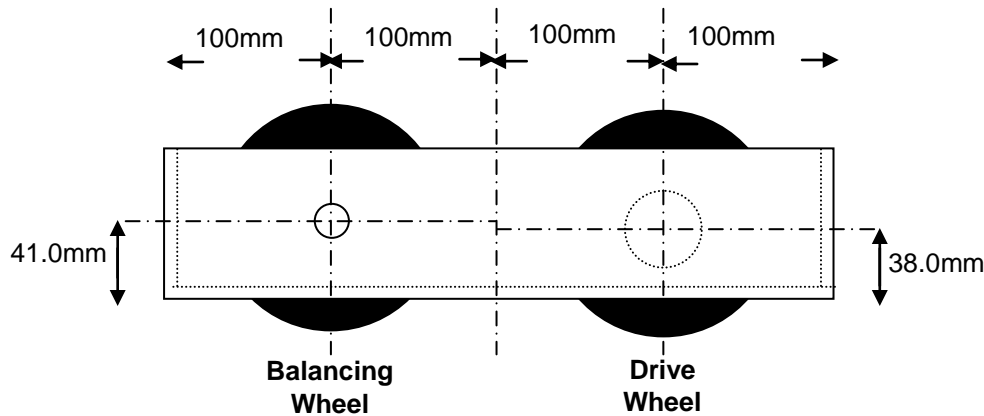
Check that the top of the countersink head bolts holding the lower casing to the chassis are not preventing the drill motor from correctly seating in the plastic holders . If this occurs use a 7mm diameter drill bit to remove a small piece of plastic at the high side of each hole on the inside of the lower drill casing to let the bolts fit more vertically in the holes without interfering with the motor.

66. Fit the second motor and drive wheel in the front right position (Diagonally opposite).

### **Balancing Wheels**

The balancing wheels are bolted directly to the side of the chassis in the front left and rear right positions.

67. Each balancing wheel should be 2.5 - 3mm higher than the drive wheels so that the robot rocks on the drive wheels and keeps these wheels in contact with the ground.



**Axle Bolt**

68. Insert the clear plastic axle tube into the wheel hub.
69. Insert the coach bolt through the MDF from outside and fit an ordinary nut on the inside until the bolt thread protrudes about 10mm through the nut. Fit a washer followed by the wheel with its plastic axle. Continue to insert the coach bolt whilst tightening the nut. This will draw the square shank of the coach bolt into the MDF. Tighten the nut very tight to hold the axle bolt firmly to the chassis. Fit another washer and then the self locking nut with the nylon insert. Tighten the nylon nut until the wheel just stops rotating. Then loosen this nut by quarter of a turn to allow the balancing wheel to rotate freely.



**Position of Balancing Wheel**

**Hint:** The Chariot should rock on the drive wheels such that there is a 5mm to 6mm gap under one balancing wheel whilst the other is touching the ground. If necessary, you can adjust the height of the balancing wheels by elongating the 10mm fixing holes in the sides of the chassis with a round file.



## Batteries

The batteries are mounted flat on the chassis with Velcro to prevent them leaving the Chariot during a spirited football match. This, however, makes it more difficult to disconnect them quickly in an emergency. We therefore file down the release catches holding the battery to the drill handle so that you no longer have to press the two hexagonal push buttons in order to separate the handles from the batteries.



Release Catch



Catch Before  
Filing Down



Catch After  
Filing Down

### Battery Release Catch

70. To Enable you to disconnect the batteries quickly in an emergency use a flat file to file down the release catch on both sides of the battery leaving a smooth tab as shown above.
71. Cut two strips of Velcro loops 70mm long for the battery, and two strips 50mm for the handle. Peel off the backing paper and press onto the batteries in the positions shown.



### Velcro Loops on Base of Battery and Handle

72. Place 70mm and 50mm strips of Velcro hooks onto the Velcro loops on each battery. Peel off the backing paper and press each battery firmly onto the chassis in the correct location. Allow the Velcro glue to harden for at least two minutes before lifting off the batteries.

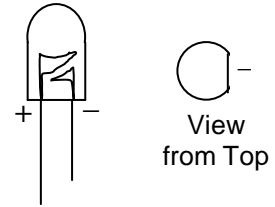


Position of Batteries in Chassis

## Rear Safety Lights

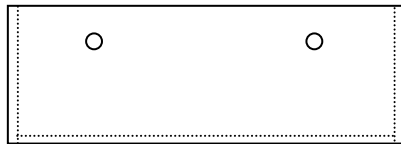


Rear Safety Light Connections

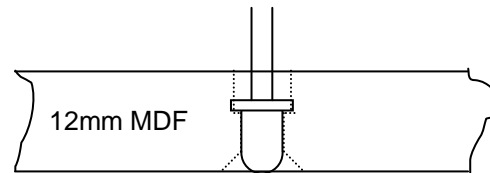


LED Polarity

73. Prepare the ends of the two pieces of twin grey flex (length 120mm and 500mm). Cut the leads of the high brightness Red LEDs to a length of 10mm. Slide a 20mm length of heat shrink over each flex wire end and solder the wires to the LED **ensuring the wire with the black stripe goes to the negative lead of the LED**. Slide the heat shrink over the bare wire and heat it with the side of the soldering iron until it has shrunk to a tight fit.
74. Tin the other bare ends of the leads with a solder coating to make them stiff.
75. Insert the LEDs into the 4.5mm holes at the back of the robot and when they are flush with the outside bend the leads downwards against the MDF and tape them to the inside of the back of the chassis.



Rear Elevation



Plan View Section of Rear

## Tug-of-War Towing Eye

76. Screw the Tug-of-War towing eye into the rear of the robot 45mm from the bottom. The point of the towing eye should not protrude through the back to the inside of the chassis.



Position of Towing Eye



### Radio Receiver and Aerial

77. Cut and fit a short 20mm piece of Velcro loops to the bottom of the receiver and a 40mm piece of Velcro hooks to the bottom of the chassis, and fit the receiver in the position shown. The Velcro should hold the receiver and cushion it from shocks, bangs and vibration.
78. Use insulating tape or 'duck' tape to hold the aerial firmly to the inside of the chassis sides.

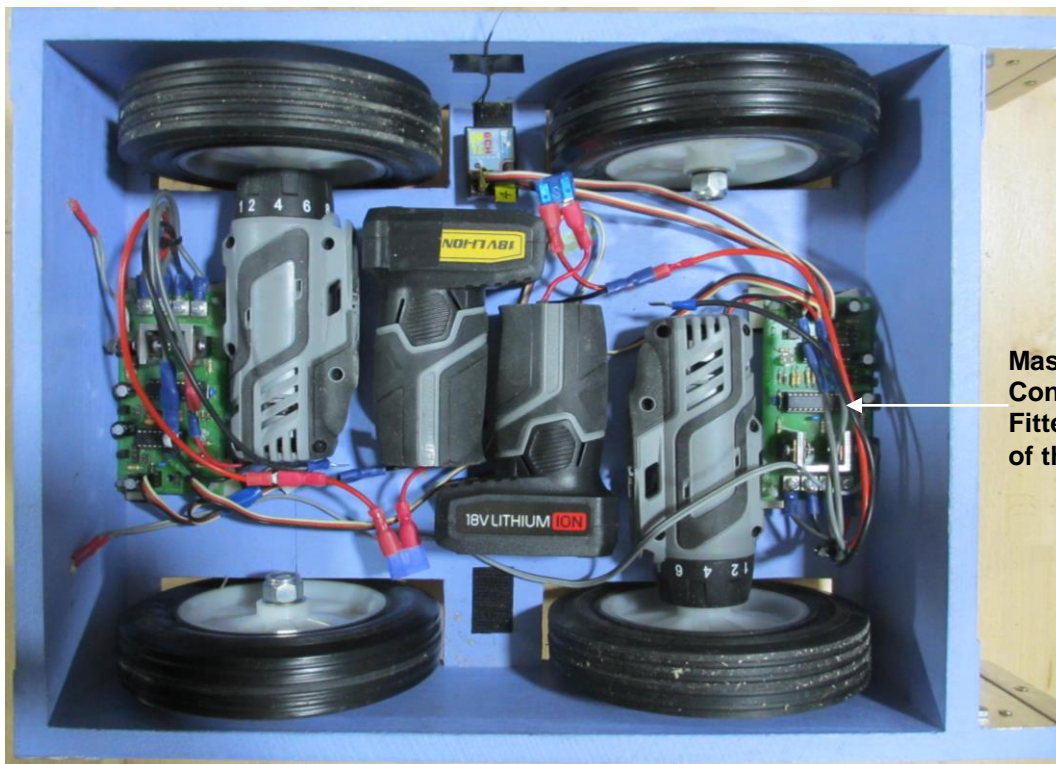
**Note:** This position has been chosen to keep the receiver as far away as possible from sources of electrical noise such as the motor drive electronics boards and the drill motors.



**Position of Receiver and Aerial**

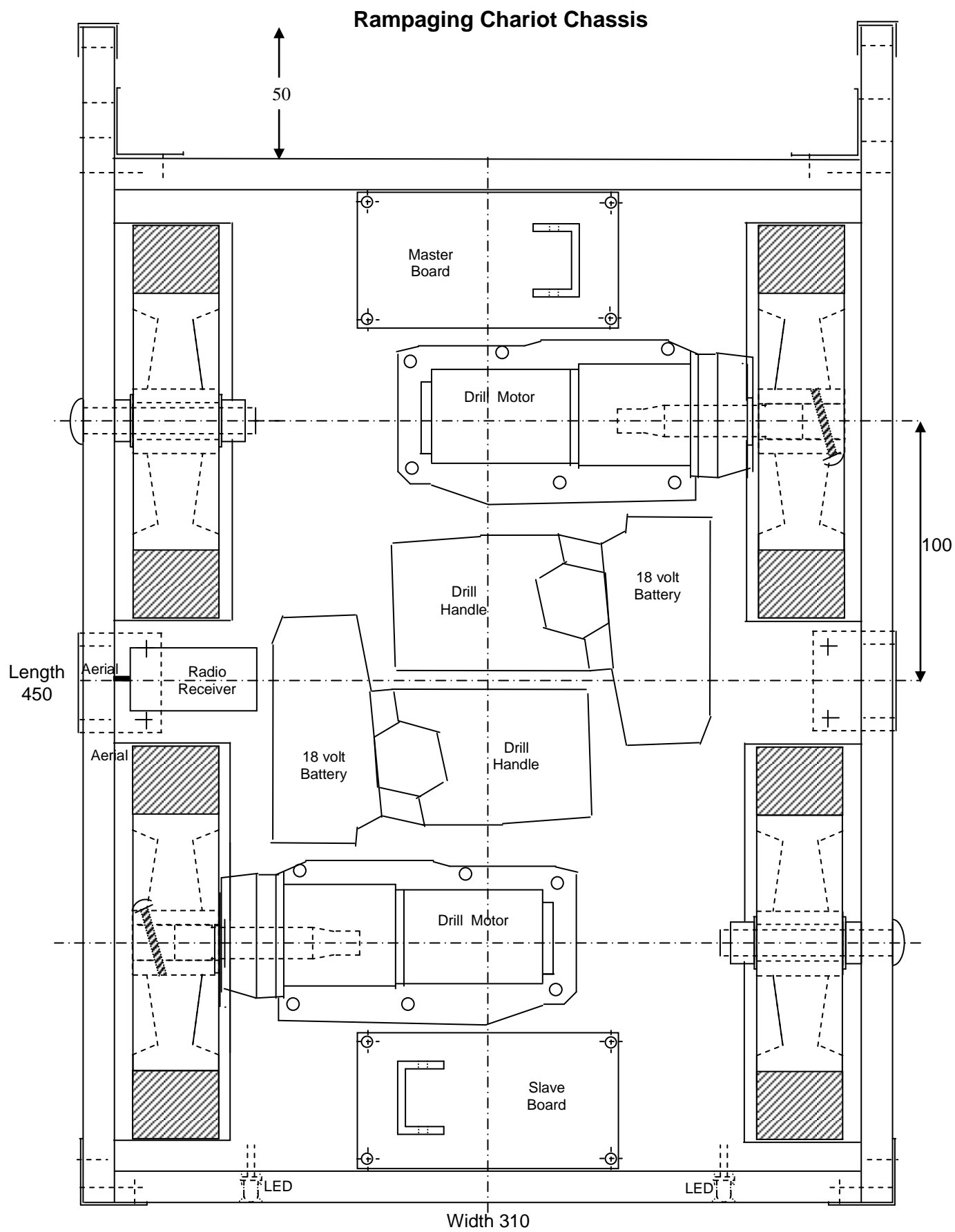
### Finishing

79. Paint the Chassis and personalise your Rampaging Chariot.
80. Think of ways of improving your Rampaging Chariot such as adding a superstructure. Hints are given in chapter 'Build 12'.



**Master Motor  
Control Board is  
Fitted in the Front  
of the Chassis**

**Finished Rampaging Chariot**



PJB V4.0

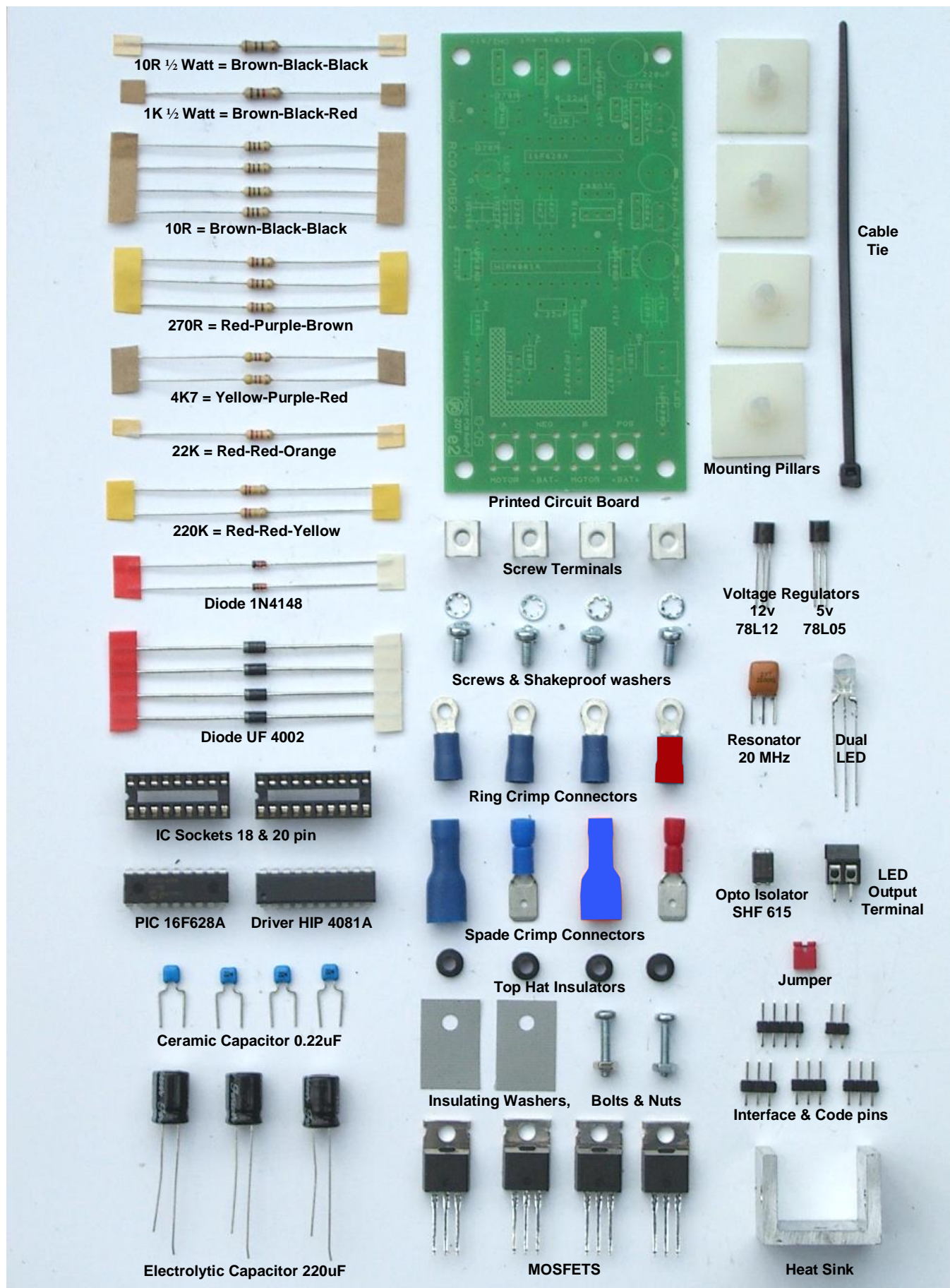
PLAN VIEW

Scale 1 : 2

## Build 8 – Constructing The Motor Controllers

### Identifying Components

Identify all your components and keep them in a safe place so that none are lost.





## Component Insertion 1 – Small Resistors

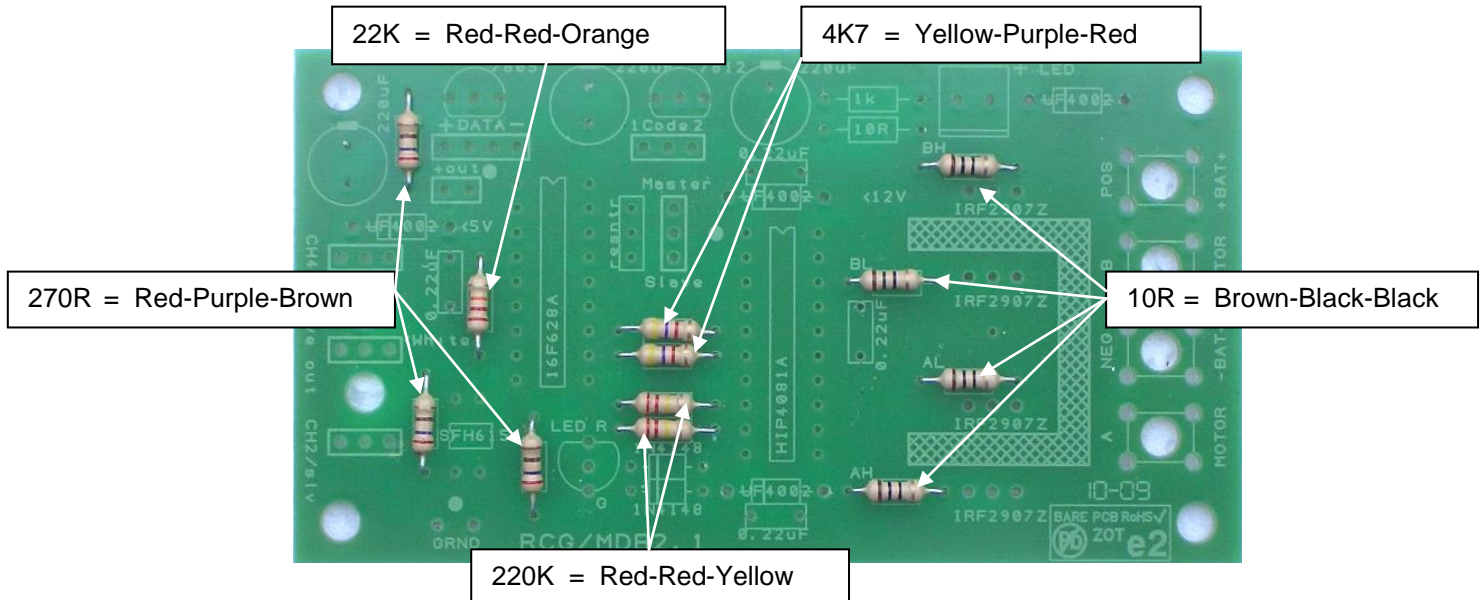
As a general rule it is easier to solder in components with a low profile first, such as resistors, and finish with soldering the high profile components such as the Capacitors.

**Small Resistors** Check the values of the small resistors from the colour code chart and bend both resistor wires using pointed nose pliers through 90 degrees so that the bent leads are the same distance apart as the holes.

Insert the resistors and hold them close and flat to the board with some masking tape or sealotape.

The board will look more professional if the resistors are all the same way round.

Cut off the excess wire 3mm from the under surface and solder them in.



## Component Insertion 2 – Large Resistors and Test Point

**Large Resistors.** Take the larger 1K and 10R resistors and bend both resistor wires by hand through 90 degrees very close to the body of the resistor.

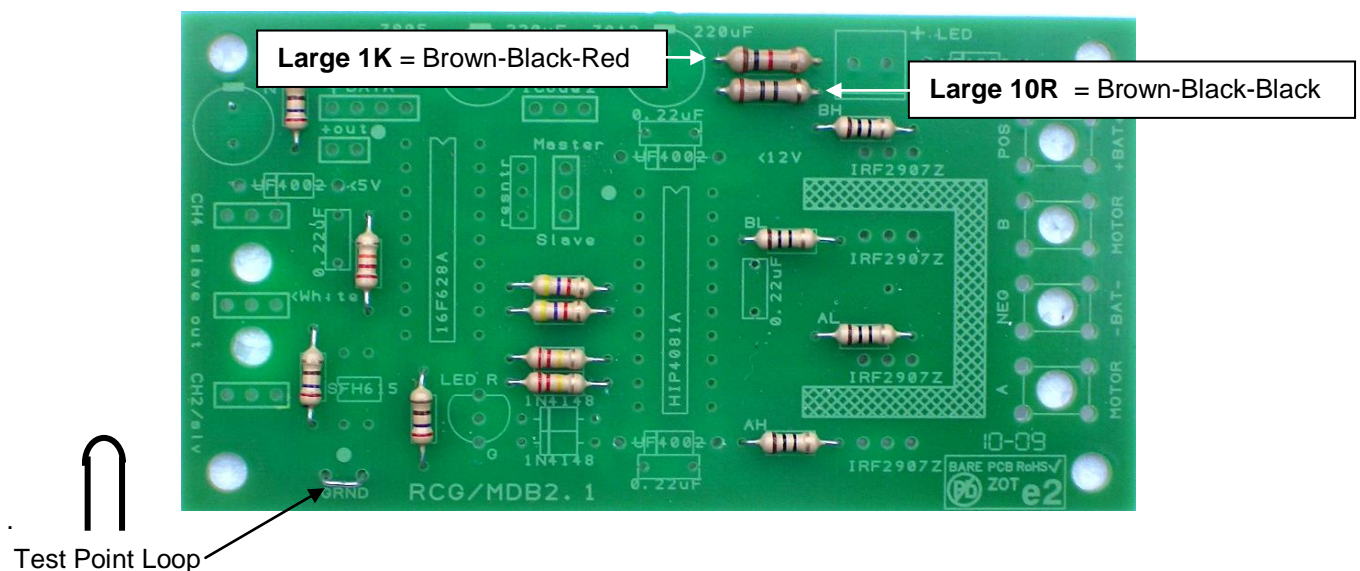
Insert the resistors in the holes shown below so that they lie flat on the board.

Hold the resistors close and flat to the board with some masking tape.

Cut off the excess wire 3mm from the under surface and solder them in. **One of the wire offcuts** is now used to make a test point.

**Negative Test Point:** Bend a wire offcut round the ends of the long nose pliers and insert the loop into the two holes marked GRND. The loop should stick up about 3mm from the top of the board so that you clip a test lead to it.

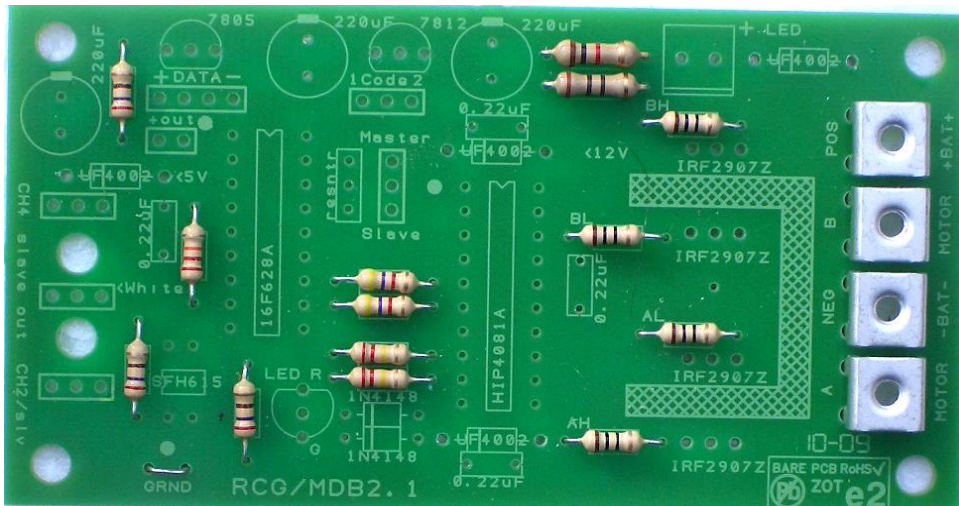
**Hint:** Solder one end of the loop first. Adjust the height of the loop and then solder in the other end



### Component Insertion 3 – Screw Terminals

**Screw Terminals** Insert the screw terminals into the board and hold them against the top surface with masking tape. Turn the board over and solder one of the legs in. Check the terminal is still fully down on the top surface and then solder the other legs.

**Hint:** The screwed terminals and the large copper area underneath have a large thermal mass and depending on the wattage rating of your soldering iron will take tens of seconds to heat up sufficiently for the solder to melt and flow. Ensure the iron is well tinned and in contact with both the copper conductive layer and the leg of the terminal and ensure the solder flows evenly right round each leg.



### Component Insertion 4 - Diodes

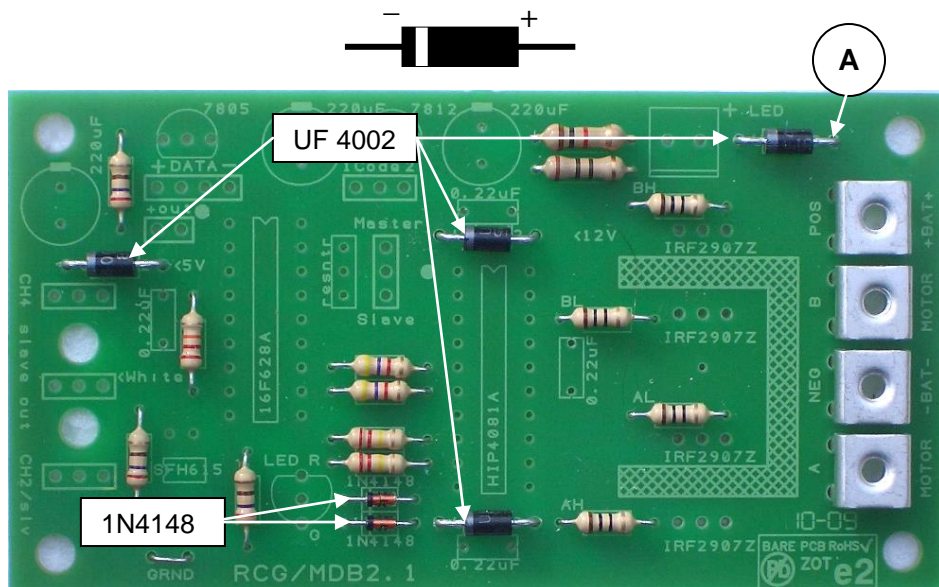
**Diodes** Note the two different types, size and numbers.

Bend the wires using pointed nosed pliers through 90 degrees so that the bent leads are the same distance apart as the holes.

Insert the Diodes with the **CORRECT ORIENTATION**. (The white band denotes the negative end).

Cut off the excess wire 3mm from the under surface and solder them in.

**Note:** The leg of the diode marked **A** goes into a large area of copper and it may take longer for this to heat up and for the solder to flow.





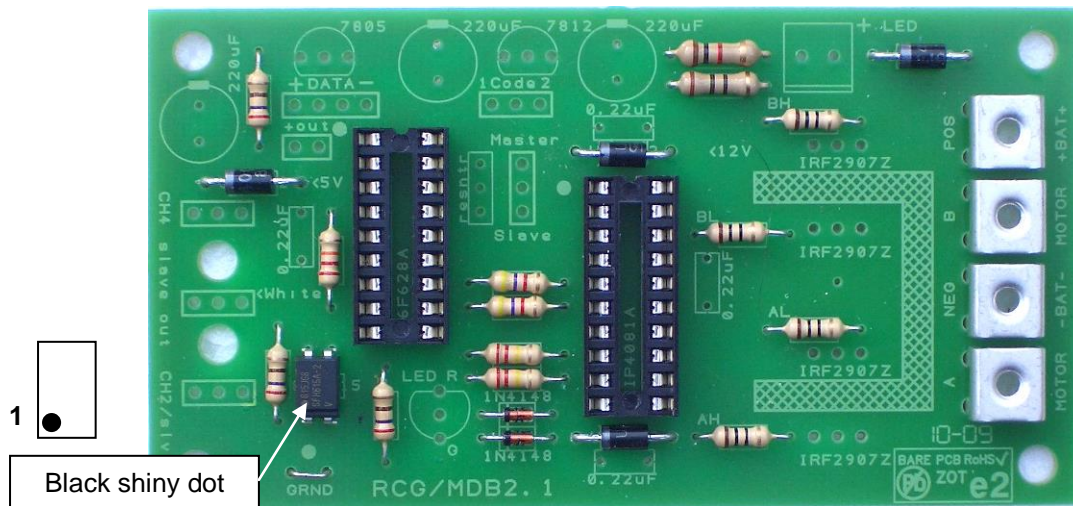
## Component Insertion 5 – IC Sockets and Opto-Isolator

**IC Sockets.** Gently insert the ICs with the small indentation towards the top of the board (this orientation is not critical). Do not force the sockets down as you may bend a pin or push a pin up above the top of the plastic. The socket must lie flat on the board

Solder two opposite corner pins first and then ensure the socket is still flush with the top of the board and all the tops of the pins are flush with the top of the plastic before soldering in the rest of the pins.

**Hint:** Check there is a pin in every hole under the socket to ensure you have not bent a pin between the socket and the top of the board.

**Opto Isolator.** Insert and solder in the Opto-Isolator with the **CORRECT ORIENTATION** for pin No 1 (The black shiny dot must be towards the bottom left of the board).



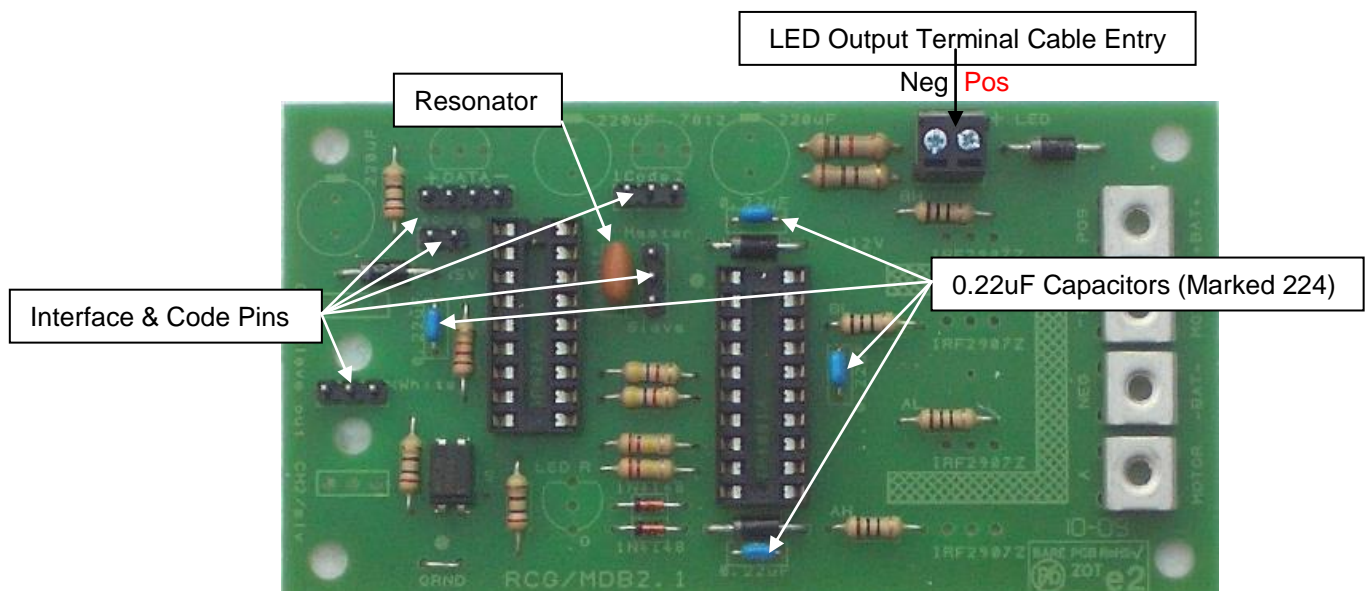
## Component Insertion 6 – Small Capacitors, Resonator, Interface & Code Pins, and LED Output Terminal.

**Small Capacitors** Insert and solder in the 0.22uF Capacitors (marked 224) (Insert either way round).

**Resonator.** Insert and solder in the resonator (Either way round)

**Interface and Code Pins.** Insert and solder in the 2, 3 and 4 pin interface and code pins with the **shorter end** of the pins through the PCB.

**LED Output Terminal** Insert and solder in the LED Output Terminal with the holes for the cable entry towards the top edge of the board.

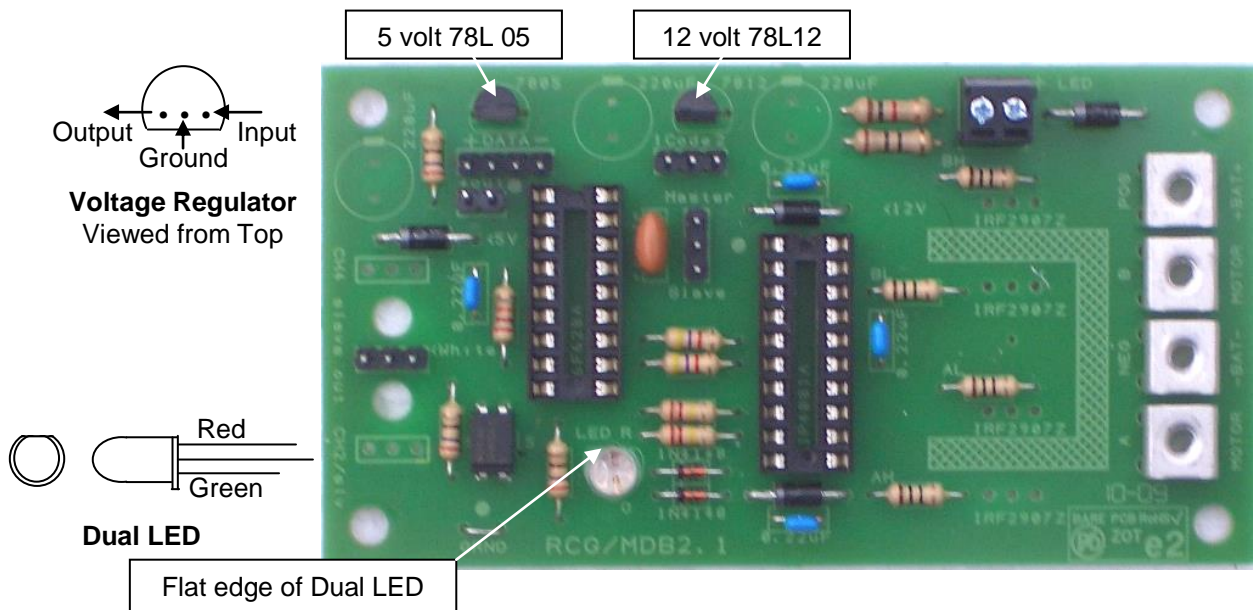




## Component Insertion 7 – Voltage Regulators and Dual LED

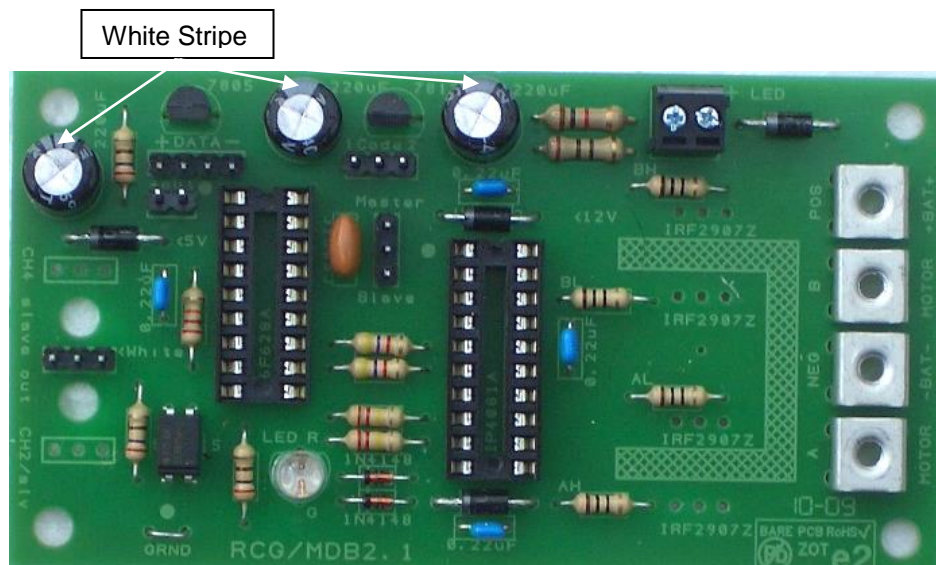
**Voltage Regulators.** Insert and solder in the 5v (labelled 78L 05) and 12v (labelled 78L 12) voltage regulators in the **CORRECT POSITIONS with the CORRECT ORIENTATION**

**LED.** Insert and solder in the Dual Light Emitting Diode (LED) with the **CORRECT ORIENTATION**. The longer lead and flat edge is the red side (R).



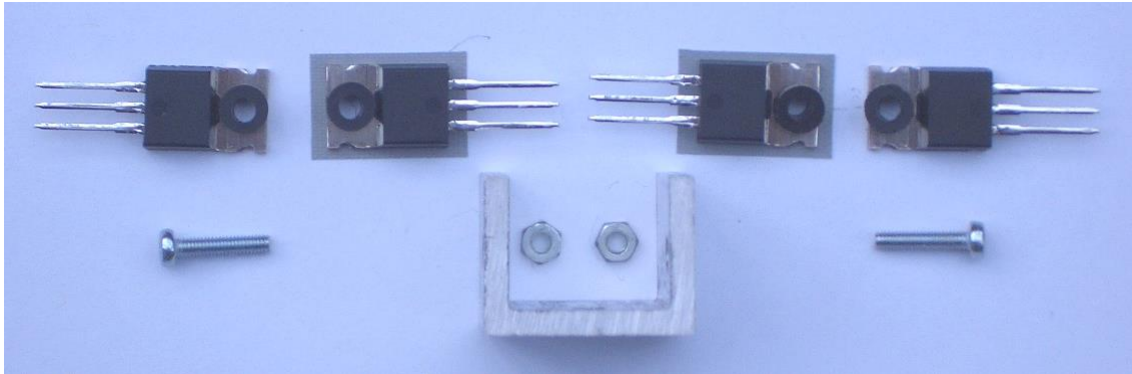
## Component Insertion 7 – Large Capacitors

Insert and solder in the large 220uF electrolytic capacitors in the **CORRECT ORIENTATION**. The white stripe denotes the negative connection and should be towards the top of the board.



## Component Insertion 10 – Heat Sink Assembly

Check the heat sink is free of burrs and the holes are clear. **The inner surface must be smooth to the touch as rough edges and burrs will cut through the insulation sheet and cause an expensive short circuit.**



Heat Sink Components

The Heat Sink and MOSFETS are assembled away from the board and then the whole assembly is fitted to the board as one item. **DO NOT SOLDER THE MOSFET LEGS UNTIL THE HEAT SINK IS ASSEMBLED** or you will find it impossible to line up the holes and top hat insulators.

Fit the top hat insulators in the holes in the MOSFET tabs.

Fit two insulation sheets to the back of the inner MOSFETS with the top hat poking through the insulator.

**Note:** The outer MOSFETS are electrically connected via the metal heat sink.

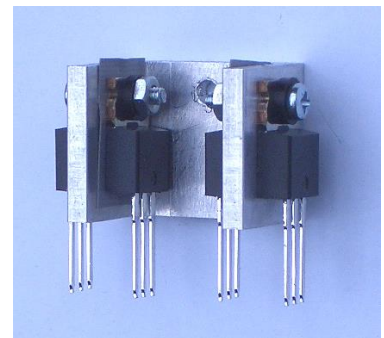
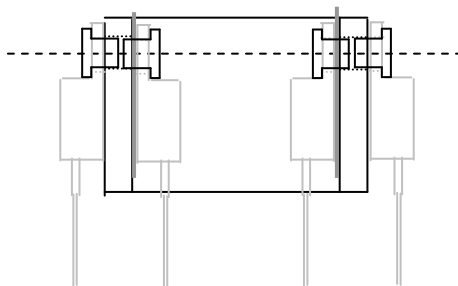
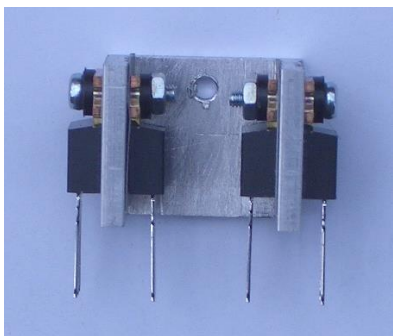
Fit the inner MOSFET with the insulation sheet attached. With your finger pressing the top hat insulator and MOSFET into place. Fit the outer MOSFET and insert a 2.5mm pan head screw through the two MOSFETS and heatsink.

Fit the nut finger tight and ensure the top hat insulators are properly located and seated in the hole of the heat sink and the insulation sheet has not slipped out of place.

Repeat this sequence from the other side of the heat sink as shown in the photographs below.

The assembly should be in the following order from outside to inside on both sides:

**2.5mm screw – Top Hat – MOSFET – Heat Sink - Insulating spacer – MOSFET – top hat – Nut.**



Rotate each MOSFET until all the four sets of pins are vertical and exactly in line. Insert the complete heat sink and MOSFET assembly into the PCB.

Cut off **half the length** of the MOSFET pins protruding through the PCB.

One or two of the pins of each MOSFET have a rectangle of bright metal next to them.

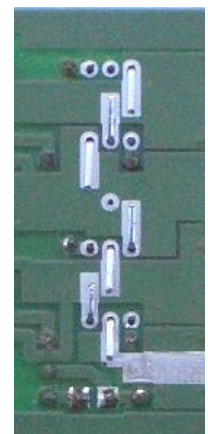
**Bend over these pins flat against the under side of the board on top of the shiny rectangles.**

Solder these pins along their length to ensure there is a good high current connection between the MOSFET pins and the large areas of copper.

Solder the remaining pins as normal and cut off the excess length.

Tighten the Heatsink bolts.

**Hint:** Stop the screw rotating with a screwdriver and finally tighten the nut with pliers.



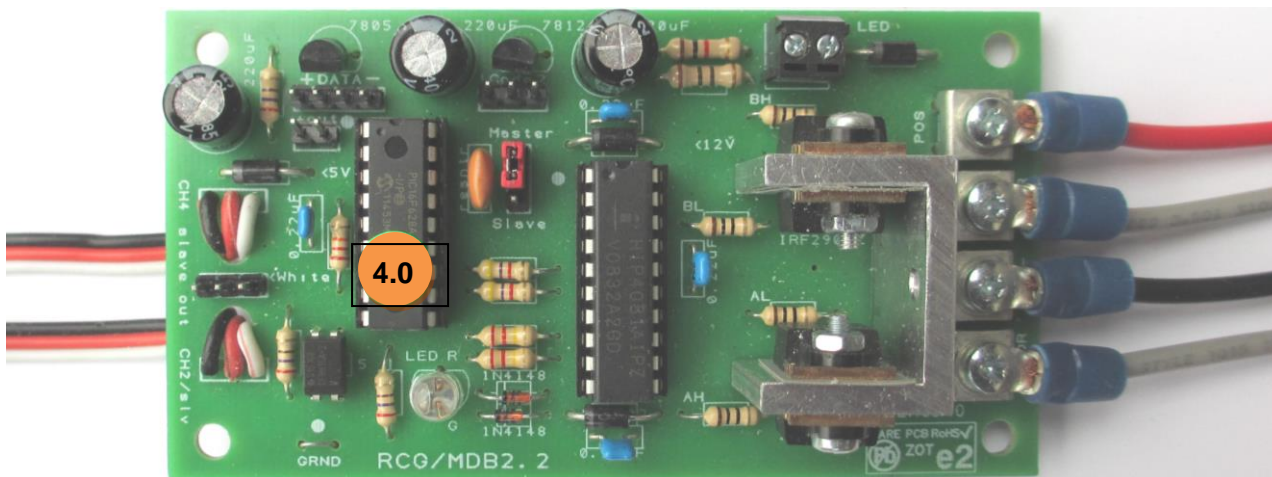
## Component Insertion 11 – Radio Control and Power Leads

**Radio Control Leads.** If the ends of the radio control leads are not already tinned with solder, remove 4mm of insulation from each wire, twist the strands of each wire together and apply solder to the ends to keep the strands together. (This is called tinning the wire.)

**Hint:** When the solder melts draw the soldering iron towards and off the ends of the wire to remove excess solder and ensure the wires are thin and pointed enough to pass through the holes in the board.

Pass the wires through the board from bottom to top (this provides strain relief), make a large (approx 5cm) loop above the board and insert the bare ends of the wires into the board with the **CORRECT SEQUENCE** (Black wire to the edge of board for Black-Red-White leads). (Brown wire to edge of board for Brown-Red-Orange leads).

Solder in the three wires and pull the wires until they are flat with the top of the board. Check there is no bare wire or single strands of wire left above the board.



### Power Leads.

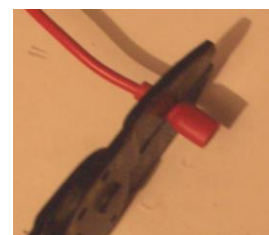
The Red wire with the Red male connector is the Positive wire to the battery (POS).  
The Black wire with the Blue male connector is the Negative wire to the battery (NEG).  
The Grey wires with the Blue Female connectors are the motor wires (A and B)

Using the special crimping tool supplied:

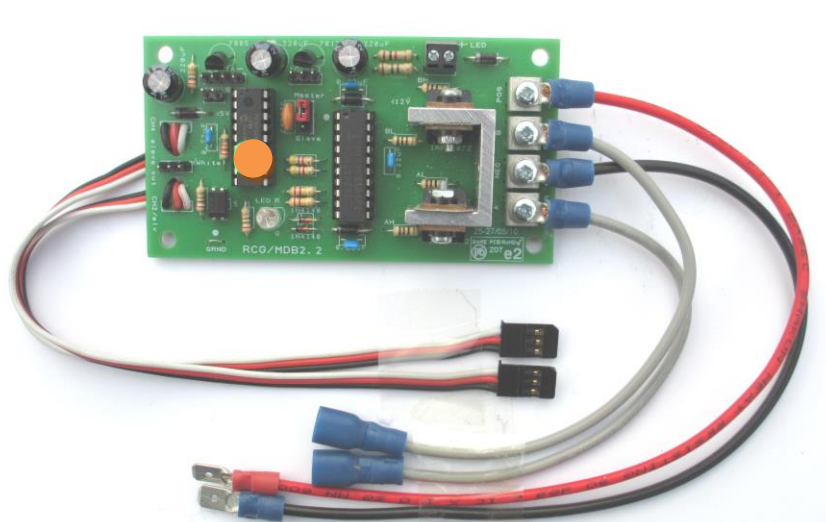
Crimp Red and Blue **Male** Spade terminals to one end of the longer Red and Black power wires. Crimp Red and Blue Ring terminals to the other ends.

Crimp Blue **Female** Spade terminals to one end of the two Grey motor wires. Crimp Blue Ring terminals to the other ends.

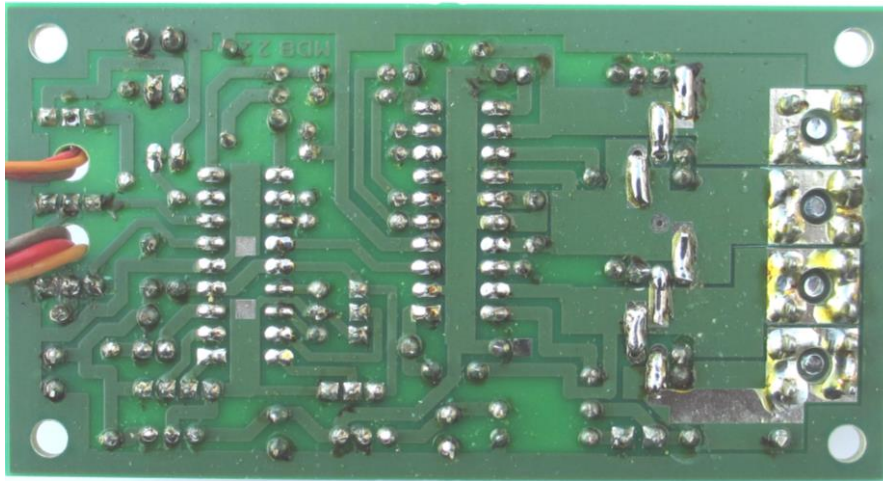
Attach the four Blue ring terminals to the screwed terminals using 3mm screws (6mm long) and shakeproof washers.



**Note: It is vital that you connect the (+) red wire to the battery positive and the (-) black wire to the battery negative or you will burn out the reverse current diodes in the MOSFETS.**







**The Completed Board – Bottom View**

The only components not fitted prior to testing are the two ICs.

### **Making the Test Equipment**

To test the boards you will need to make two pieces of test equipment. These items are used to check that the board is functioning properly without causing any expensive smoke.

**Warning Bulb.** To avoid blowing up the expensive MOSFETS if there is a fault on the circuit board, it is important to limit the current by inserting a 12v bulb and 6.8 ohm resistor in series between the battery and the board. If there is a major fault the bulb will light and protect the MOSFETS. If this happens during testing **disconnect power immediately as the bulb and resistor can get extremely hot with prolonged running and will burn you.**

You will also undertake initial checks using a small 3v test motor with a 27 ohm resistor in series.

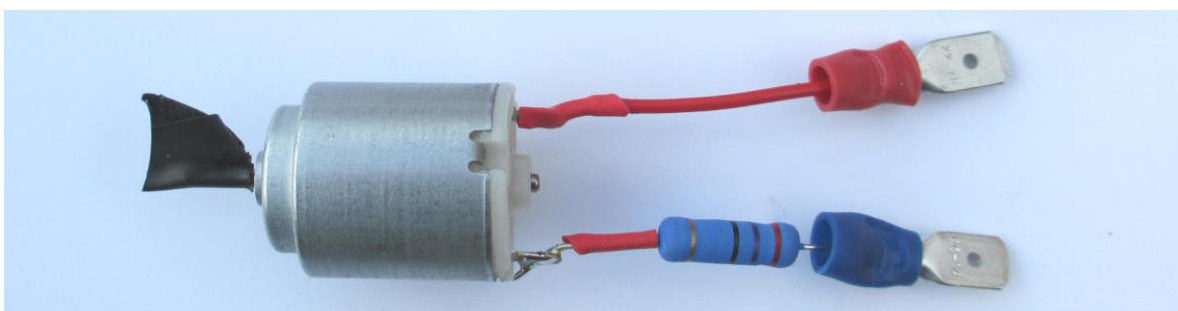
When testing is complete and you are happy the board is functioning correctly and the small motor can be controlled forwards and backwards at varying speeds, the bulb and small motor can be disconnected and the proper drill motors connected. These drill motors can draw currents of up to 40 amps.

Connect up the test equipment parts as shown in the two photos below.

Hint: Fix a piece of tape to the motor shaft so that you can see which way it is rotating.



**12v Halogen Bulb and 6R8 10W Resistor for Initial Testing of Small Motor**



**Small 3 volt Motor with 27R Series Resister**

## Build 9 – Testing the Motor Control Boards

### Configuration

**Master or Slave.** Two motor drive boards are required to run your robot. They are made as identical boards and configured as a **Master Board** or a **Slave Board** by the position of a jumper. Connecting the top two jumper pins together configures the board as a Master and connecting the bottom two jumper pins together configures the board as a Slave.

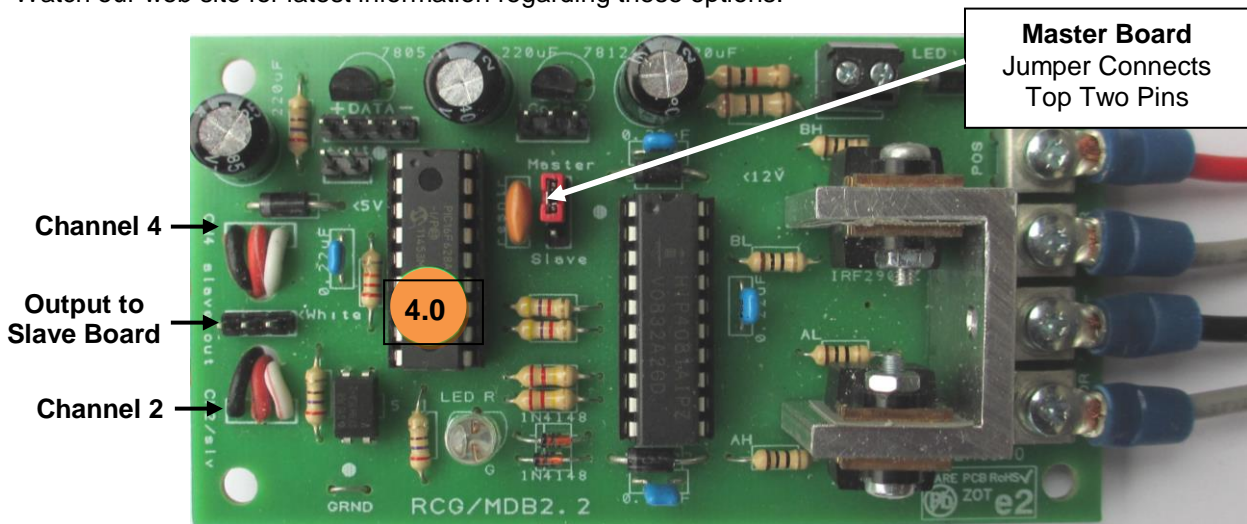
**Note:** Three other sets of pins are also fitted on the board, but may not be activated in the PIC software code.

The block of 2 pins is provided for an additional LED output such as a reversing light.

The block of 4 pins is provided for a future output to a data logger and a Formula 1 type telemetry link.

The second block of 3 pins is provided to select future control law options.

Watch our web site for latest information regarding these options.



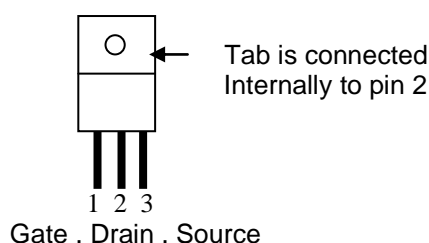
### Initial Checks

For testing, each board should be configured as a **Master Board** (Jumper connects top two pins). The boards are tested separately and should exhibit identical characteristics.

Each step in the test process is numbered 1 to 30. If you contact the Rampaging Chariots Guild for advice you should refer to the associated fault numbers so that we can better provide advice and assistance.

### Ensure the Battery, Motor, Receiver and both ICs are disconnected

- 1 Check all components are in the correct place and are fitted the correct way round.  
This is a major cause of problems. Components may be the wrong values (particularly the resistors). The 5v and 12v regulators may be reversed. Components such as diodes and electrolytic capacitors may be fitted the wrong way round.
- 2 Check for dry solder joints and solder bridges shorting adjacent tracks together. - This is another major cause of problems.
- 3 Check the two outer MOSFETS have their metal tabs in contact with the heat sink (screws tight) and the two inner MOSFETS are insulated from the heat sink.  
**Note:** The MOSFET tab is connected internally to the centre pin called the 'Drain'. The outer MOSFETS are therefore electrically connected through the metal heat sink.



- Check the battery plug is **wired the correct way round** and the red wire is connected to the positive terminal.

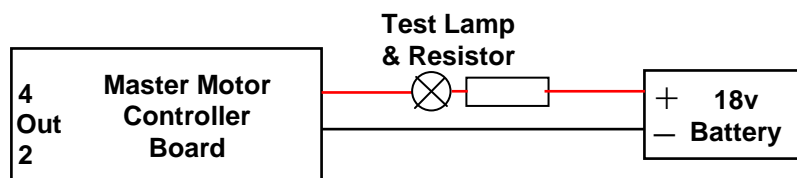
**Note:** If you connect the battery the wrong way round you will probably blow the MOSFET internal protection diodes which will cause the expensive MOSFETs and the expensive driver IC to fail the first time you try to stop your chariot from a high speed.

- Check the board has the jumper connected in the Master position.

### Applying Power

Initial power checks are done with the 12v test lamp and series resistor in circuit and **without the two ICs** fitted in their sockets.

- Apply power to the board from the fully charged 18v drill battery through the 12v test lamp and series resistor as shown in the diagram below. **Be ready to disconnect quickly.**



- Check the lamp does not light up and touch the two voltage regulators to check they are not heating up. Be aware of any unusual smell.

A major fault (probably a short) is indicated by:

The test bulb illuminating.

The large 10 ohm resistor heating up.

The 12V or 5V regulator heating up.

A burning smell.

Fault 7a

Fault 7b

Fault 7c

Fault 7d

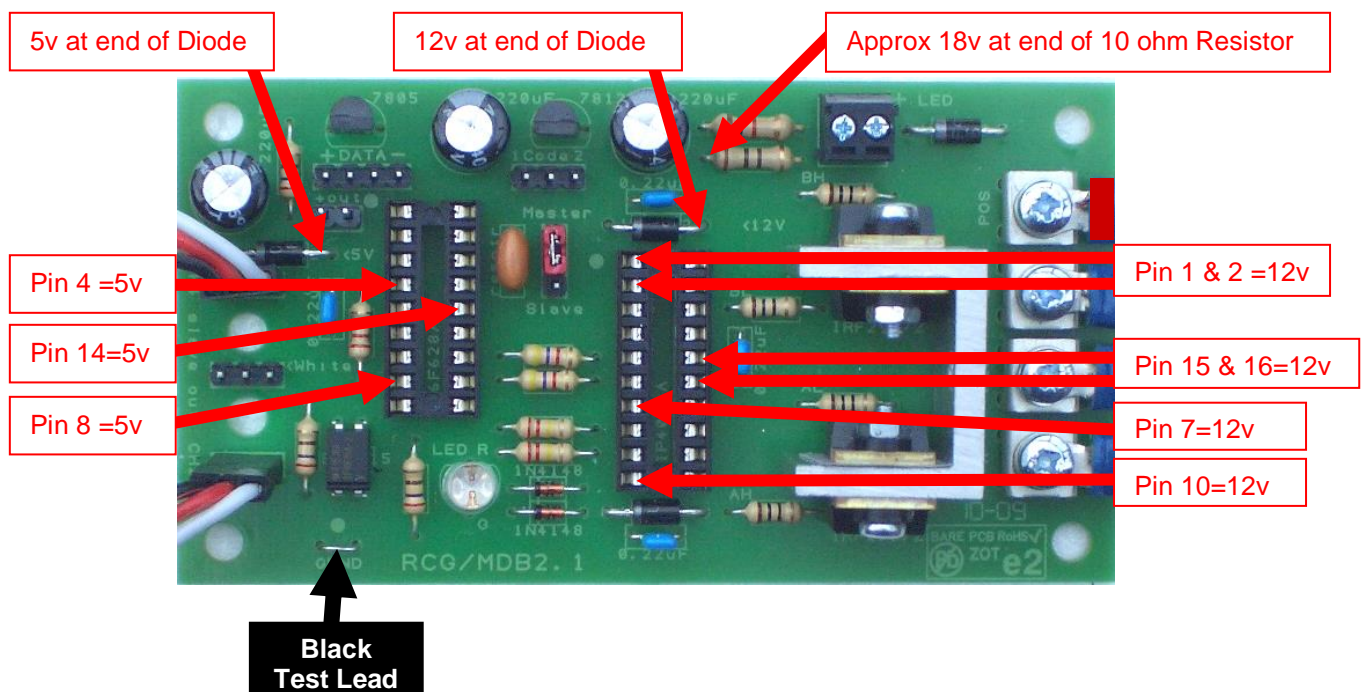
**Note:** It is possible that if you have been touching the MOSFET pins with your fingers a temporary static charge on the gate pin can cause a MOSFET to switch on and cause the bulb to light. This can only occur without the driver IC fitted. Disconnect the battery and the charge is likely to leak away in a few minutes.

- Connect the Black test lead from your meter to the negative test point.
- Check approx 18v on input to board from the drill battery (End of large 10 ohm Resistor)  
If the voltage is low there is either a short, or the battery is not charged.
- Check 12v +/-0.5v on output from first regulator (At the end of the diode shown)
- Check 5v +/- 0.2v on output from second regulator (At the end of diode shown)

Fault 9

Fault 10

Fault 11





12. Check voltages on IC1 socket  
All pins < 0.2v except  
Pin 4 = 5v  
Pin 8 = 5v  
Pin 14 = 5v

Fault 12

13. Check voltages on IC2 socket  
All pins < 0.1v except  
Pin 1 = 11 to 12v  
Pin 2 = 12v  
Pin 7 = 12v  
Pin 10 = 11 to 12v  
Pin 12 = Reducing to stabilise < 0.5v  
Pin 15 = 12v  
Pin 16 = 12v  
Pin 19 = Reducing to stabilise < 0.5v

Fault 13

**DO NOT CONTINUE IF YOU DO NOT GET APPROXIMATELY THE CORRECT VOLTAGES**  
**Investigate and Contact: [technical@rampagingchariots.org.uk](mailto:technical@rampagingchariots.org.uk)**

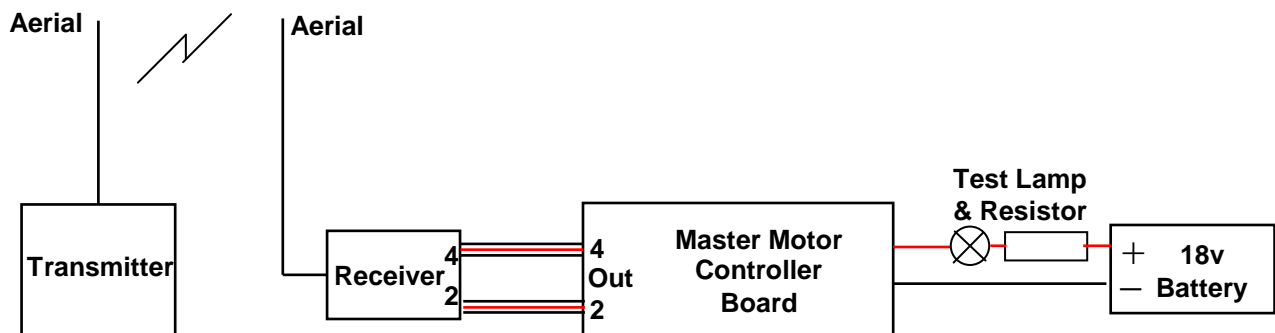
### Inserting The PIC

14. With the battery disconnected, insert the PIC IC (18 pins) with **correct orientation** (Pin 1 is identified by a small indentation in the top surface of the PIC at the end)

**Hint:** You may need to bend the pins slightly inwards to get it to fit in the socket. This is best done by pressing each side of the PIC down onto a flat surface in turn.

15. Plug the two radio control leads (labeled **CH4** and **CH2/slv** on the board) into the Channel 4 and Channel 2 positions of the radio receiver.

**Note:** The plugs are keyed and should only fit in one way round.



15. Apply power to the board from the 18v battery through the 12v test bulb and resistor.  
Check the dual colour Light Emitting Diode (LED) lights RED (No radio pulses being received). Fault 15
16. Switch on the Transmitter ensuring that the control sticks and the four trim sliders are all central.  
Check the Red LED goes out. (Radio pulses are being received) Fault 16
17. Move transmitter right stick up and down slowly (Channel 2). The LED should glow GREEN and increase in brightness with control deflection. Fault 17
18. Move transmitter right stick down slowly (Channel 2). The LED should glow GREEN and increase in brightness with control deflection. Fault 18
19. Move transmitter left stick to left and right (Channel 4). The LED should glow GREEN and increase in brightness with control deflection. Fault 19
20. If the LED glows GREEN faintly with controls at neutral, adjust the transmitter trims for neutral. Fault 20

Switch off the Transmitter and disconnect power from the Board.

21. If steps 15 to 20 give the correct results the first half of the board is working correctly and you can insert the driver IC.

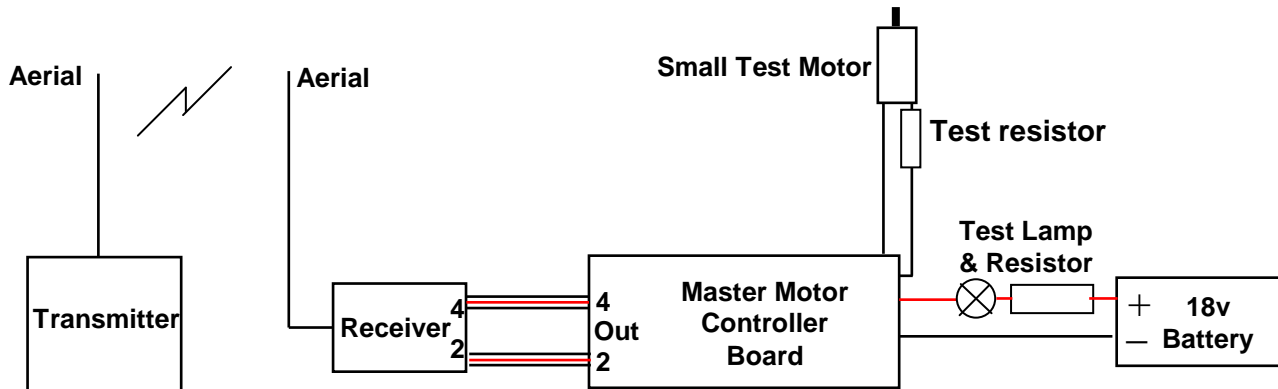
**DO NOT INSERT THE DRIVER IC UNLESS THE GREEN DIODE IS LIGHTING CORRECTLY WHEN YOU MOVE THE CONTROL STICKS. Investigate and Contact: [technical@rampagingchariots.org.uk](mailto:technical@rampagingchariots.org.uk)**

### Inserting The Driver IC

21. With the battery disconnected Insert the Driver IC (20 pins) with correct orientation ((Pin 1 is identified by a small indentation in the top surface of the PIC at the end).

**Hint:** You may need to bend the pins slightly inwards to get it to fit in the socket. This is best done by pressing each side of the PIC down onto a flat surface in turn.

22. Connect the small test motor with its series resistor.



23. Apply power to board from the 18v battery through the 12v test bulb and resistor.

24. Touch the two voltage regulators and the large 10 ohm resistor to check they are not heating up and be aware of any unusual smell. Fault 24

25. Check the LED is RED (No radio pulses being received) and the test motor is not rotating. Fault 25

26. **Switch on the Transmitter** and check the LED goes out to indicate pulses are being received from the receiver. If the battery needs charging the transmitter will 'beep' at you. Fault 26

27. If the LED glows GREEN (the motor may also be rotating slowly) adjust the transmitter trims for neutral. Fault 27

28. Move transmitter right stick up slowly (Channel 2). The LED should glow GREEN and increase in brightness with control deflection and motor should increase in speed. Fault 28

29. Move transmitter right stick down slowly (Channel 2). The LED should glow GREEN and increase in brightness with control deflection and the motor should increase in speed in the opposite direction. Fault 29

30. Move transmitter left stick to left and right (Channel 4). The LED should glow GREEN and increase in brightness with control deflection and motor should increase in speed. Fault 30

**Note:** The resistor in series with the small test motor will heat up with prolonged running and may smell slightly.

### **Eureka It Works!**

Once you are happy the board is functioning correctly and the small motor can be controlled forwards and backwards at varying speeds, the test bulb can be disconnected.

Now test the other board configured as a master board in exactly the same way.

## Troubleshooting

Nothing is happening.

- Is the battery connected the correct way round?
- Are the batteries fully charged?

The large 10 ohm resistor is heating up.

- You have a short. Check for solder bridges.

The 12v bulb illuminates

- Check for solder bridges round the MOSFET pins
- Allow time for any static charge on the MOSFET gate pins to leak away

You have reached the stage of inserting the PIC IC, but the Red or Green LED is not showing the correct indications.

- Check for bad soldered joints and solder bridges.
- Check the control board is configured as a Master.
- Check component Values and orientation.
  - Are resistance values correct?
  - Are the diodes inserted the correct way round?
  - Are radio leads in the correct way round?
  - Are the 5v and 12v voltage regulators inserted in the right place and the correct way round?
  - Are electrolytic capacitors values correct and are they in the correct way round?
  - Are the ICs inserted the correct way round?
  - Is the dual colour LED in the correct way round?

**NB: If the LED is not giving the correct indications **Do not insert the Driver IC** as you could cause consequential damage to the expensive MOSFETS and Driver IC. Ask for advice (see below).**

IF YOU HAVE PROBLEMS TESTING THE BOARD AND ARE NOT GETTING THE CORRECT INDICATIONS, **STOP** AND REEXAMINE THE BOARD WITH A MAGNIFYING GLASS.

RESIST THE TEMPTATION TO TRY THE NEXT STAGE OF TESTING.

DO NOT SUBSTITUTE COMPONENTS FROM YOUR OTHER BOARD.

DO NOT REMOVE THE CURRENT LIMITING TEST BULB.

SOME TEAMS HAVE IGNORED THIS ADVICE, DESTROYED EXPENSIVE COMPONENTS AND MADE OUR TROUBLESHOOTING TASK MUCH MORE DIFFICULT.

## Advice

If all else fails, try reading the instructions!

Seriously; do not be shy about contacting the Rampaging Chariots Guild for help. We are very keen to see you build a successful Chariot and like hearing about your engineering exploits and ideas.

**The Guild operate a diagnostic and repair service and only charge in exceptional circumstances.**

If you have a designated STEM or Selex-ES ambassador then they are also there to help you.

### **Contacting The Rampaging Chariots Guild Engineers.**

If you have any problems you cannot resolve after inspecting the board for wrongly positioned components & poor solder joints STOP TESTING and contact [technical@rampagingchariots.org.uk](mailto:technical@rampagingchariots.org.uk) we will give you advice by e-mail and if this does not solve your problem we will give you an address to post it to.

You should put your board, with both ICs inserted to protect the pins, in a jiffy bag together with your return address. Please give us an idea as to what the problem is by referring to the fault numbers above; e.g. Faults 16 / 17 / 18 / 19.

We will get the board functioning and post it back to you. The Guild provide this diagnostic and repair service and also supply replacement parts at no charge (except in exceptional circumstances) as we are very keen to see you build a successful Chariot and enjoy competing it.

## Build 10 - Wiring up Your Robot

### Fitting the Motor Controller Boards

When both boards are working correctly and identically as master boards, configure one as a **Slave** by moving the jumper onto the adjacent pins.

Fit four nylon pillars through the corner holes in both boards.

Rotate the pillars to align the retaining catch with the long side of the board.

**Hint:** This allows you to squeeze the catches with a pair of long nosed pliers if you need to remove the board from the chassis.

Peel off the protective sticky paper and fit the boards to the centre of the back and front ends of the chassis. The Master board is fitted at the front or you will need to reverse a radio channel. You can if you like mount the boards onto the base and cut the nylon pads to fit, or you can mount them on the front and back providing you don't screw the rear hook in too far.

### Interconnections

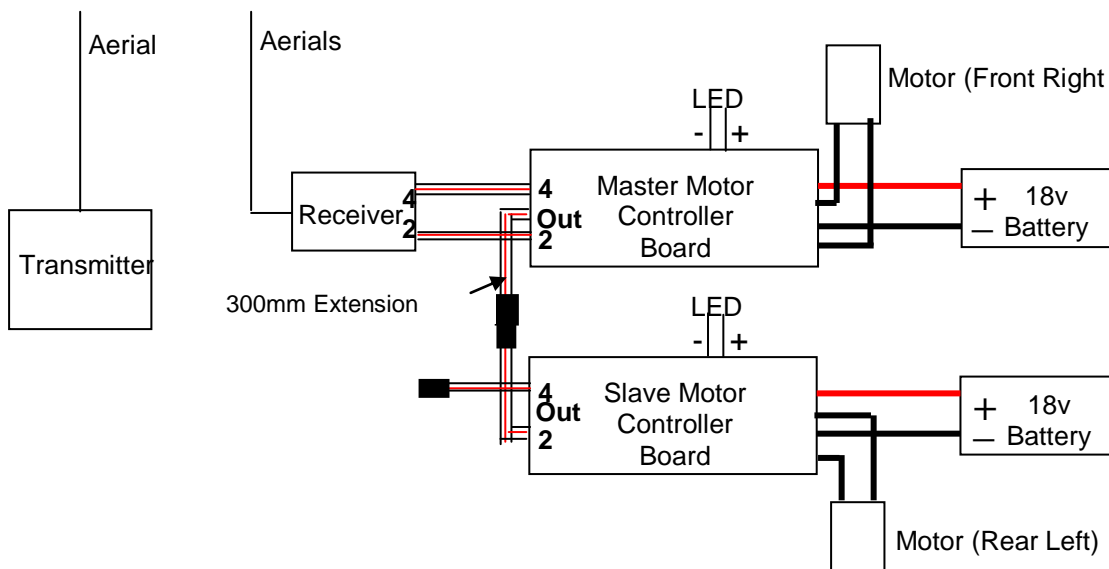
For the **Master** board both radio control leads are used and these plug into Channel 2 and Channel 4 of the radio receiver.

For the **Slave** board the Channel 4 lead is not used and should be neatly coiled up and insulated. The Channel 2 lead should be extended with the extension lead provided and is plugged into the central plug on the Master board labelled '**slave out**' (**Black wire towards the edge of the board**).

Connect the grey power leads to the drill motors.

Connect the red and black leads to the battery connectors **with the correct orientation**

**Note:** The drill motors will not turn with the test bulb in circuit as the bulb limits the current.



Master Motor Control Board is Fitted in the Front of the Chassis

2020 Model Rampaging Chariot

## Build 11 – Testing the Completed Robot

### Testing On The Bench

#### **Support the robot on blocks so that the wheels are off the ground.**

Insert the transmitter batteries and check that the radio leads are in channel 2 and channel 4.

**Note:** Receiver holes are keyed for correct orientation of the plugs, so do not force the plugs in.

Connect the charged batteries and check the rear red LEDs are both ON and both motor board LEDs are Red.

Switch on the transmitter. The Board Red LEDs should go OFF within half a second indicating a valid control signal is being received.

1. Select forward control. Both wheels should move forward and the Green LEDs should light  
If either motor moves in the backwards direction **swap over its motor wires**.
2. Select backwards control. Both Wheels should move backwards and the green LEDs should light.
3. Select a Left Turn. Left Wheel should go backwards. Right Wheel should go forwards.  
If they go the wrong way, check if you have fitted the Master Motor Control Board in the front of the chassis. If everything appears correct you should try reversing channel 4 on the transmitter.
4. Trim the control system by slowly selecting forwards on the **right stick** and seeing if the wheels start turning at the same time. If not adjust (pulse) the **left trim (Channel 4)** until both wheels just start to turn at the same time. Release both sticks and adjust (pulse) the **right trim (Channel 2)** until the wheels just start to move. Then adjust this trim in the opposite direction and count the pulses until the wheels just start to move in the opposite direction. Then pulse the trim half the number of pulses back to the central zero position.

**Hint:** There is an audible whine from the motor control boards when the stick is moved or the trims are not correctly set. You can use this whine to help you get the zero position on both trims by adjusting them until the robot is silent.

### Testing In The Arena

Connect the batteries and switch on the transmitter.

Check the robot moves forward and back in a straight line.

Check it turns on the spot

Check it turns whilst it moves forwards and back.

### **Practise, practise, practise.**

Our website [www.rampagingchariots.org.uk](http://www.rampagingchariots.org.uk) includes video clips of the games which are invaluable for prospective entrants to appreciate the size and shape of the arena and obstacles. It will also give you a good appreciation of the tactics and standard of the opposition.



## Build 12 – Ideas For Improving Your Robot

### 1. Aesthetic Appearance

The first improvement is to add a superstructure that personalises your chariot and improves its appearance. Why not enlist the help of your art department?

Any superstructure must be capable of easy removal so that you can remove the battery caps quickly to immobilise your chariot if anything goes wrong. You may need a hole for the aerial and must keep below the 12 kg mass limit.

Remember you need it to negotiate the obstacle course so it can't be too high or wide. Also, don't make it too top heavy or the superstructure will fly off when you 'accidentally' bump into an opponent when playing football.

### 2. Ruggedness

If you do hard tackles in football you will find that the basic design may need strengthening. You could re-manufacture the chassis using 12mm plywood and fit the pieces together with mortise and tenon joints. If you are ambitious and make a metal chassis, remember to insulate the motor drive boards and position the receiver aerials well clear of the metalwork.

### 3. Battery Switch

Think about installing a 16A double pole switch to connect and disconnect the two red wires from the batteries.

### 4. Traction

There are many ways to increase traction (Friction) and we challenge your ingenuity.

### 5. Major Redesign

DO NOT be tempted to modify the basic design until you have constructed a standard Rampaging Chariot and have a working robot. You can then test it thoroughly, discover any weaknesses and formulate ideas (within the rules) that will improve upon the standard design and thereby gain a possible advantage over your opponents.

You can then, if you wish, make a replacement chassis and transfer the working and tested components into it. Do the design on paper and check all the components will physically fit in before you cut anything.

Remember the layout of the wheels is very important and you should consider the ball guides and ensure there is clearance to go up a 1 in 10 ramp without grounding.

The positions of the electronic components are also important to avoid radio (electromagnetic) interference. The example layout has proved to be satisfactory in this respect, but other layouts may also be acceptable.

### Considerations

- Width

- Length

- Ball guides

- Ramp clearance

- Shape of the front

- Weight – The mass of a standard Rampaging Chariot is about 6.6 Kg.

  - The maximum mass allowed is 12 Kg.

- Centre of Gravity

- Motor gearing

- Control Laws

- Gyro assisted stability

- Wheel base

- Aesthetic appearance

## Frequently Asked Questions

1. Why does my Robot make a horrible clicking sound when starting off and reversing?  
*A. Check that the drill motor torque settings are at maximum.*
2. Can I reposition the Receiver in the Chassis?  
*A. Yes the receiver can be repositioned within the chassis, but remember to keep it away from metal, sources of electrical noise such as the electronic motor drive boards and the drill motors.*
3. Can I shorten the aerial?  
*A. The aerial has to be exactly the length supplied for best performance and range.*
4. My chariot keeps getting stranded with the drive wheels spinning when it crosses the join in two floor boards.  
*A. This is probably the result of tyre wear. On a flat board the Chariot should rock on the drive wheels such that there is a 4mm to 6mm gap under one balancing wheel whilst the other is touching the ground. You can adjust the height of the balancing wheels by elongating the 10mm fixing holes in the sides of the MDF chassis with a round file.*
5. Why do I have trouble mounting the see-saw when I approach from the left?  
*A. This is because of the diagonal drive configuration which causes the two drive wheels to lift off the ground. If you approach the ramp either straight, or from the right, you will have no problem.*
6. Does the Rampaging Chariot have Fail Safes in both channels?  
*A. The Latest Saturn X transmitters are designed for model aircraft and if radio contact is lost the receiver continues to pass the last received commands. This will happen if the Radio Transmitter is switched off before the Receiver and the transmitter sticks are not in their central positions.*  
*B. The Rampaging Chariot motor control boards incorporate some fail-safe software which checks that the radio signals in both channels are within normal limits. If either channel goes outside these limits the system is programmed to switch off both motors.*  
*We do not guarantee that the system will switch the motors off under every failure condition, or under certain radio interference conditions. This is why you must always treat the robot as live whenever the batteries are connected and take the safety precautions described in this booklet. Rampaging Chariots are powerful robots that can bite.*
7. Why does my robot not work if I plug a standard servo into a spare receiver channel?  
*A. The receiver is powered from the master motor control board. The voltage regulators on this board are only designed to supply 100mA which is insufficient to drive an extra servo, Either plug a separate battery into the receiver or change the 5V and 12V regulators on the master board to MC7805CT and MC7812CT which are capable of supplying 1 Amp.*  
*Note: These substitute regulators go in the same holes with their metal tabs towards the centre of the board. You **must insulate these tabs** or they can short to other components. If you are only driving one servo intermittently it should be acceptable to cut off the portion of the metal tab above the plastic package to reduce the height of these components and their vulnerability to bending.*
8. Can I operate my Rampaging Chariot from one control stick?  
*A. If you unplug the channel 4 lead from the receiver and insert it in the channel 1 slot you can control the Rampaging Chariot from the right stick only. You can use any combination of channels that suit your style.*
9. My chariot goes OK in a straight line, but won't turn?  
*A. More power is needed to turn than to go in a straight line. Check your batteries are fully charged.*

## Appendix A - Motor Control Board Technical Description (For Geeks)

### MOSFET Bridge

MOSFETs can be used as very fast switches. If you connect four of them in what's called a 'Bridge' configuration you can make a DC electric motor turn forwards and in reverse by switching on the appropriate pair of MOSFETs (Figure 1 and Figure 2) to make the current flow in different directions through the motor.

The MOSFETs connected to the +ve battery terminal are called the 'High Side' MOSFETs and those connected to ground (-ve battery terminal) are called the 'Low Side' MOSFETs.

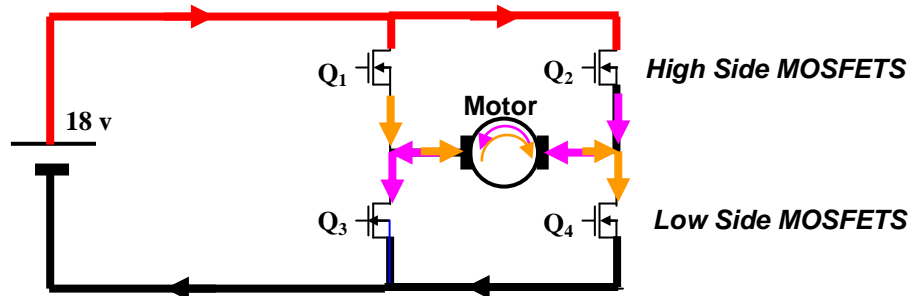


Fig 2 MOSFET Bridge

### Shoot-Through

A major issue is 'Shoot-through' which causes expensive blue smoke and a horrible smell. Shoot-through occurs when both High Side and Low Side MOSFETs on the same side of the bridge are turned on at the same time. This shorts out the Battery terminals causing a huge current to flow thereby blowing your MOSFETs. The IC which drives the MOSFET bridge is designed to overcome this issue by introducing a short delay between switching from high side to low side and vice versa. This delay is determined by the two 220K resistors

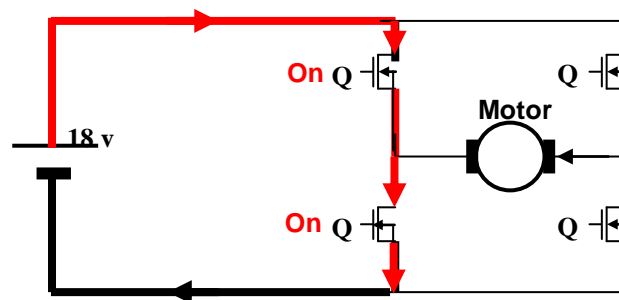
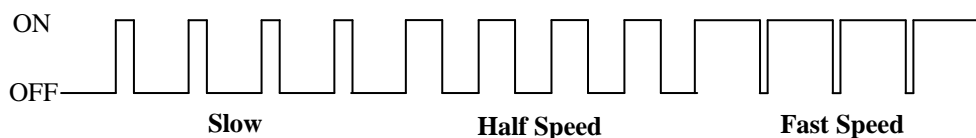


Fig 3 Shoot-Through Causing Burnt Out MOSFETS

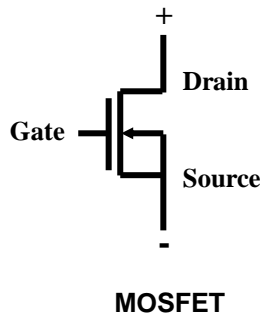
### Pulse Width Modulation

To vary the speed of the motor Pulse Width Modulation (PWM) is used. In normal operation the appropriate High Side MOSFET is kept on and the Low Side MOSFET is pulsed on and off several hundreds of times a second. The motor then sees an average voltage that is proportional to the time the MOSFET is on; compared to the time it is off.



### Gate Voltage

To turn a MOSFET fully on and make current flow from its Drain terminal (+ve) to its Source terminal (-ve) you apply a positive voltage of about 10 volts to its Gate terminal relative to its Source terminal. This is easy when the Source is connected to GND (like in the low side MOSFETs) as all it needs is 10V which can be obtained from the battery.



The High Side MOSFETs are more difficult to turn on, and keep on, as their Source is not connected to GND, but connected to one of the Motor connections. This motor connection is effectively connected directly to the positive battery terminal (18v) through the High Side MOSFET. To keep the High Side MOSFET on we need to supply its gate with 10 volts above its Source which is already at maximum battery volts. If the battery is 18 volts we need 28 volts relative to ground.

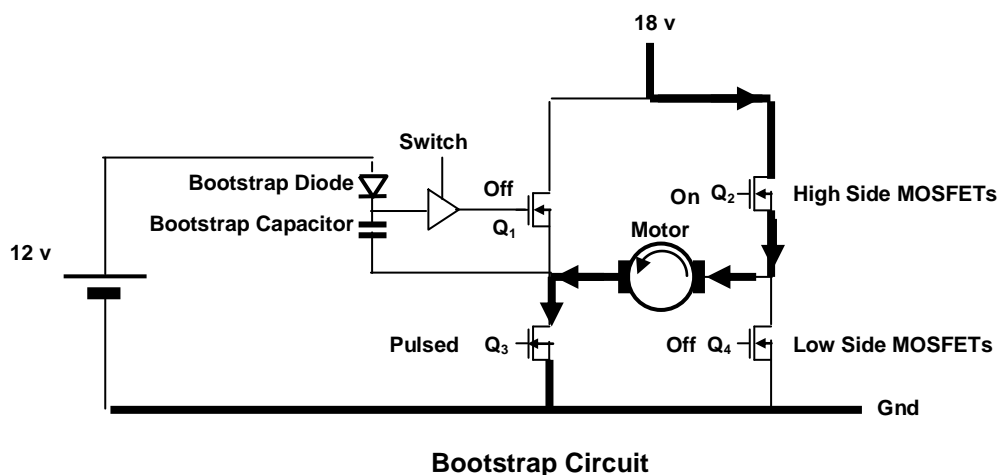
The IC that drives the MOSFET Bridge is designed to get around this problem by having special circuitry to generate 10V higher than the supply voltage and it does this using only 4 extra components. The circuitry used is a combination of a 'Boot Strap' circuit and a 'Charge Pump' circuit

### Boot Strap Circuit

This is named after a German scientist who claimed to have lifted himself out of a bog by pulling up on his own boot straps.

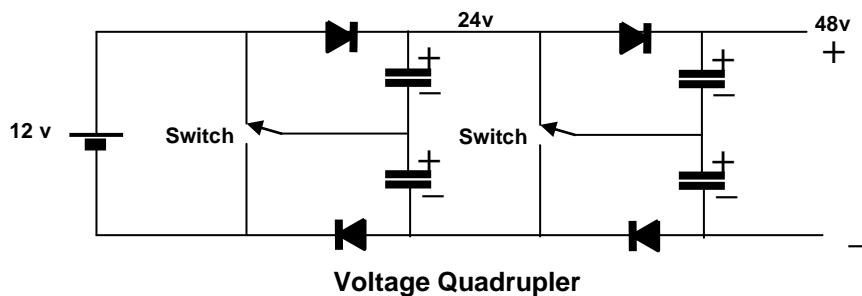
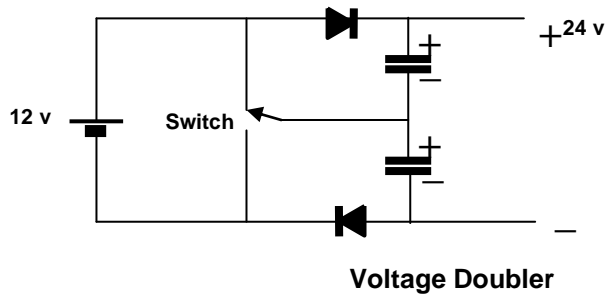
Each High Side MOSFET has a bootstrap capacitor. When a Low side MOSFET is conducting, the equivalent High Side MOSFET is off and its Source is connected to GND. The IC voltage charges the bootstrap capacitor to about 10 volts through a diode (which later prevents a reverse current flow). When the motor is reversed, the Low Side MOSFET stops conducting and the 10 volt charge on the bootstrap capacitor is applied to the Gate of the High Side MOSFET through a transistor switch. Because the capacitor is now isolated from GND, but still connected to the MOSFET Source terminal, it delivers a voltage of about 10 volts above the Source terminal which is enough to turn on the MOSFET. The bootstrap capacitor can be thought of as a dry cell battery that is free to float up and down with the motor terminal and continue to power the Gate driver. The only snag is that the bootstrap capacitor will slowly discharge and its voltage will decay to zero.

Whenever the motor is reversed the bootstrap capacitor is again connected to ground through a Low Side MOSFET and recharged, but we can't rely on regular reversals.



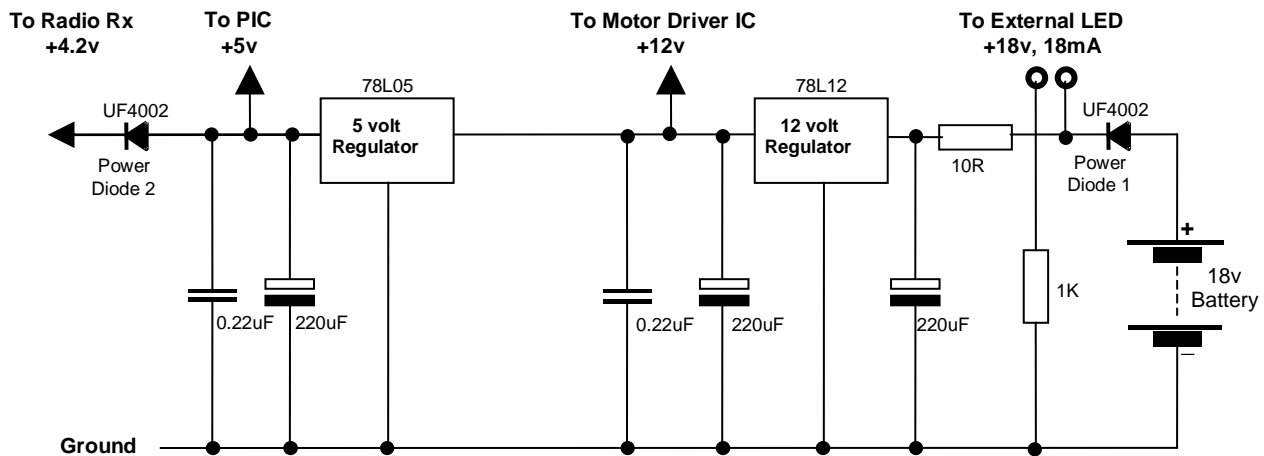
### Charge Pump

Another circuit (within the IC) called a charge pump is able to supply a very small current (about 50  $\mu\text{A}$ ) at the required high voltage to keep the bootstrap capacitor charged. It works on the principle of using small capacitors as energy storage elements to convert a low voltage into a higher voltage output. Charge pumps use transistor switches to control the connection of voltages to a number of capacitors. For instance, to generate a higher voltage, the first stage involves the capacitor being connected across a voltage (e.g. 12 v) and charged up. In the second stage, the capacitor is disconnected from the original charging voltage and a second capacitor is connected with its negative terminal to the original positive charging voltage. Because the capacitor retains the voltage across it (ignoring leakage effects) the positive terminal voltage is added to the original, effectively doubling the voltage. Additional stages of capacitors can triple or quadruple the voltage. The charge pumping action typically operates at tens of kilohertz. A zener diode within the IC prevents the charge pump voltage exceeding the motor voltage plus 10 volts.





## Motor Control Board Circuit Diagram Voltage Regulation Section

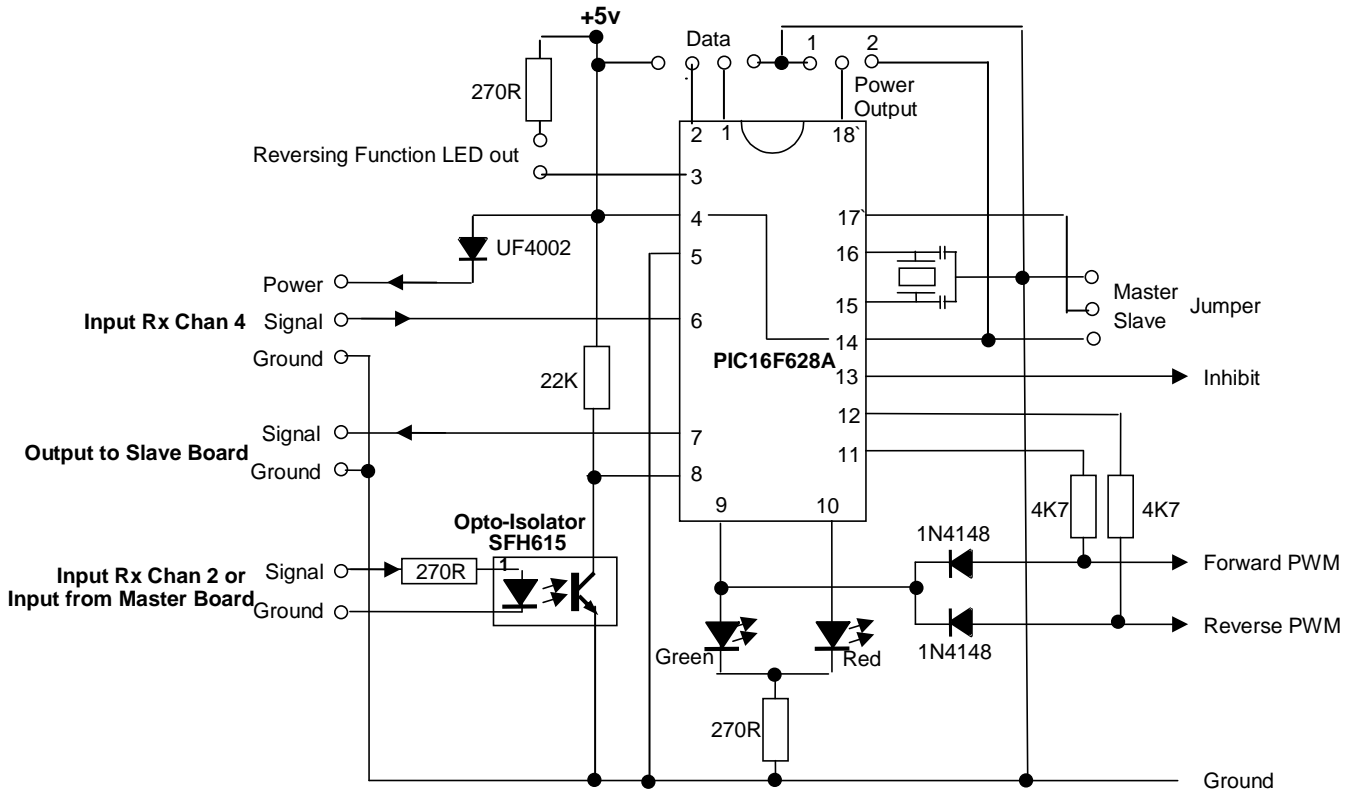


Power diode 1 protects the voltage regulation section against reverse connection of the battery. In conjunction with the 220uF reservoir capacitor this diode also maintains the voltage at the input of the 12 volt regulator during fluctuations of battery volts caused by pulsing of the drive motors. At the output of each voltage regulator two capacitors smooth the voltage and suppress voltage spikes caused by high speed switching of the two integrated circuits. Power diode 2 prevents reverse current flow if the radio receiver is powered from another source. A socket is provided for an external high brightness LED to indicate that the robot is powered up and the circuits are live.



## Power Regulation Section on PCB

## Motor Control Board Circuit Diagram Programmable Interface Controller (PIC) Section



Master Board receives PWM inputs from the radio receiver channel 2 and channel 4. The PIC mixes these inputs and calculates the left motor and right motor demands. The right motor demand is sent as an output to the Slave Board via a PWM link.

Each PIC then converts its own motor demand into a Pulse Width Modulated (PWM) output to its Motor Control IC. Forward and Reverse demands are obtained by grounding the unwanted signal through pins 11 or 12.

A jumper connecting pin 17 to ground tells the PIC it is a master board.

A jumper connecting pin 17 to 5 volts tells the PIC it is a slave board.

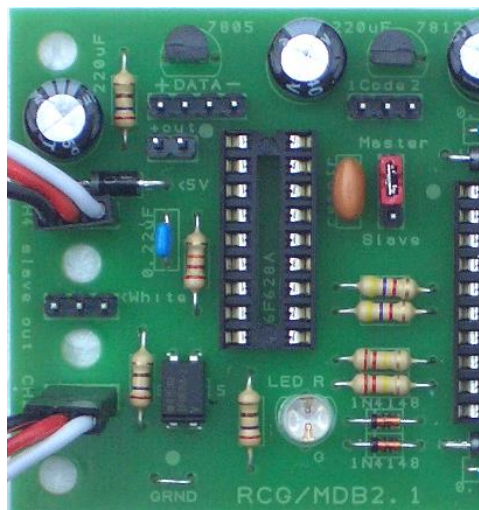
Additional pins allow selection of different control laws.e.g. Power settings, Data logger/telemetry, Reversing Indication LED. You can also connect a Raspberry Pie etc. for Autonomous operation.

A green LED indicates the PWM output to the Motor Driver IC. The brightness is proportional to the motor speed demanded.

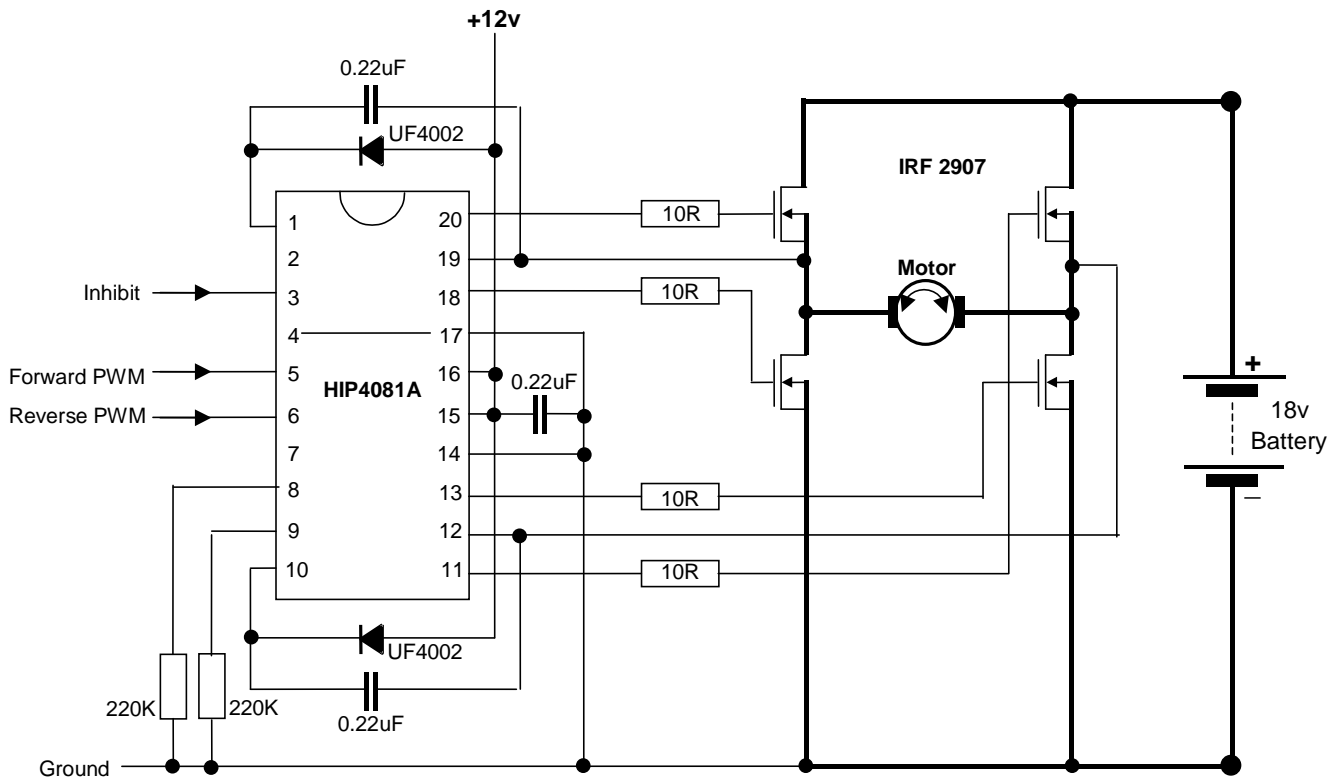
A steady red LED indicates an invalid signal is being received from the radio receiver and the Motor Control IC is inhibited.

The opto-isolator prevents glitches caused by electromagnetic interference (EMI) from the second board.

The opto-isolator on the Master Board is not strictly required.



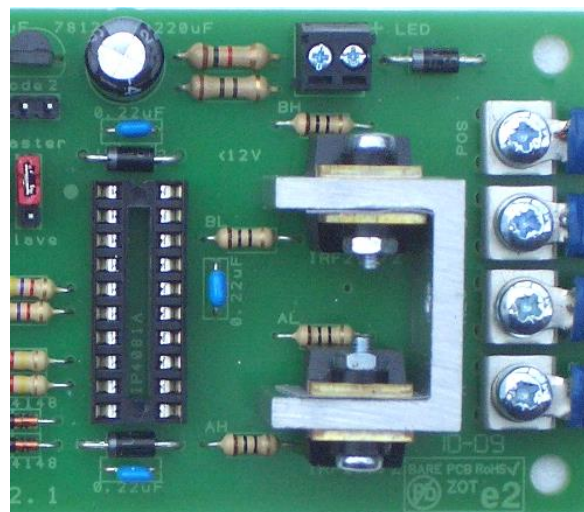
## Motor Control Board Circuit Diagram Motor Drive Section



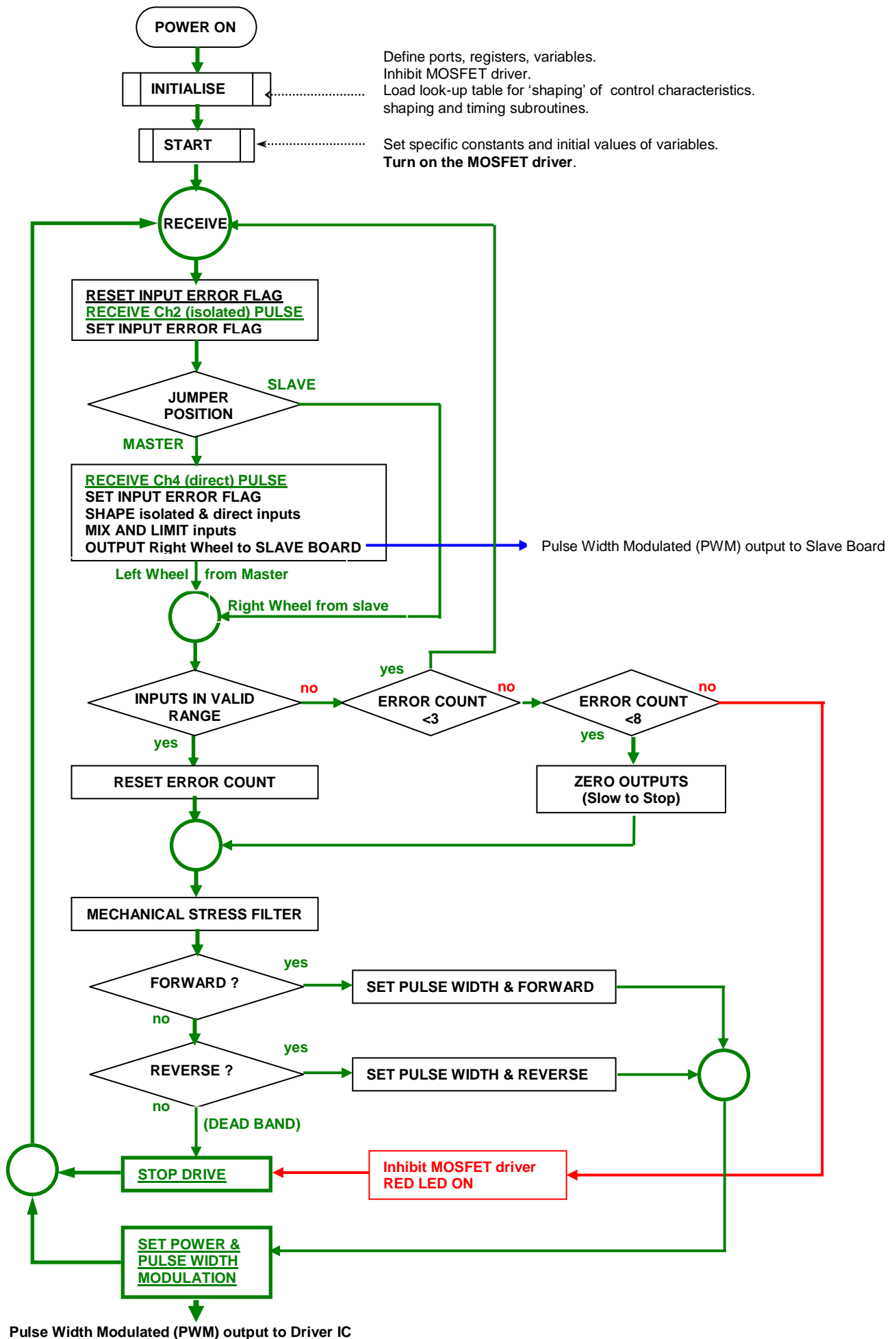
The Motor Control IC switches the MOSFET bridge and prevents 'shoot through' (a direct short between the battery terminals). Either a forward or a reverse PWM signal is received from the PIC and this is translated into appropriate turn-on signals to the four MOSFET Gates. The required high side MOSFET is held on and the opposite low side MOSFET is pulsed.

Two bootstrap diodes and capacitors, in conjunction with an internal charge pump, provides 28v to the high side MOSFET gates. The 220K resistors control the MOSFET turn-on delay.

All 4 MOSFETS are turned off by an Inhibit signal from the PIC or if the motor drive IC voltage drops below 7.5V.



## Motor Drive Board PIC Programme Logic Overview V3.0





## Appendix B – Risk Assessment Example

Unit: .....

Activity / Exercise: Robotic Games

Risk Assessment Number:	<b>GENERIC RA: NO</b>
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<b>Relevant Publications / Pamphlets/Procedures:</b>  <div style="margin-left: 20px;"> 1 Construction Booklet Chapter 2 - Safety   2   3 </div> <p>The following steps relate to the Risk Assessment Process.</p>	Assessor   Date:  Review Date	Related RAs (e.g. Manual Handling)  <div style="margin-left: 20px;"> 1. Use of Tools   2. Soldering   3. Manual Handling </div>
---	--	---

### General description.

This competition involves featherweight robots weighing less than 12 Kg designed to negotiate an assault course consisting of obstacles, ramp, and barrel, to push each other off a low platform and to play 2-a-side football. The robots do not have any weapons.

The robots are powered by two cordless electric drill motors that independently drive two of the four wheels. Their top speed is approximately 6 MPH.

The robots are controlled by commercial 40 MHz or 2.4 GHz radio links. Removal of battery connectors isolates all robot electrical circuits. Two red lights at the rear of the robot show when the electrical circuits are live.

Ser	Activity	Hazards Identified	Existing Controls	Residual Risk acceptable YES or NO	Additional Controls	Residual Risk Acceptable YES or NO
(a)	(b)	©	(d)	(e)	(f)	(g)
1	Maintenance	Robot runaway	Battery connectors are only to be inserted when the robot is off the ground with wheels free to rotate.	Yes		
2	Maintenance	Internal Fire	Fire extinguisher to be readily available	Yes		
3	Maintenance	Electrical fault	Removing battery connectors isolates all electrics.	Yes		
4	Maintenance	Injury from tools	Maintenance involving the use of sharp tools is only to be	Yes		

			undertaken by cadets under the direct supervision of an adult engineer or staff member.			
5	Maintenance	Electric shock	Robot electrical voltage is approximately 18 volts. Batteries are charged using commercial 18v chargers supplied with the cordless drills.	Yes		
6	Manual Handling	Physical strains	Maximum weight of robot is 12 Kg and within the capability of a single person to lift using standard techniques.	Yes		
7	Robot Activation	Robot Runaway	Robot is to be activated in the arena with the person connecting the batteries standing to the side of the robot.	Yes		
8	Robot Competition and Practice	Robot runaway, Collision damage, Radio Failure and Driver error	Practice for competitions is to be undertaken in a designated area with a physical barrier between the robots and the spectators. Intentional collisions are prohibited. Arena safety analysis at competitions is undertaken by organisers of the Robotic Games	Yes		

**Details of person responsible for carrying out this Risk Assessment / Review**

<b>CONTROLS</b>	<b>NAME (print)</b>	<b>POST</b>	<b>DATE</b>	<b>SIGNATURE</b>
Existing & Additional Controls Agreed – <b>Health and Safety Staff</b>				
Additional Controls Implemented – <b>Activity Organiser</b>				

## Appendix C - Parts List

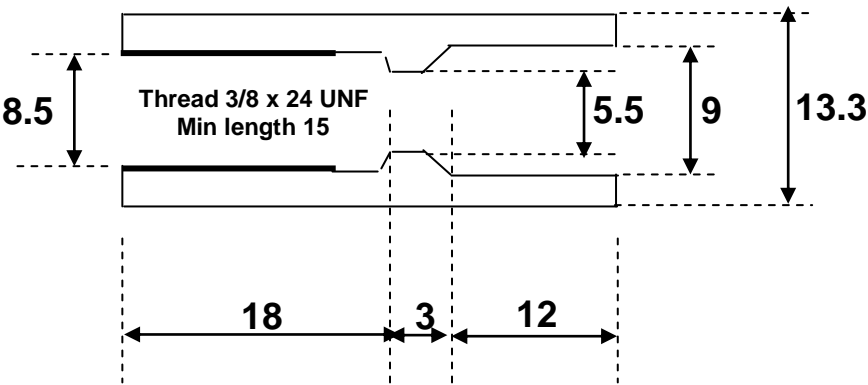
No	Item
~	<b>Main Cardboard Box (475 x 310 x 275mm)</b>
1	Instruction Booklet
1	Letter and Packing List
2	Rampaging Chariot & Sponsors Logos
~	<b>Radio Control System</b>
1	Saturn 4ch Combo 2.4 GHz FHSS
4	Batteries AA NmH Rechargeable
~	<b>Chassis</b>
1	MDF 12mm Chassis base 400x286mm
2	MDF 12mm Chassis long sides 450x100mm
2	MDF 12mm Chassis short sides 286x88mm
1	Aluminium Channel Ball Guides:(Makes 2of: 12x12x90mm)
1	Aluminium Angle Plates: (Makes 4of: 35x35x100mm)
1	Aluminium Angle Centre Plates:(Makes 2of: 35x35x45mm)
~	<b>Motors, Batteries &amp; Wheels</b>
2	18v Cordless Electric Drill (CT1787)
2	18v Li-ion Drill Batteries
2	Mains Battery Charger 18v
2	Rubber Wheels 38x153mm (Machine Mart ML605-1)
2	Rubber Wheels with Drive Axles 3/8"x 24 UNF
1	Crimp Tool
~	<b>Chariot Pack (140 x 140mm)</b>
1	Velcro Loop 20x330mm (For Receiver & Batteries)
1	Velcro Hook 20x330mm (For Receiver & Batteries)
1	MDF 6mm Drive Wheel Spacer Plate 50x50mm
1	Futaba servo lead extension 300mm
~	<b>Balance Wheel Axles</b>
2	Full Thread Coach Bolts M10 x65mm (Axle)
2	Hex Nuts M10
2	Plastic Tubing - Free Wheel Axles 13x33mm.
4	Flat Washers M10
2	Nylon Nuts M10
~	<b>Small Components Pack (115 x 90mm)</b>
38	Wood GoldScrews CS 3x12mm (For plates)
16	Wood Goldscrews CS 3.5x30mm (For chassis)
4	Bolts C/S M4x20mm (For front brackets)
2	Bolts Pan M4x25mm (For wheel hub axles)
8	Bolts C/S M3x25mm (For motor casings to chassis)
4	Hex Nuts M4
8	Hex Nuts M3
1	Towing Eye 30mm long
4	Crimp Connector Male Blue
2	Crimp Connector Female Red
2	Crimp Connector Female Blue
~	<b>Red Rear Safety Lights Pack (115 x 90mm)</b>
2	LED 5mm Ultra Red 3500mcd 30deg 20mA,
1	Cable Fig 8 2 core Grey 7/0.25mm 500mm
1	Cable Fig 8 2 core Grey 7/0.25mm 120mm
1	Heat Shrink Red 2.4mm (4of: 20mm)
~	<b>Test Equipment Pack (115 x 90mm)</b>
1	Halogen Capusle Bulb 12v 20W
1	Small Motor 3v 340mA
1	6R8 Wirewound Resistor 10W (For Halogan Bulb)
1	27R resistor 3W (For Test Motor)
1	Wire, Red 30core 18A 1.0 x 80mm
1	Red Flex 1.6 dia 16/0.2 80mm
1	Heat Shrink Red 2.4mm x 20mm
1	Crimp Connector Male Red
2	Crimp Connector Male Blue
1	Crimp Connector Female Red

Bd1	Bd2	Item
~	~	<b>Motor Drive Boards Electrical Pack (140x140mm)</b>
1	1	PC Board 53x100mm (RC Guild)
~	~	<b>Connecting Wire</b>
1	1	Wire, Black 30core 18A 1.0 x 250mm
1	1	Wire, Red 30core 18A 1.0 x 250mm
2	2	Wire, Grey or White 30core 18A 1.0 x 160mm
2	2	Futaba servo leads 200/300mm
~	~	<b>Small Components Pack (Antistatic 150x100mm)</b>
1	1	Conductive matting (35 x 45 x 6)
1	1	Full Bridge Driver IC, HIP 4081A
1	1	Controller, PIC 16F628A (RC Guild)
1	1	IC socket, 18pin
1	1	IC socket, 20pin
1	1	Opto Isolator SFH 615A-2
4	4	FET, IRF 2907
1	1	12V Regulator, 78L12 100mA TO-92
1	1	5V Regulator, 78L05 100mA TO-92
2	2	Diode signal 1N4148,
4	4	Diode Ultra Fast, UF4002
4	4	0.22uF ceramic, 5mm lead.sp.,
3	3	220uF 25v Elec., 2.5mm lead.sp. 6.3mm dia
1	1	10R, 1/2W 5%, Carbon
1	1	1K 1/2W 5%, Carbon (Rear Red lights)
4	4	10R, 1/4W 5%, Carbon
3	3	270R, 1/4W 5%, Carbon
2	2	4K7, 1/4W 5%, Carbon
1	1	22K, 1/4W 5%, Carbon
2	2	220K, 1/4W 5%, Carbon
1	1	Resonator, 20MHz. Ceramic,
1	1	5mm LED Tricolour Red/Green
1	1	2 pin Single row Pin Header
3	3	3 pin Single row Pin Header
1	1	4 pin Single row Pin Header
1	1	Jumper
1	1	Terminal block 2way Black 3.5mm pitch 10A
~	~	<b>Heat Sink &amp; Miscellaneous Pack (115 x 90mm)</b>
1	1	Aluminium.Channel 1in x 3/4in x 1/8in x 20mm
2	2	Insulation washer TO220 (Grey or brown with hole)
4	4	Insulation bushes TO220
2	2	Bolts Pan Head M2.5 x 12mm
2	2	Hex Nuts M2.5
4	4	Terminal Threaded M3
4	4	Bolts Pan M3 x 6mm
4	4	Washers Shakeproof M3
1	1	Crimp Connector Ring M3 Red
3	3	Crimp Connector Ring M3 Blue
1	1	Crimp Connector Male Blue
1	1	Crimp Connector Female Red
2	2	Crimp Connector Female Blue
4	4	Nylon pillars M4 x 6mm with sticky base
1	1	Cable tie 2.5mm x 100mm
4	4	Nylon pillars M4 x 6mm with sticky base
1	1	Cable tie 2.5mm x 100mm

**Appendix D – Parts Specially Manufactured for the Rampaging Chariots Guild**

**Aluminium Axle**

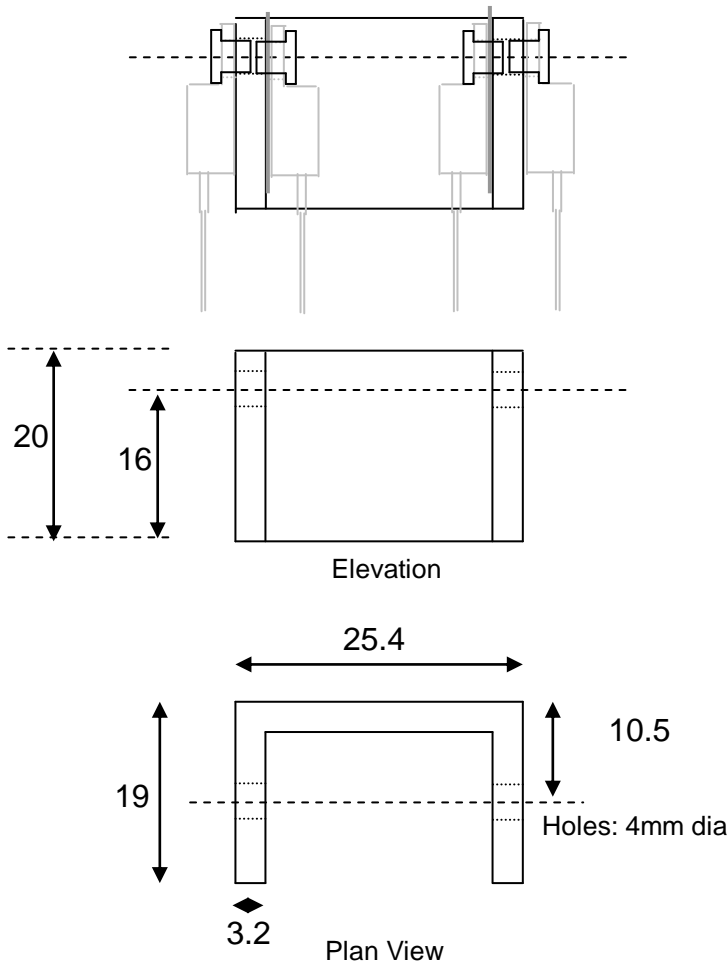
The Aluminium Axles are tapped with a 3/8 x 24 UNF thread and screwed onto a drill shaft. The axle is then turned down to a diameter of 13.3 mm in a lathe to ensure it is concentric with the shaft.



**Section Through Aluminium Wheel Axle**

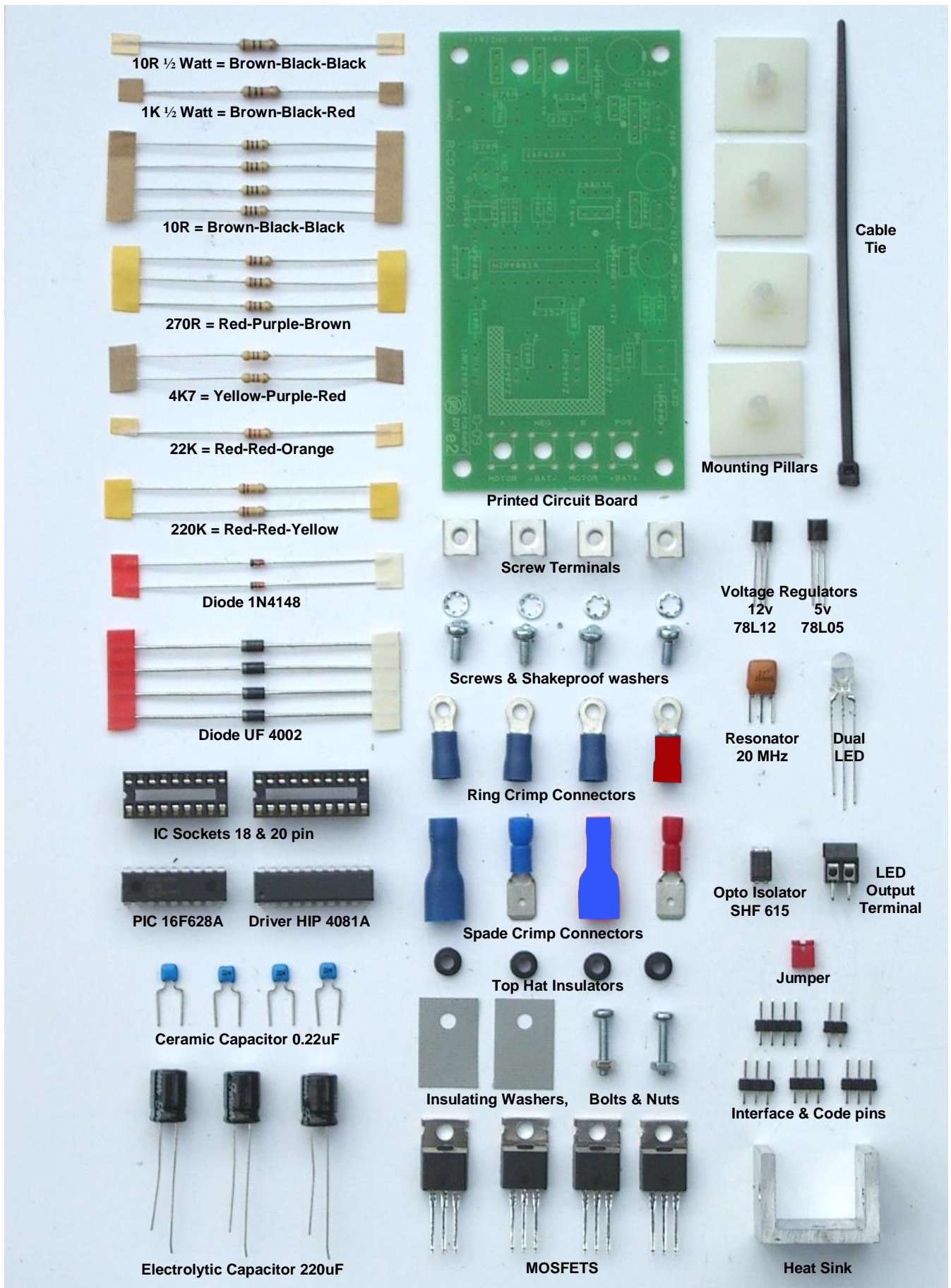
**Heat Sink**

The heat sinks are made from 1" x 3/4" x 1/8" aluminium channel and are drilled with 4mm diameter holes





## Build 8 – Constructing The Motor Controllers (Duplicate tear-out sheet)

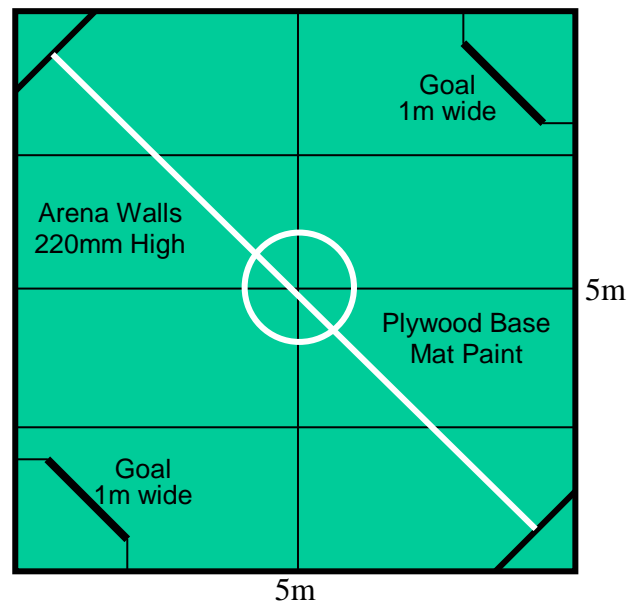


## Notes

## Appendix E - Rampaging Chariots Robotic Games Arena



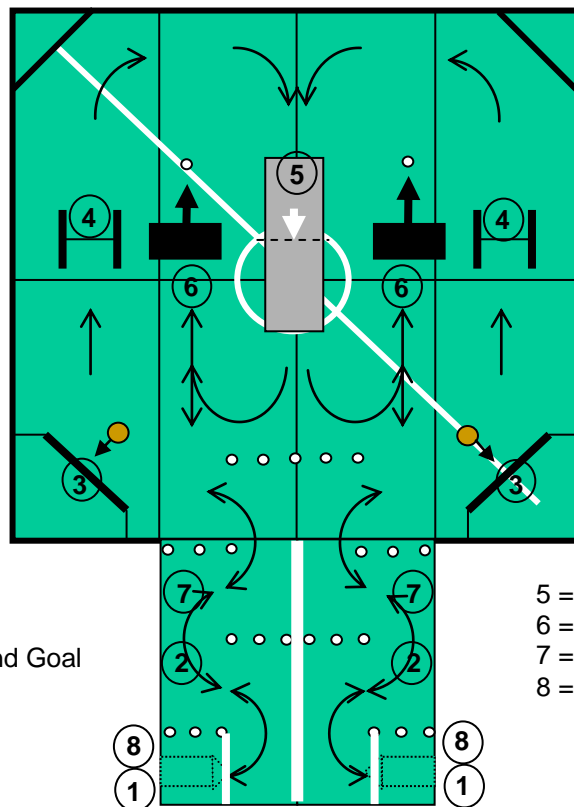
### Football Arena



Sumo table is 6ft (1829mm) diameter and placed in centre of arena  
Tug of War is conducted two on raised plinths with a central chasm

### Typical Assault Course Sequence

The Paddles (4) are  
~500mm wide and  
~300mm below the pivot



The See-Saw (5) is  
1200mm x 500mm  
Gradient ~1 in 10

1 = Garage  
2 = Chicane  
3 = Football and Goal  
4 = Paddle

5 = See-Saw Ramp  
6 = Push Barrel  
7 = Reversing Chicane  
8 = Garage

The Rampaging Chariots Guild reserves the right to alter the arena, sequence and sizes.

## **Rampaging Chariots Guild**



The primary aim of the Rampaging Chariots Guild is to interest young people in engineering through the construction and operation of robots designed to take part in various sporting challenges. The Guild consists of unpaid volunteers and all funds are used to further the aims of the Guild.

We hope you have enjoyed making this Rampaging Chariot and in doing so have learnt a lot about robotics, engineering and electronics. We wish you success in competitions and also in improving and modifying your basic Rampaging Chariot design.

### **Help**

Our web site [www.rampagingchariots.org.uk](http://www.rampagingchariots.org.uk) includes a frequently asked questions section. The 'Construction' section of this Web Site is planned to include Video Tutorials covering the construction of the chassis, construction of the motor drive boards, testing the motor drive boards and testing the completed Rampaging Chariot.

If you are having difficulties please contact the team at: [technical@rampagingchariots.org.uk](mailto:technical@rampagingchariots.org.uk)  
We will either answer your query by e-mail or arrange for one of our local volunteer engineers to visit your school / club and assist you.

The Guild provides a comprehensive spares, repairs, troubleshooting and advice service. This service is normally free, but we reserve the right to make a charge in exceptional circumstances.

### **Rampaging Chariot Spare Parts and Kits**

You will find a list of spare parts in this booklet at Appendix C.  
Additional kits of parts for the electronic motor controller boards are available @ £20 each.  
Additional full kits of Rampaging Chariot parts are available whilst stocks last @ £100 each.  
We do expect pupils to have reached a reasonable standard in soldering before being let loose on the circuit boards, but we do not expect them to be soldering experts.

### **Rampaging Chariots Robotic Games**

The full rules of the Rampaging Chariots Robotic Games are available on our website:  
[www.rampagingchariots.org.uk](http://www.rampagingchariots.org.uk)

This site also includes pictures and video clips of the games that are invaluable for prospective entrants to appreciate the size and shape of the arena and obstacles. It will also give you a good appreciation of the tactics and standard of the opposition.

<p>The intellectual property rights of the design of the Rampaging Chariot is the property of the Rampaging Chariots Guild. Youth groups and educational establishments may freely copy this booklet for their own use provided the Guild is suitably acknowledged on each copy. Anyone wishing to exploit any aspect of the design for commercial purposes must obtain the written agreement of the Rampaging Chariots Guild.</p>
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