Construction of a
Rampaging Chariot

Instructions on how to make a powerful featherweight sporting robot to compete in the
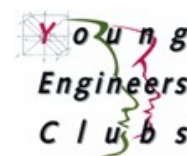
Assault Course, Sumo and 2-a-Side Football Competitions at the Rampaging Chariots Robotic Games.

by

Rampaging Chariots Guild (Team Typhoon)

Winners of the 2005 UK Robotic Games Assault Course and 2-a-Side Football competitions
BBC Technogames Assault Course World Record Holders
Current UK Robot Wars Lightweight, Middleweight and Heavyweight Grand Champions
World RobOlympics Silver Medallist - San Francisco 2005

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Young Engineers Clubs

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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:

a.   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.

b.   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.

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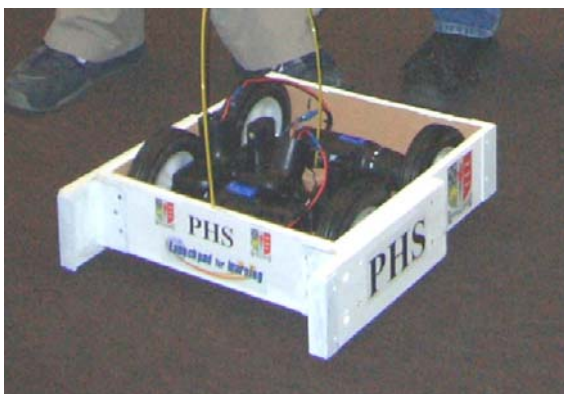d.   Install in the chassis: two drill motors, four wheels, two batteries, radio receiver and aerial.
e.   Wire up the components.
f.   Test.

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

Tools
You will need the following basic tools:

Small & Medium Posidrive Screwdrivers	Wire Cutters
Pointed Nose Pliers	Hand or Power Drill
17mm Open-ended Spanner	Bits 3.5, 7.0, 10mm (1.5, 2.5, 3, 4, 5, 6mm provided)
Coping Saw	Countersink
Hacksaw	Soldering Iron with a small Bit
Flat and Round Files	Solder
Scissors	Electrical Test Meter

Main Components
Proportional 40 MHz FM 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

Duratool
D00013

Rules for the Rampaging Chariots Robotic Games
No weapons of any kind may be fitted.
Dangerous projections will be disallowed.
Robots must not have any device that can physically hold the ball, but may have guides fitted to the front of the machine to gather and control a small football (Ball diameter is approximately 125mm)
Up to 2 Ball guides with a maximum projection of 50mm may be fitted.
There must be easy access to 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: 36 volts
Radio control - 40 MHz or 2.4 GHz band.
All team members must be under 18 years of age on 1 September of the year of the competition, although adult supervision is permitted.
Robots will be examined at Tech checking to ensure their build is consistent with that anticipated from an under 18 team.
The full rules of the Rampaging Chariots Robotic Games are available at www.rampagingchariots.org.uk

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.
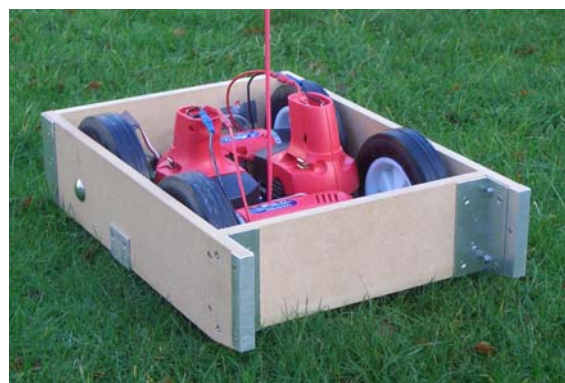
Basic Robot Example

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 will 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. Max charge rate is 0.4 amps.

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 clips should do so slowly and stand to the side of the robot so that the battery clips can be removed immediately if any movement occurs.

Radio Control
There are a limited number of frequencies which are identified by channel numbers. Frequencies are changed by plugging different crystals into the transmitter and receiver. Each transmitter should be fitted with a coloured flag or clothes peg to identify its current frequency.
If two teams share the same frequency, both robots will move when the transmitter is operated. This could be highly dangerous if the other team is doing maintenance.
Batteries must therefore only be connected when the transmitter is physically in your possession.
Transmitters have an audible beep to indicate a low battery.
Switch off transmitters when they are not in use.

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). Unfortunately the normal variable speed control selected by the drill trigger works in one direction only and we need the robot to be able to reverse under radio control.

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 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.
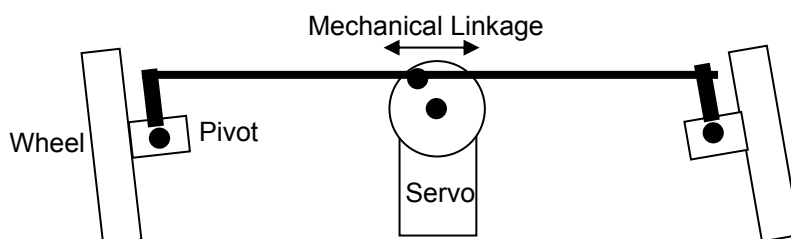
Car Type Steering Mechanism

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, but 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 we have chosen to use 'tank type' steering and make two electronic speed controllers to achieve proportional control of the motor speeds and direction. You may use 'car type' steering if you wish, but you will need to design and procure all the parts yourself. Steering when moving forward will be more precise, but remember how difficult it is to park a car in a confined space.

THEORY

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. We therefore recommend that you 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.
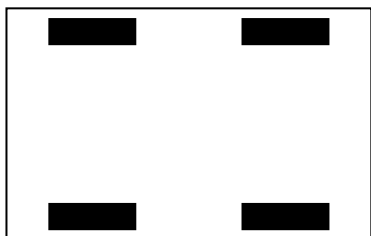
The wheelbase (the distance between the front and rear wheels) is important and has to be a compromise. Increasing the wheelbase increases straight line stability (minimise the tendency to move in a curve). It will also prevent the robot tending to tip up when it starts or stops quickly. Also, the nearer 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. Motors sometimes use slightly different amounts of power to turn in each direction which 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.

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.

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 maximum horizontal speed of the robot is the circumference of the wheel times its maximum speed of rotation.
Wheels are 0.08m radius. The circumference of the wheel is 2π x radius   = 0.5 m
Motors turn at over 20000 rpm and are geared down to give approximately 0 to 900rpm = 15 revs per second.
Maximum horizontal speed   = 0.5 x 15
                                                    = 7.5   metres per second
                                                    = 16.7   miles per hour

In practice, friction and other losses will reduce this top speed slightly.

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Batteries

Voltage.   Your cordless electric drill batteries are rechargeable NiCad batteries. Each cell is 1.2 volts, so to provide an output of 18 volts, 15 cells are connected in series. 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.

Capacity.   The capacity of the drill batteries is 1.2 Amp Hours each which means the battery will deliver a current of 1.2 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 30 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, 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 or cable ties. There must be easy access to the battery connectors so that in the event of a run-away the robot can be inhibited easily.

Charging

The mains chargers supplied will recharge the batteries from zero charge to maximum in 3 to 5 hours.
Do not exceed this charging time or you will damage the batteries and charger.
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 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 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).
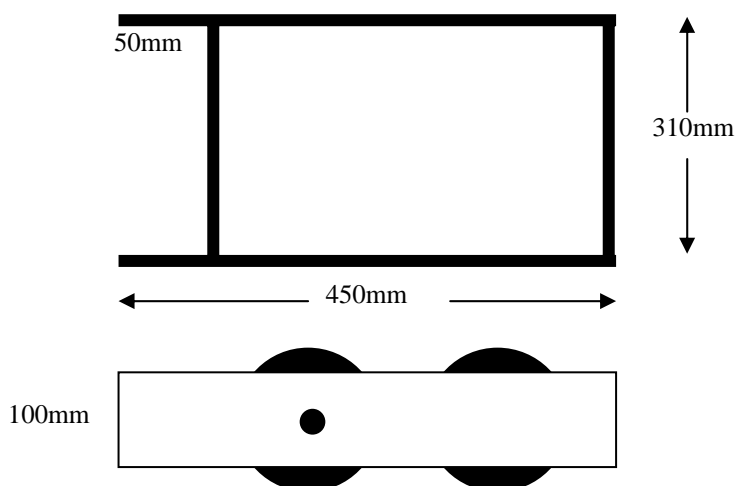
Aerial

Keep the aerial away from the electronics and don't loop it back on itself. The length is very important for good radio control distance.

Bend over the end of the stiff wire to avoid it sticking in your eye.

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.
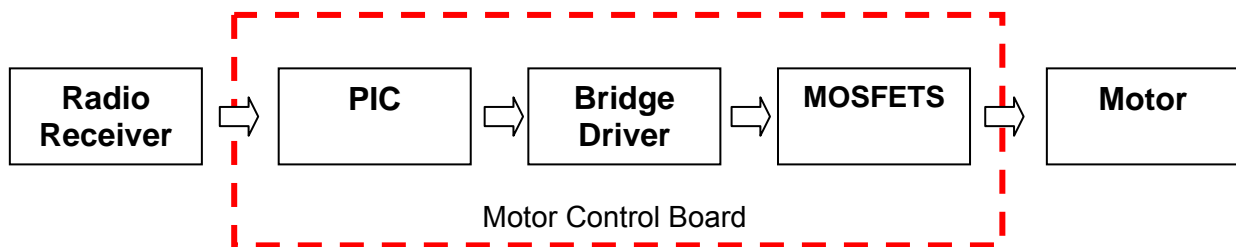

a. The Radio Receiver outputs pulses. The width of these pulses determines the required speed and direction.
b. A Programmable Interface Controller (PIC) decodes the pulses and checks that a valid control signal is being received. If not, it shuts down the controller and stops the motors. The PIC also 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.
c. 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.
d. 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.
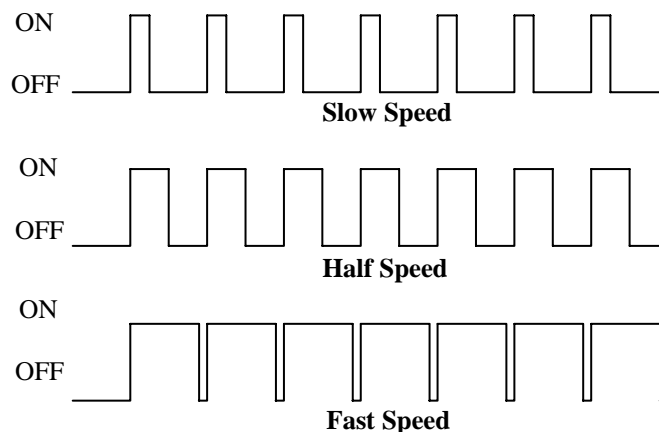
MOSFET Bridge

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.
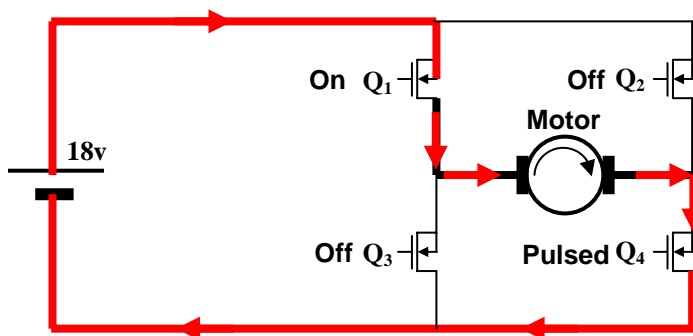
MOSFET Bridge – Motor Turning Forwards

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.
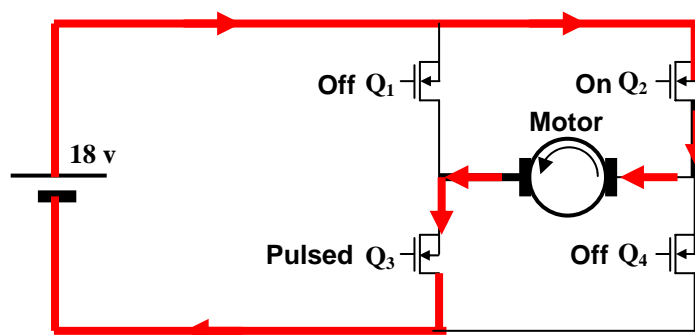
MOSFET Bridge – Motor Turning Backwards

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 27 or 40 MHz bands. (35MHz band is reserved for model aircraft).

The 27MHz band has 13 channels, which are like different radio stations. It is prone to interference by CB (Citizens Band) radios that use the same band. 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. Some cheap toys have 'splat' transmitters that transmit over (and interfere with) a number of adjacent channels and are identified by Band 1, Band 2, Band 3 etc.

The transmitter looks at the position of each control stick and sends this information to a receiver which is tuned to the same frequency. There are 2 methods used by the transmitter to superimpose the control stick information onto the carrier wave:

a.   Amplitude Modulation (AM). This suffers from interference.

b.   Frequency Modulation (FM). This suffers much less from interference but is more expensive.
      (Your Rampaging Chariot contains an FM radio transmitter and receiver).

To avoid two robots being on the same frequency, channels can be altered by changing the crystals in both the transmitter (Tx) and receiver (Rx). You must ensure you use the right type and make of crystal in your Tx and Rx as different manufacturers crystals are incompatible. The Skysport 4 radio control uses Futaba crystals. AM and FM crystals are not interchangeable and 'single conversion' crystals are not the same as 'dual conversion' crystals. Crystals are quite delicate and should not be dropped.

Pulse Position Modulation (PPM) is normally used to "multiplex" the control channels together onto the single radio channel. 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 25 times a second so that it appears that the servos instantly know you have moved a control stick.

With Pulse Position Modulation, the position of the pulse within the sequence tells the Receiver which servo/motor to send the pulse to. The first pulse after the long gap is sent to Servo Channel 1, the next pulse to Channel 2 etc.

Another system called Pulse Code Modulation (PCM) sends the stick position data from the transmitter to the receiver in a digital format. PCM in conjunction with a special 'Dual Conversion' receiver has by far the best performance, is resistant to interference, but is also the most expensive system.

The receiver converts the PPM or PCM signals into Pulse Width Modulated (PWM) outputs to the individual servos or the electronic motor control boards. The way the stick position is conveyed 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.

Full Reverse	Zero	Full Forward

0	1.0	1.5	2.0	2.5

Pulse Width in milli seconds
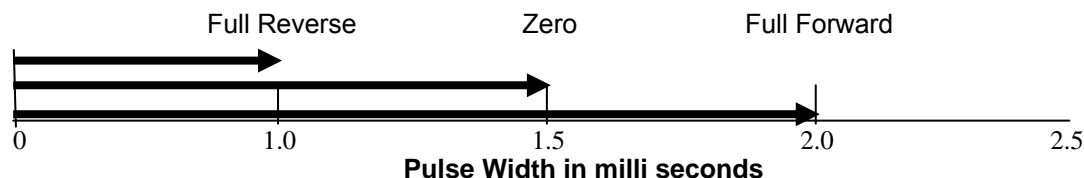
The motor control boards then convert these PWM signals into the motor speed and direction of rotation.

Always turn on the transmitter first, then the receiver. When turning off the system always turn off the receiver first. The object is never to have the receiver on by itself or stray radio interference may activate the robot motors in an unexpected and dangerous way.

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
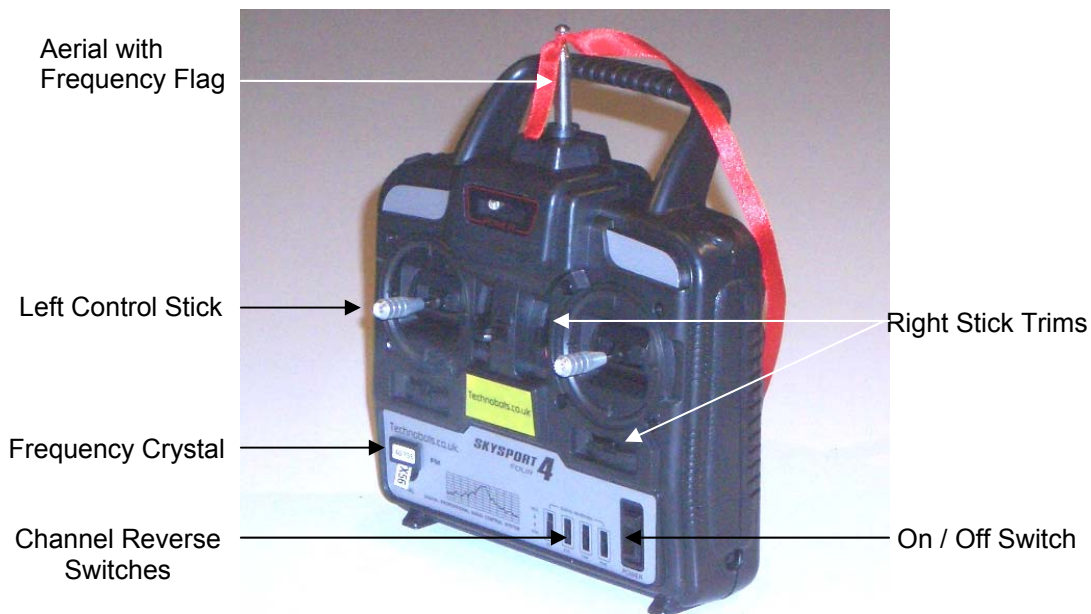
Method 2 – Control Mixing:

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.

Your transmitter and receiver have four separate functions (or channels) controlled by two sticks. Your robot uses two of these control functions and which ones you use is a matter of preference.

You can therefore implement control mixing by using two separate sticks or one stick moved in two directions. e.g.

a.   **Left stick left/right controls Direction (Chan 4),   Right stick forward/back controls Speed (Chan 2)**
b.   **Right stick left/right controls Direction (Chan 1), Right stick forward/back controls Speed (Chan 2)**

Aerial with
Frequency Flag

Left Control Stick

Right Stick Trims

Frequency Crystal

Channel Reverse
Switches

On / Off Switch

Transmitter Controls

The control mixing can be done within expensive computerised transmitters, but to minimise the cost of the radio control equipment we have done the mixing ourselves within the motor control boards. Wherever the mixing is done, the effect is that moving one control lever on the transmitter forward commands both motors to run forward at the same speed. Moving the other (or possibly the same) 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.

Most drivers prefer that speed and direction are controlled by separate control sticks (Method 'a' above). You can easily implement single stick control (Method 'b' above) by moving the lead plugged into the receiver channel 4 slot to the receiver channel 1 slot.

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. Expensive computerised transmitters generally have this facility. 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.
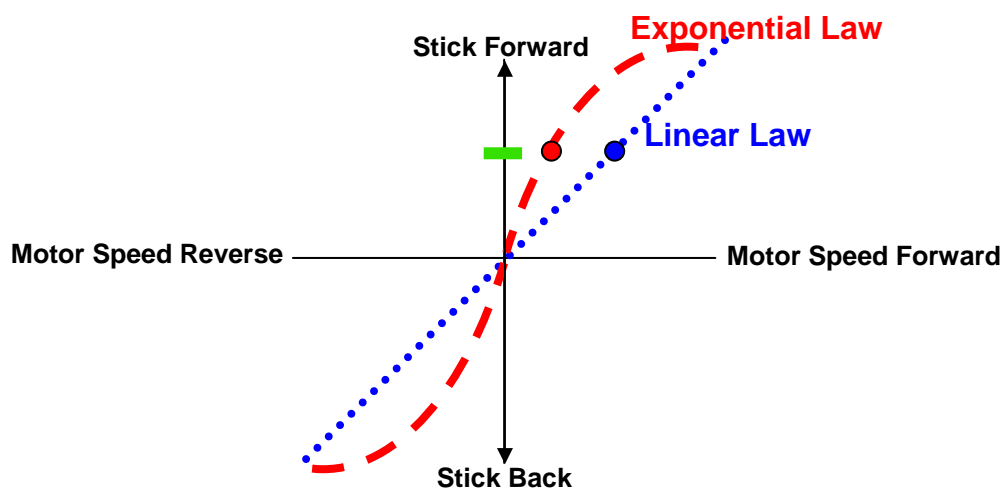
Burning Rubber

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.

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. Static friction is 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.

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

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.

Normal 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 much 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 two or three seconds at most, to solder the average PCB joint. 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 an inordinately 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 beaded to form globules around the wire.

Remedy. Sometimes it's enough to simply remelt the existing solder. If this doesn't produce visible results, add more solder.

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

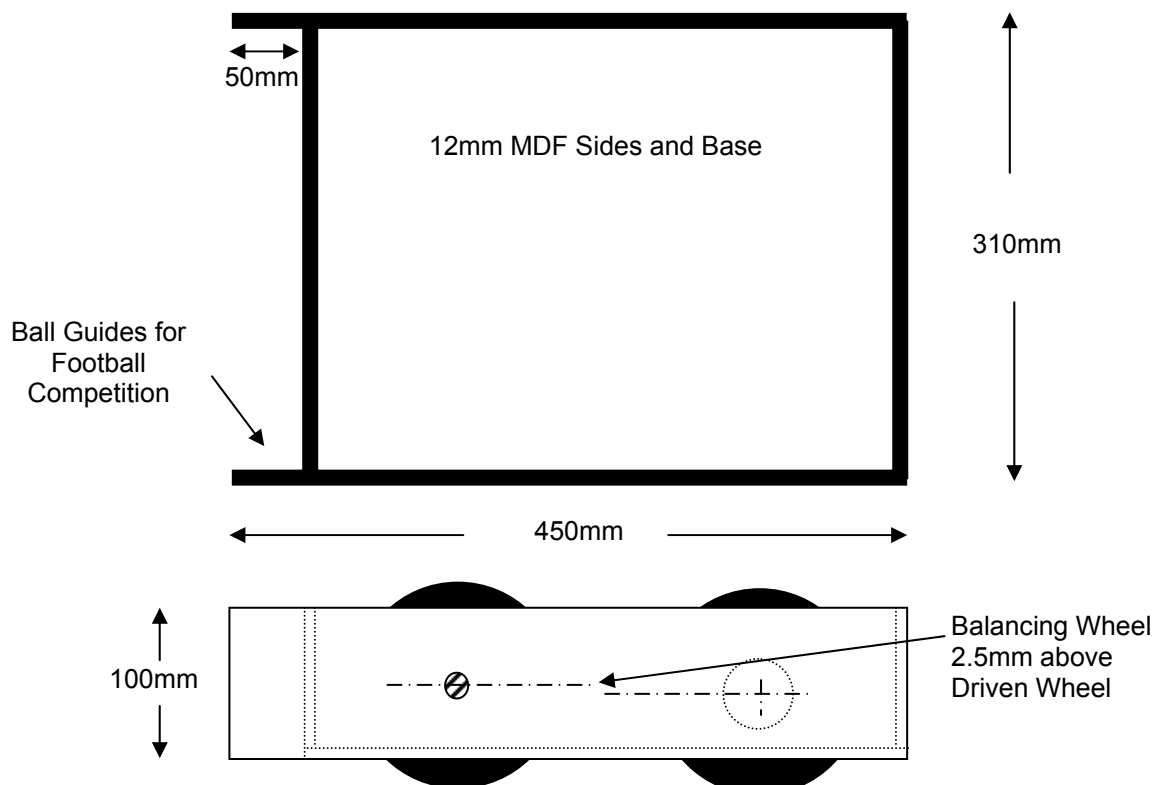## Build 7 – Constructing The Chassis

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 (Unpainted) Rampaging Chariot Should Look Like

50mm

12mm MDF Sides and Base

310mm

Ball Guides for
Football
Competition

450mm

100mm

Balancing Wheel
2.5mm above
Driven Wheel

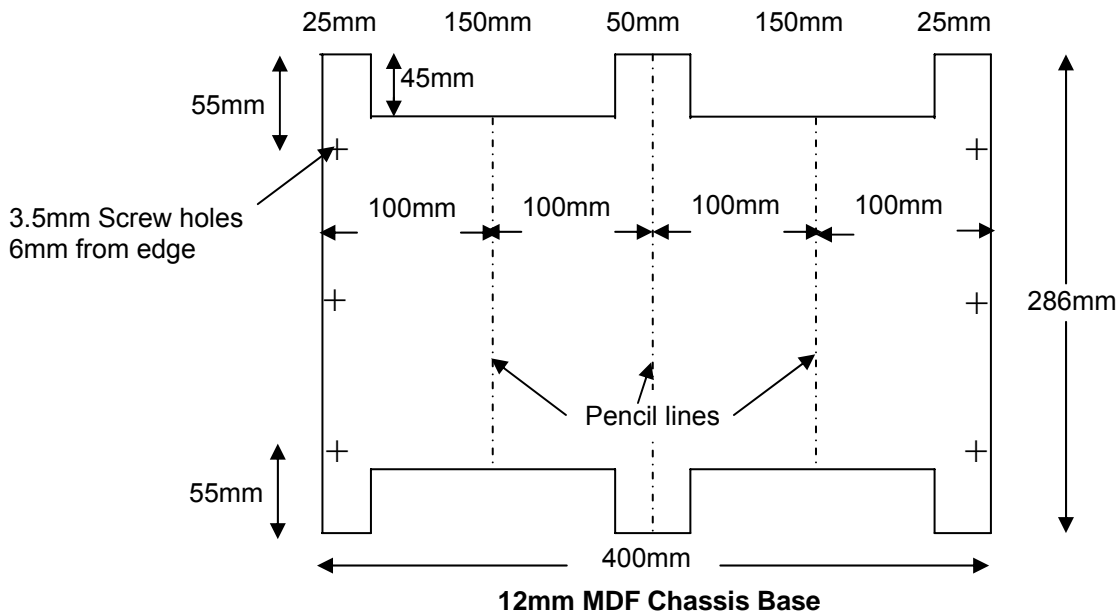**General Arrangement of the Base and Sides**

Chassis Base

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.

25mm   150mm   50mm   150mm   25mm

45mm

55mm

3.5mm Screw holes
6mm from edge

100mm   100mm   100mm   100mm

286mm

Pencil lines

55mm

400mm

12mm MDF Chassis Base

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.

13mm   13mm

286mm

400mm

**Position of Motor Drive Boards
on Chassis Base**
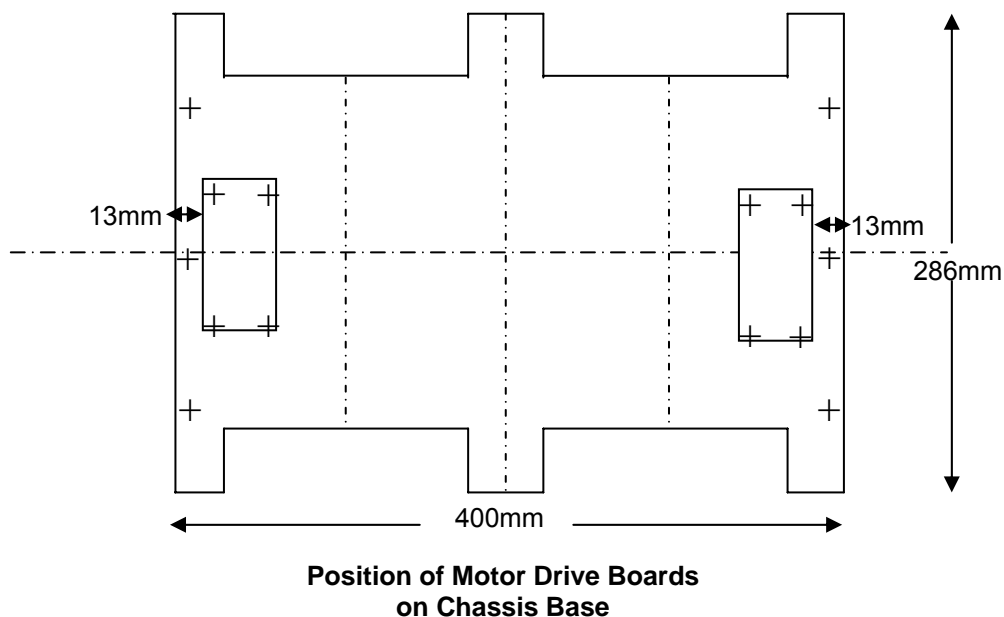
3.   Place the two motor drive board PCBs (printed circuit boards) onto the chassis base 13mm from the edge. With a pencil mark the positions of the PCB retaining screws through the four corner holes.

4.   Drill eight holes **2.5 mm** diameter through the base.

Aerial Housing

5.   Cut a scrap piece of 12mm MDF to a size of 32 x 32mm. Drill two 3.5mm dia holes through the block in opposite corners and countersink the hole to make the screw head flush with the surface. Drill a 1.5mm hole in the centre for the aerial wire.
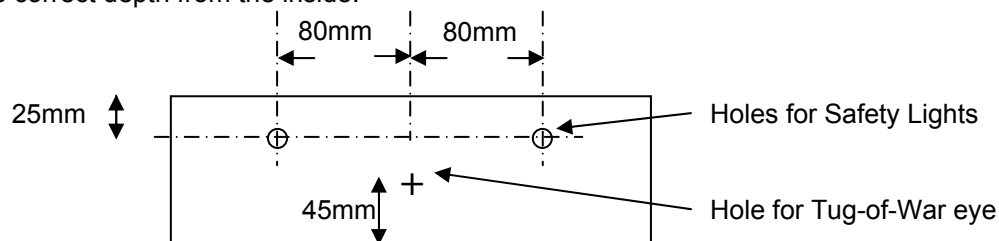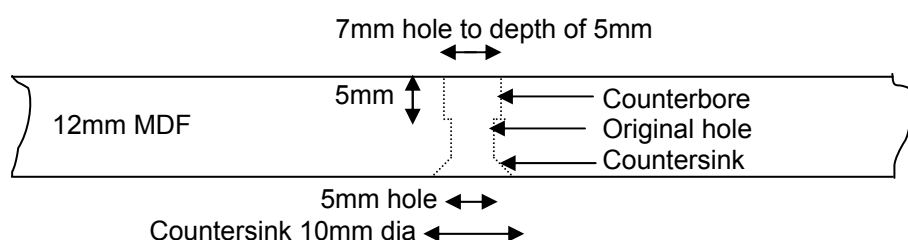**Note:** This aerial housing will be fitted later.

1.5mm dia

6mm

Aerial Housing

1mm Greater than
screw head

Countersunk Hole

Chassis Sides

Left Side

Right Side

6. Mark out the positions of the five screw holes in each of the two sides (Black crosses) and drill clearance holes 3.5 mm diameter through the sides and countersink the holes on the outside of each side.

7. Mark out the positions of the two 4mm bolt holes in each of the two sides (Blue crosses) and drill clearance holes 4mm diameter through the sides and countersink the holes on the **outside** of each side.

8. Mark the positions of the centre of the balancing wheels (Shown in red). Centre punch the position of the holes and drill a 5mm diameter pilot hole and then a 10mm diameter hole for the coach bolts.

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

Hint: Recheck you have marked the correct positions before drilling. The critical dimension is **43.0 mm above the bottom of the chassis**. (Duratool Red Drills) or (44.5mm Nutool MPK18 Black Drills)

9. Cut off the **front bottom corner** of each side as shown.

Note: This is to allow the Rampaging Chariot to mount a ramp without grounding.

Chassis Front and Back

No screw holes are required in the front or the back.

Chassis Front

Holes For Rear Safety Lights

10. Drill two 5mm diameter holes completely through the rear 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.

80mm   80mm

25mm

Holes for Safety Lights

45mm

Hole for Tug-of-War eye

Chassis Back

7mm hole to depth of 5mm

5mm

12mm MDF

Counterbore
Original hole
Countersink

5mm hole
Countersink 10mm dia

Plan View
Section Through Hole for LED in Rear of Chassis

11. Drill a 3.5 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.

12. 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.

13. Repeat this procedure for the chassis rear ensuring you have it the correct way round.

14. 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

15. 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.
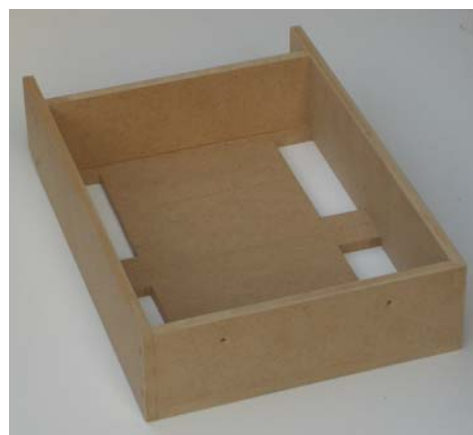
MDF Chassis

Chassis Protection and Strengthening

Front of Football Guides

16. 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.

17. 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

18. 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.
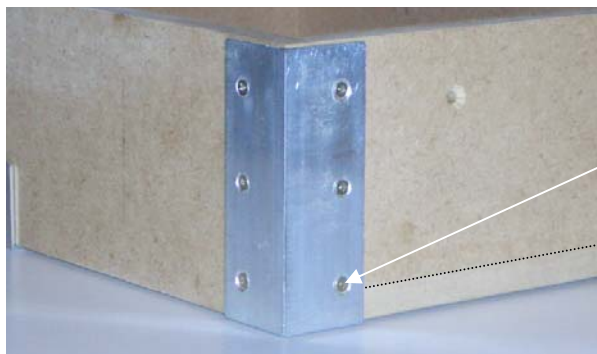
Mistake. This screw is positioned much too close to edge of MDF

Rear Protection and Strengthening Plate

Centre Strengthening

19. 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.
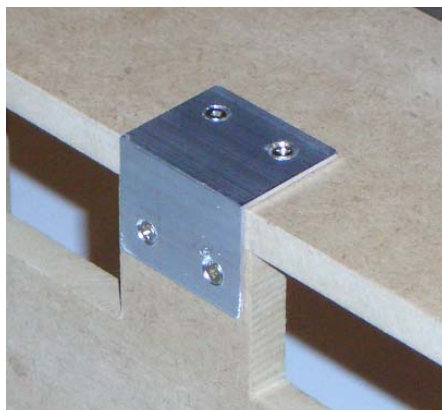
Centre Strengthening Plate

Front Corners

20. 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. In addition, during a football match, the protruding football guides will be hit in three directions:
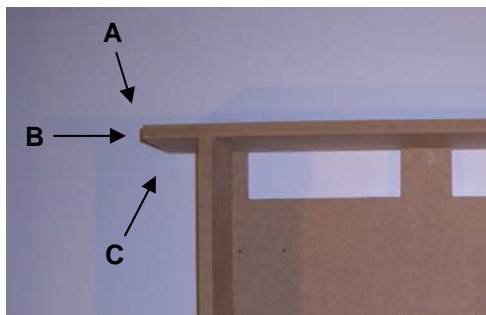
Direction 'A' will cause the side to pivot about the front of the chassis and pull away at the center and rear. (This is solved by the rear and center strengthening plates).

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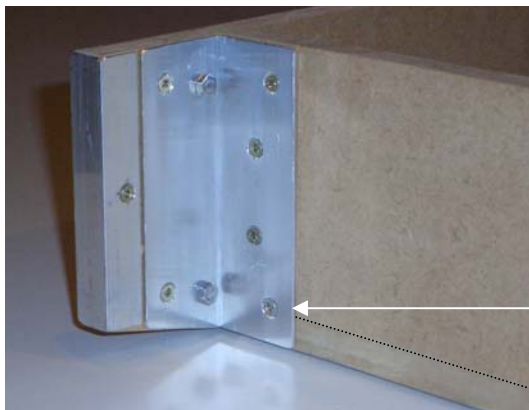
Mistake. This screw is positioned much too close to edge of MDF

Ball Guide and Front Corner Strengthening Plates

21. 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.

22. Cut off the corners of the aluminum where the chassis corners have already been removed.

Painting

23. Paint the inside and outside of the chassis with a white undercoat paint before installing the motors.

24. 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.

Dismantling The Drills

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

25.   Turn the Torque selector ring fully clockwise as viewed from the front (chuck) for maximum torque (Twisting Power). The drill symbol will then be in line with the small arrow on the top of the drill.

Removing the Chuck

The drill chuck is attached to the drill shaft by a normal thread. To stop it coming loose when you operate the drill in reverse it also has a special screw in the centre of the chuck that has a reverse thread (or left hand thread). Which ever way the drill is rotating, one method of attachment is always trying to tighten up the chuck.

26.   Remove the chuck by opening its jaws to the maximum size and unscrewing the screw in the centre of the jaws. This screw has a left hand thread and **is removed by twisting in a clockwise direction viewed from the front**. Then unscrew the chuck from the drill by twisting the whole chuck in a normal counter-clockwise direction viewed from the front.

Hint: If the chuck refuses to budge and the motor turns instead, check you are twisting in the correct direction. If more twist is needed, fit a fully charged battery, select forward or reverse as appropriate and operate the trigger just enough so that the motor tries to turn in the direction to oppose your twist. This should loosen the screw or chuck immediately.

To Remove the Chuck Screw
Twist the Screw Clockwise

To Remove the Chuck
Twist it Anticlockwise

27.   Discard the chuck, remove the battery and put the battery on charge for 3 to 5 hours.

28.   Turn the torque selector fully clockwise until the drill symbol is at the top of the drill in line with the red arrow.

Drill Casing

29.   Prise up the edges of the black plastic hand grip at the rear of the drill and remove this hand grip.
Hint: Use a small flat blade screwdriver to release the four retaining tabs shown in the next picture.

30.   Place the drill on a clean table or bench as there is a good chance some loose parts may drop out. Remove the two black U shaped metal clips from the bottom of the battery connector.
**Hint:** Insert a small flat blade screwdriver at the top of the clips and lever them up.

31.   Turn the casing so that the Duratool logo is underneath.
Unscrew the six self tapping screws and **very carefully** lift off the top half of the red plastic casing starting at the handle, then the rear and finally the front.
Note: The front lower screw is shorter than the others.
      Do Not dismantle the torque selector or you will have ball bearings running all over the floor and no one will know how to reassemble it.
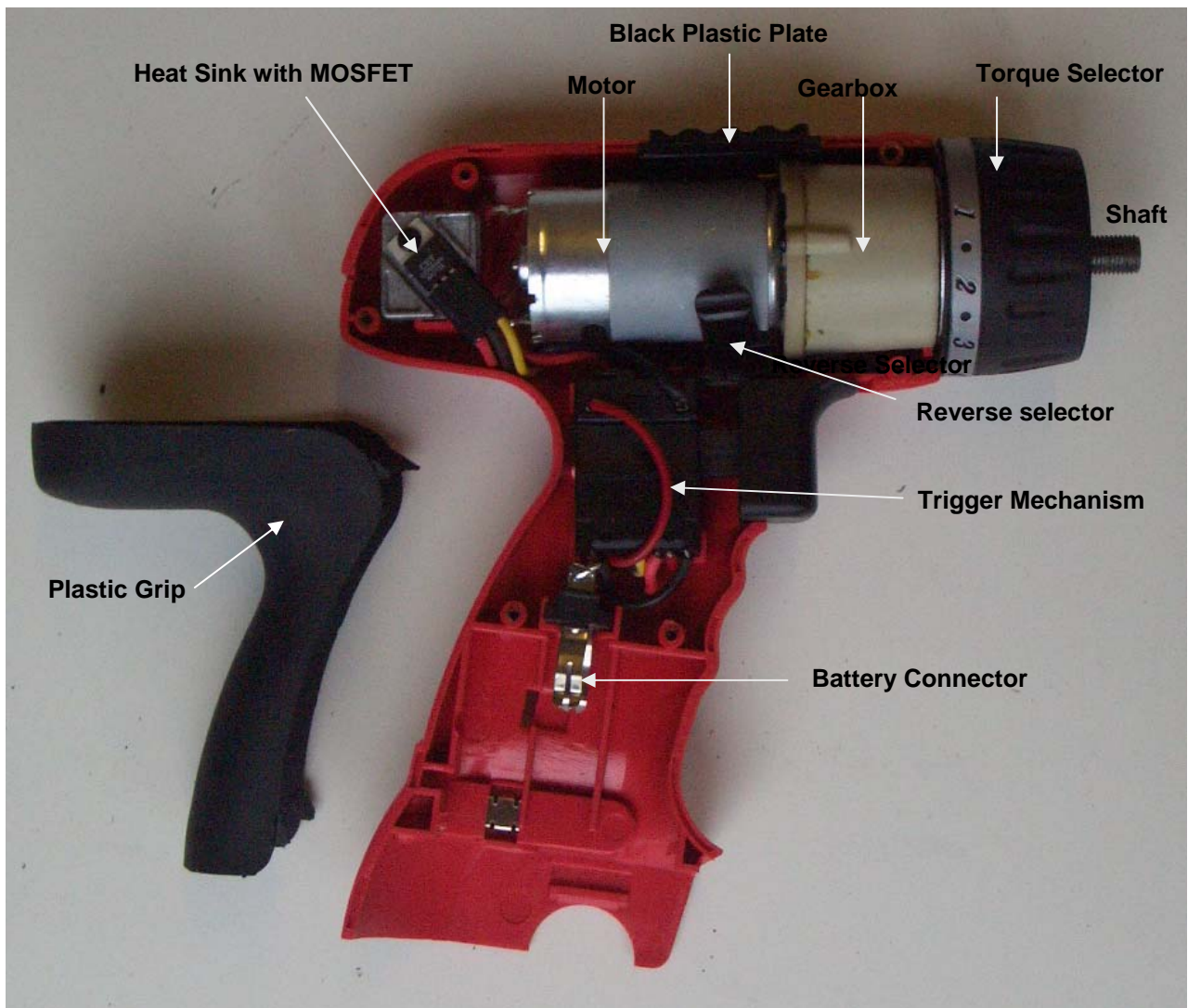
Drill With Top Half of Casing Removed

Hint: Note how all the parts fit in the lower half of the drill casing. **Carefully store all the parts you remove for later reassembly**.
Note: During reassembly of the motor and battery connector, these photographs will assist you.

32.   Remove the Reverse Selector and the black plastic plate.

33. Lift up the motor, gearbox and torque selector as a single unit.

Note: The gearbox in front of the metal motor has a plastic tab that locates into a slot in the lower half of the black plastic drill casing.

34. Remove all the parts shown below from the casing and place them on the bench.

Hint: When storing and working with the motor be careful that no metal filings or screws are allowed to enter the ventilation holes attracted by the magnets inside. **Never put the motor in the same bag as metal screws or nuts.**
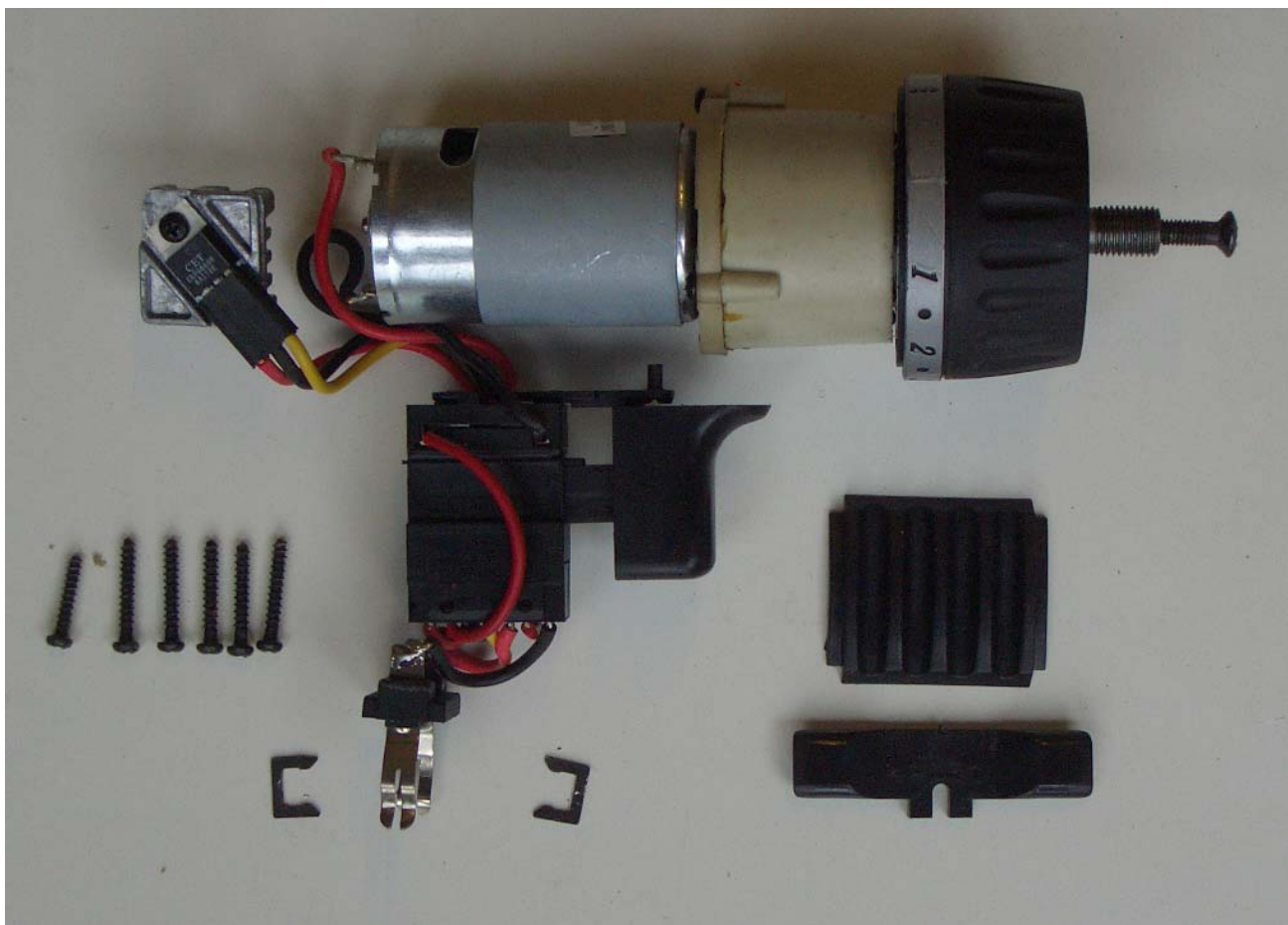
Parts Removed from Drill Casing

35. Using a pair of taper nose pliers, hold the trigger mechanism firmly and lever out the electrical wires coming from the motor. Then do the same with the electrical wires coming from the battery connector. The Trigger mechanism and heat sink with MOSFET are no longer required.

**Disconnecting Wires
from Trigger Mechanism**

**Motor and Battery Connecter
After Disconnection**

Cutting The Motor Casings

36.   Take the top drill casing (The one with the six screw holes) and mark exactly where you are to cut off the plastic handles (see photo). Carefully remove the central section with a hacksaw.

Note: The lower cut is above the upper screw hole and parallel with the bottom of the drill.
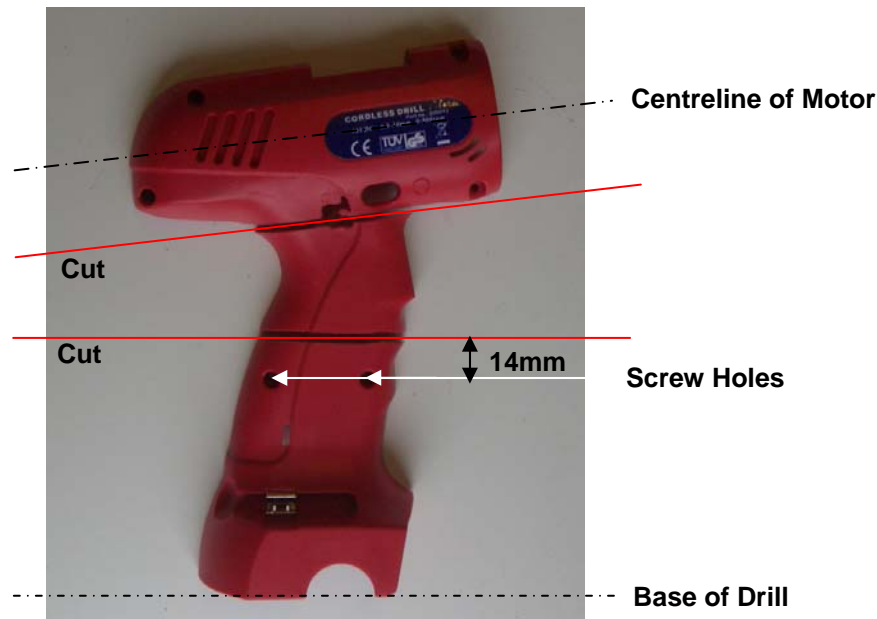
Position and Angle to Cut Drill Handle

37.   Place the cut off motor casing onto the mating part of the lower drill casing and continue the hacksaw cut though the lower casing. In the same way place the cut off battery connector casing onto its lower mating half and continue the cut though the lower casing. Remove the burrs from the cut faces using a file or knife to make it look good.

Reassembling the Battery Connector

38.   Crimp a red and blue **female** terminal to the appropriate colour wires emerging from the top of the connector using a special crimping tool or a pair of pliers 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!
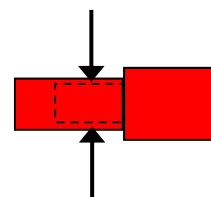
Where to Crimp the Spade Terminals

Warning: Unless it is November 5th, Do Not Fit the connector onto a battery until you have fitted the crimp terminals or the leads may short together.

39.   Place the battery connector clip in its housing in the lower half of the connector. The Black wire is at the top.

Black Wire Top Side

Plastic Strip
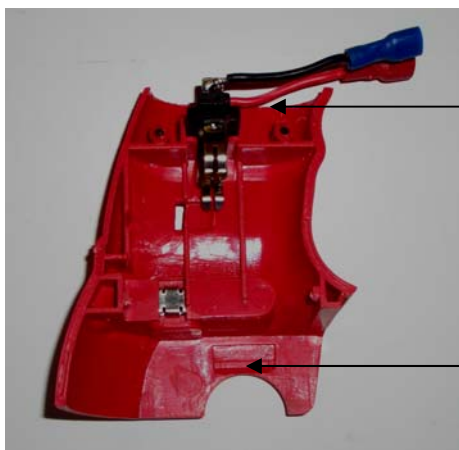
Reassembly of Battery Connector

Plastic Strip Removed
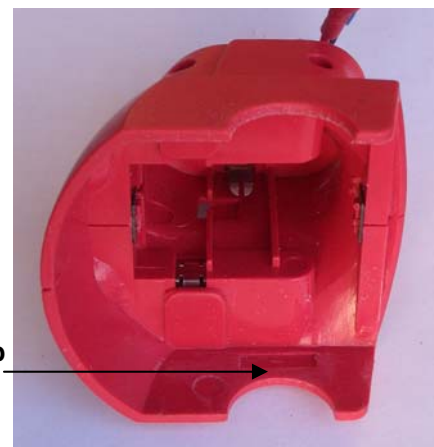
Removal of Battery Strip/Clip

40. Fit the upper half of the battery connector cover and carefully locate and squeeze the halves together. Insert and tighten the two black screws and insert the two U shaped clips.

41. File off the strip of plastic on both sides that engages with the battery.

Note: In an emergency, this should allow the battery connectors to be removed easily from the batteries without pressing the black buttons on the battery. (You may also need to file the edge of the battery clips).

42. Crimp a red and blue **male** spade terminal to the appropriate coloured wires connected to the motor.

43. Repeat for the other drill.

Drive Wheels

There is a huge twisting load between the two drive wheels and their shaft /axle when you try to reverse direction at high speed. It is therefore important to fix the aluminium axle firmly to the drill shaft and the wheel firmly to the axle. If either comes even partially loose the drill will turn without the wheel and you will have difficulty steering the chariot.

The wheel axle is manufactured and fitted to the wheel for you by the Rampaging Chariots Guild. We also pre drill the wheel and axle to take a 4 x 25mm pan head bolt.

Motor and Wheel

4mm LH thread chuck bolt

4 x 25mm pan head wheel bolt
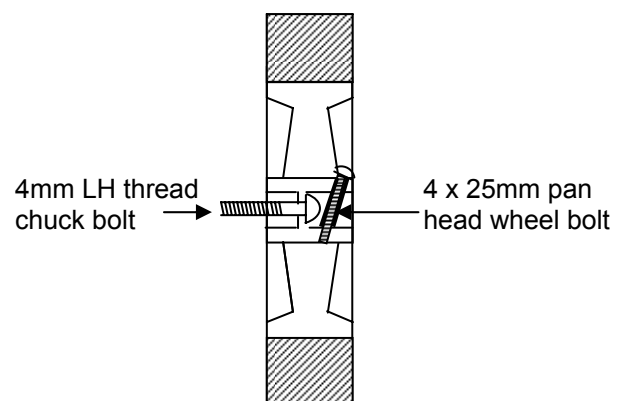
**Section Through Wheel
Showing Retaining Screws**

44. Temporally insert the 4 x 25mm pan head bolt into the wheel and axle. This bolt will cut its own thread in the lower part (3.5mm hole) of the nylon hub and this will stop the screw vibrating loose.

Note: The purpose of inserting the screw at this stage is to maintain the alignment between wheel and screw hole whilst you fit the wheel to the drill.

45. Screw the wheel and axle onto the drill (Normal right hand thread). Ensure the wheel is screwed fully on by giving it a sharp twisting jerk.

Hint: If you wish, you could apply a small amount of Loctite glue to both the drill thread and the chuck bolt thread before fitting the wheel and bolt for the last time.

46. Remove the 4mm bolt (which was originally inserted to keep alignment of the wheel and axle hole) and insert the 4mm left hand thread chuck bolt. Fully tighten this bolt by twisting anticlockwise.

47. Recheck both the wheel and chuck bolt are both tight and reinsert the 4 x25mm wheel bolt.

48. Repeat with the other motor and wheel.

Plastic Casing

49.   The motor plastic casings are fitted with the position of the handle (cut off earlier) facing towards the centre of the chassis.

Hint: Make sure the bottom half of the plastic casing is the half **without** the four black self tapping screws that join the two halves together.

50.   Drill five 3mm holes in the lower half of the plastic casing in the positions shown below.

Hint: Make sure the holes are far enough away from the moulded obstructions to allow the head of the screw to fit in.

51.   Using a round file cut two half round matching holes in the motor casings to allow the motor wires to exit.
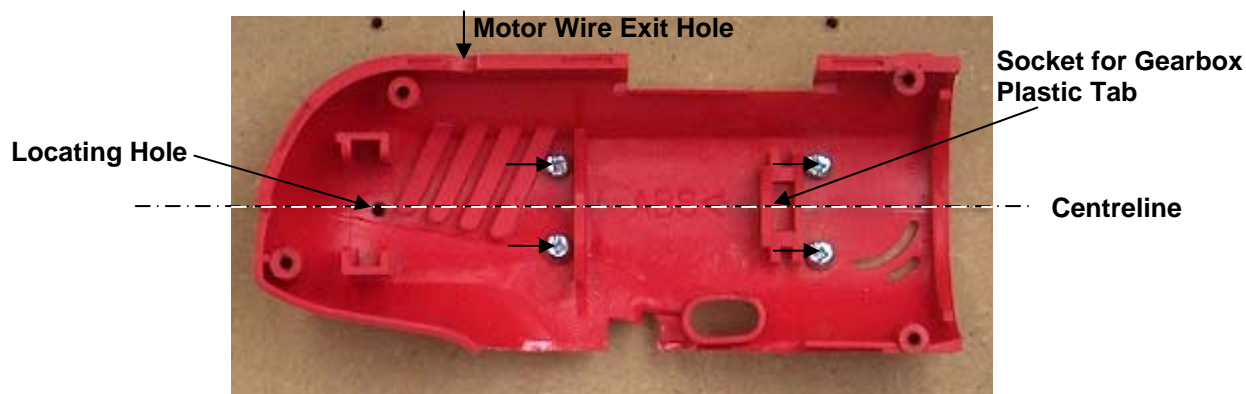
Position of Locating Hole and Four Fixing Holes in Lower Plastic Casing

Fitting The Motor Assembly

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

52.   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 positioning of the motor and wheel.

6mm MDF Used As a Temporary Spacer

53.   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 rotating. When lined up, the motor and gearbox should drop vertically into the plastic case with no forcing required.

54.   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?
   **Is the drill body on its centreline and parallel with the ends of the chassis?**
       When you are absolutely happy it is in the correct position drill through the **rear** locating hole and completely through the chassis.

Hint: Depending on how accurately you drilled the rear locating hole through the plastic casing, it should also be through the pencil centreline for the drill under the casing.
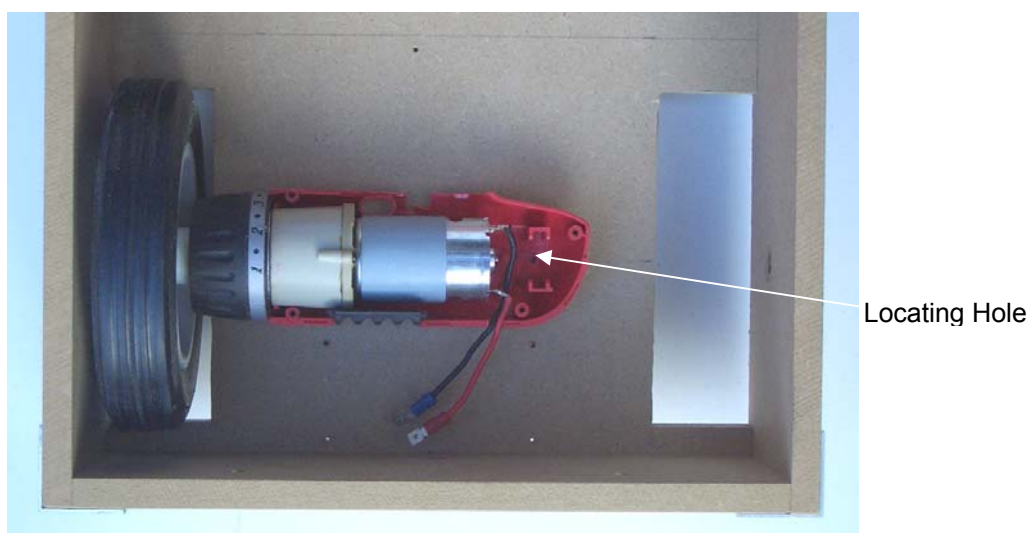
Position of Motor, Gearbox and Wheel in Chassis

55. Remove the motor, gearbox and wheel from the bottom half of the plastic casing. Remove the MDF spacer from the side of the chassis.

56. Place the lower casing in the chassis and locate it in the correct position by inserting a 3mm x 20mm bolt through the **rear** screw hole.

57. Line up the drill casing so that its centre line is exactly across the chassis.

    Is the wheel parallel to the side of the chassis?
    Is the wheel positioned centrally in its cut out hole?
    Is the drill body on its centreline and parallel with the ends of the chassis?

58. When you are absolutely happy it is in the correct position drill through the **four** other fixing holes.

59. Bolt the lower casing to the chassis using the front four bolt holes you have just drilled. Remove the rear locating screw. This rear hole is not used as the casing does not touch the chassis at this point.
Hint: Do not tighten the four bolts too tight or you may distort the lower casing and the top half will not fit.

60. Replace the motor, gearbox and wheel assembly back in the lower casing.

61. Locate and fit the black plastic plate in the lower drill casing, Route the two motor wires out of the hole you previously filed and carefully fit the upper plastic drill casing using the four black screws. Note the position of the shorter screw.
Hint: If the upper casing does not fit easily 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 the case is not distorted.

Shorter Black Casing Screw
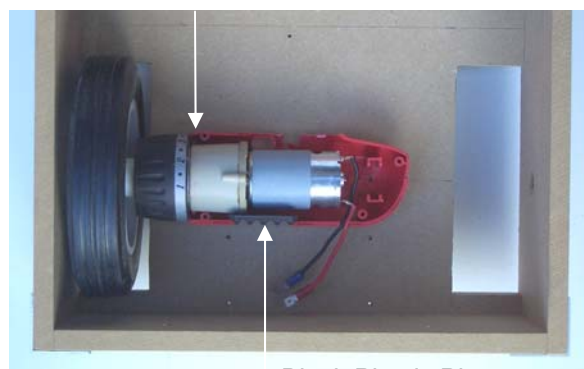
Black Plastic Plate

Position of Casing, Motor and Wheel

62. 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.

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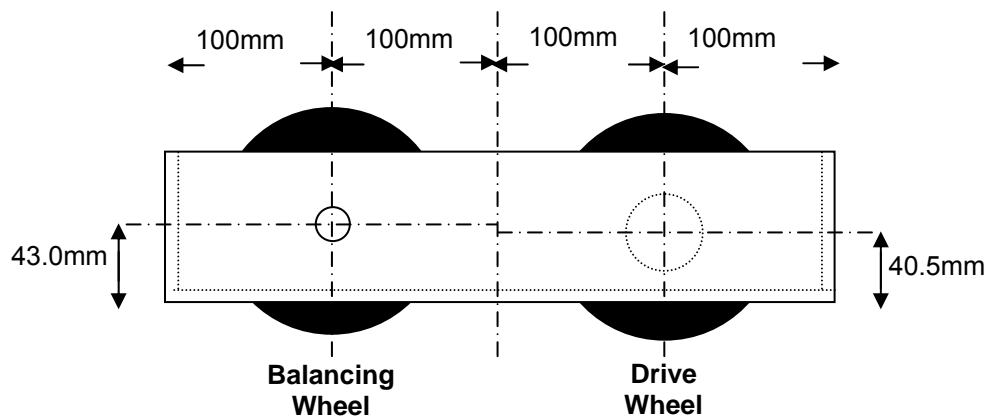
Axle Bolt

64.   Insert the clear plastic axle tube into the wheel.

65.   Insert the coach bolt through the MDF from outside and fit an ordinary nut on the inside until the bolt protrudes about 10mm. 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 4mm 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

66.   Cut four strips of Velcro loops 100mm long (leaving a 50mm long piece for the receiver). Peel off the backing paper and press onto the under side of each battery.

Velcro Loops on Base of Battery

67.   Take the small MDF aerial block you made earlier and screw it to the base of the chassis (on the longitudinal centerline) in the position shown.

68.   Place two strips of Velcro hooks 100mm long on top of 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 two minutes before lifting off the batteries.
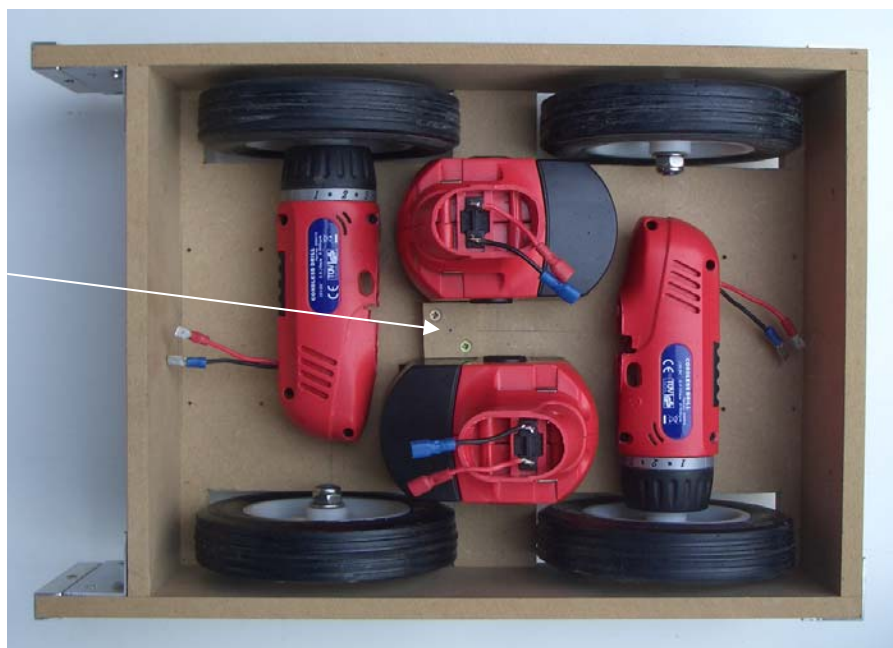
MDF Aerial Block

Position of Batteries in Chassis

Note: The section on 'Ideas For Improving Your Robot' (Build 12) describes an additional method of securing your batteries for robust football competitions.

Rear Safety Lights

Black stripe this side

View from Top
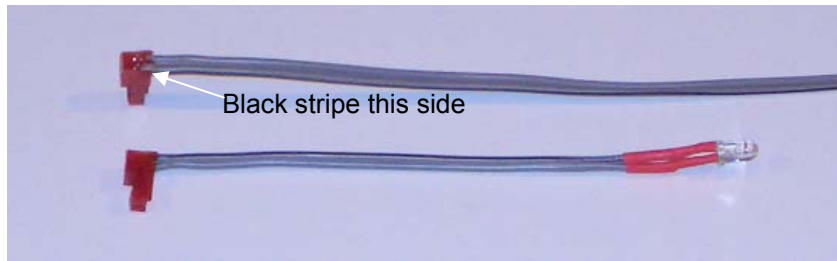
Rear Safety Light Connections   **LED Polarity**
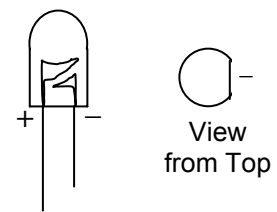
69.   Prepare the ends of the two pieces of twin grey flex (length 120mm and 500mm). Cut the leads of the high brightness Red LEDs to a length of 10mm. Slide a 20mm length of heat shrink over each flex wire end and solder the wires to the LED **ensuring the wire with the black stripe goes to the negative 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.

70.   Push the wires firmly into the top of the red plug using a small thin screwdriver. The negative wire with the black stripe is on the left side as shown in the photo above.

Hint 1: Tin the ends of the wires with solder before you push them into the plug, but don't use too much solder.

Hint 2: Get someone to hold the red plug firmly on a bench with pliers whilst you push down the wires.

71.   Insert the LEDs into the 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.

12mm MDF
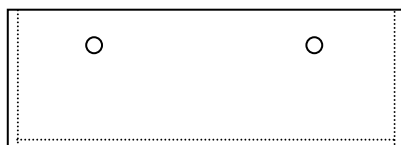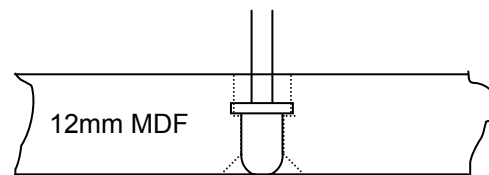
Rear Elevation   **Plan View Section of Rear**

Tug-of-War Towing Eye

72.   Screw the Tug-of-War towing eye into the rear of the robot 45mm from the bottom.
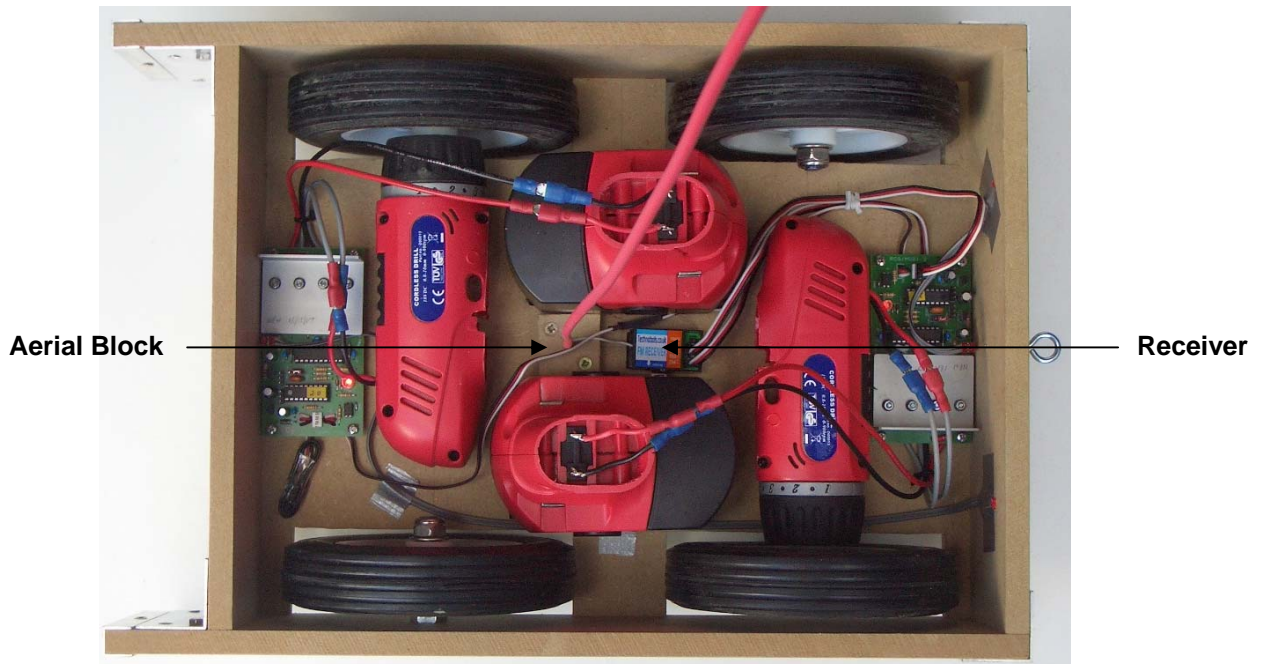
45mm
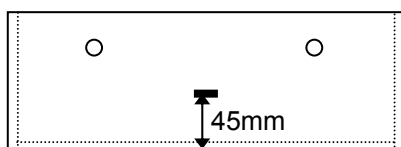
Position of Towing Eye

Radio Receiver and Aerial

73.   Cut a piece of Velcro to fit the bottom of the receiver and attach it to the chassis in the position shown.

Note: Velcro makes it easy to remove the receiver to change the frequency crystal.

Aerial Block ⟶   ⟶ Receiver

Position of Receiver and Aerial

74.   Insert the aerial and piano wire through the red 3.2mm heatshrink.

Hint: First attach the aerial to the piano wire with a small piece of sealotape and pull it through.

75.   **Bend over the end of the metal aerial support piano wire to avoid it sticking in your eye**.

NB. You will not pass the Rampaging Chariots Robotic Games safety Inspection unless this is done.

76.   Cut off the surplus piano wire (Not the white aerial wire) and fit the piano wire into the hole in the MDF aerial block.

Hint: Grip the piano wire with a pair of pliers to push it into the hole.

Finishing

77.   Paint the Chassis and personalise your Rampaging Chariot.

78.   Think of ways of improving your Rampaging Chariot such as adding a superstructure. Hints are given in chapter 'Build 12'

Rampaging Chariot Chassis 2008

50

Slave
Board

Drill Motor

100

18 volt
Battery

Aerial

Length
450

Radio
Receiver

18 volt
Battery

Drill Motor

Master
Board

LED

LED

Width 310
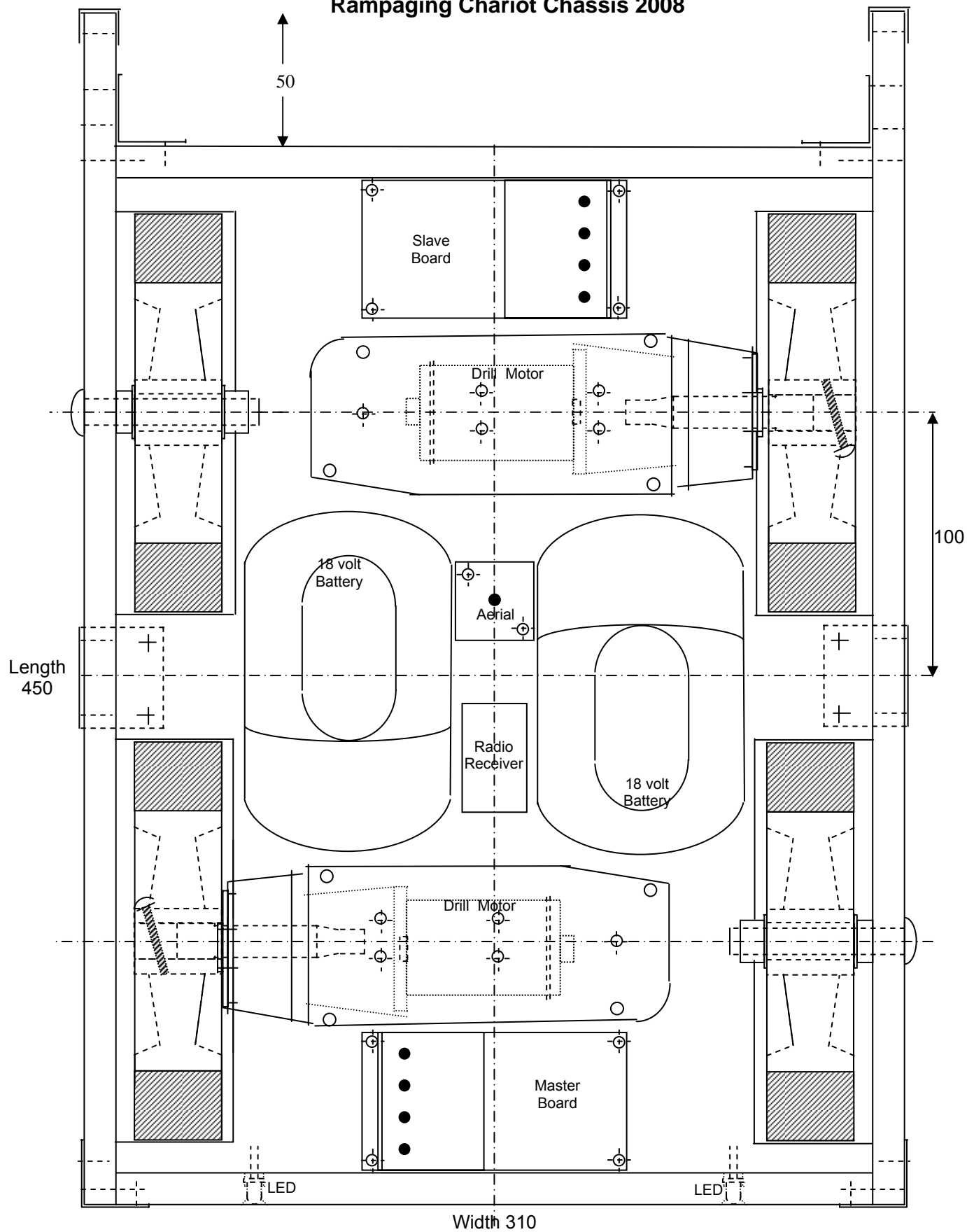
PJB V3.0   PLAN VIEW   Scale 1 : 2

Build 8 – Constructing The Motor Controllers

Identifying Components

Identify all your components and lay them out over the diagrams to ensure you have them all.

Hint: Tear out the duplicate component sheet near the end of this booklet for this purpose.

Wire Links ▬▬▬▬ ▬▬▬▬ ▬▬▬▬ (Cut from resistors)

Resistors
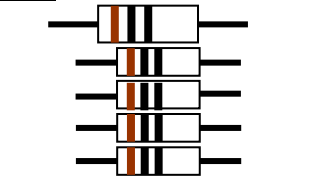
10R = Brown-Black-Black
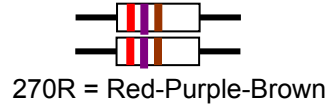
270R = Red-Purple-Brown

1K = Brown–Black-Red

Resistance Colour Code
0 = Black
1 = Brown
2 = Red
3 = Orange
4 = Yellow
6 = Green
6 = Blue
7 = Purple
8 = Grey
9 = White
Band 1 = First Digit
Band 2 = Second Digit
Band 3 = No of following zeros
Separate Gold Band =
5% Tolerance

4K7 = Yellow-Purple-Red

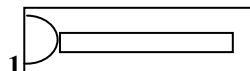22K = Red-Red-Orange
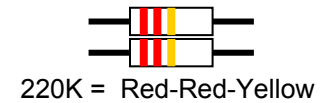
220K = Red-Red-Yellow

Diodes
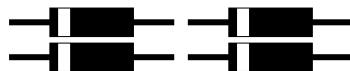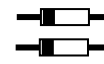
UF4002   1N4148

IC Sockets

ICs
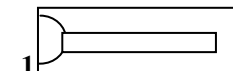
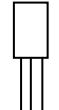PIC 16F628A (18 Pins)   HIP 4081A (20 Pins)   SHF615 (4 Pins)

LEDs   **Voltage Regulators**   **Resonator**

12 volts   5 volts

Tricolour   78L12   78L05

Capacitors

224 224 224 224
Ceramic 0.22uF   Electrolytic 10uF   Electrolytic 220uF
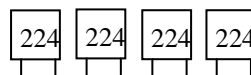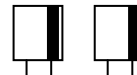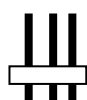
MOSFET
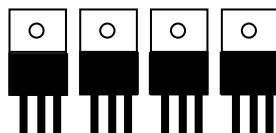
IRF2907   **Radio Control Lead**

LED Plug   **Output Plug**   **Jumper Plugs**   **Jumper**

Component Insertion 1 – Large Resistors, Wire Links and Test Point

As a general rule it is easier to solder in components with a low profile first, such as wire links and resistors, and finish with soldering the high profile components such as the Capacitors.
The board will look more professional if the resistors are all the same way round.

Large Resistors. Take the larger 1K and 10R resistors and bend both resistor wires by hand through 90 degrees close to the body of the resistor.
Insert the resistors in the holes shown below so that they lie flat on the board.
Cut off the excess wire 3mm from the under surface and solder them in. **Keep the wire offcuts** as they will be used as wire links and a test point.
Wire Links. Bend the ends of the two wire links over with a pair of long nose pliers at the length required.
Insert the two wire links in the correct holes of the Printed Circuit Board (PCB) so that they lie flat on the top surface of the board.
Hold them close and flat to the board with some masking tape.
Cut off the excess wire 3mm from the under surface and solder them in.
Negative Test Point: Bend the third wire round the ends of the long nose pliers and insert the loop into the two holes in the wide earth track. The loop should stick up about 3mm for you to 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.

Large 1K (Brown-Black-Red)   **Large 10R** (Brown-Black-Black)


Test Point Loop

Wire Links
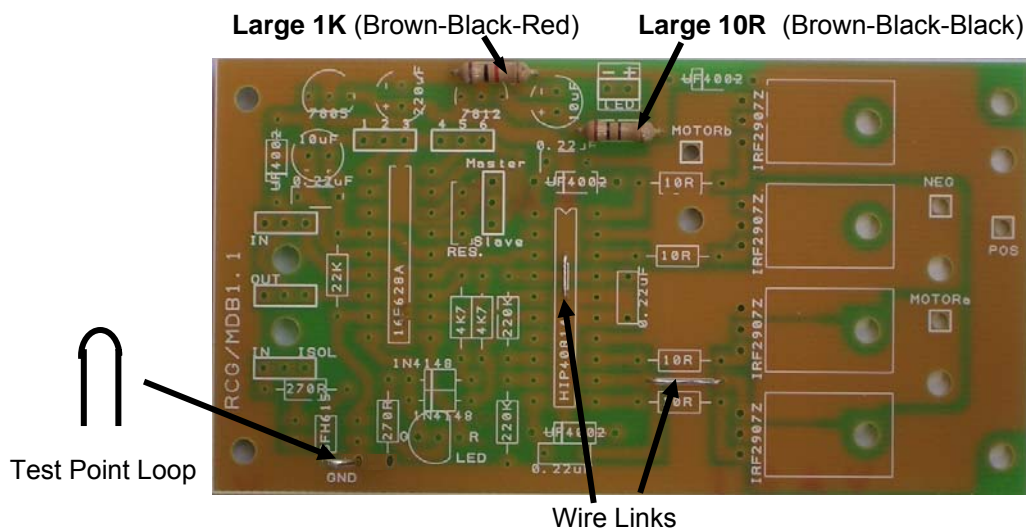
Component Insertion 2 – Small Resistors

Check the Values of the small resistors from the colour code 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.
Cut off the excess wire 3mm from the under surface and solder them in.

|					
10R	= Brown-Black-Black	x4	22K	= Red-Red-Orange	x1
270R	= Red-Purple-Brown	x2	220K	= Red-Red-Yellow	x2
4K7	= Yellow-Purple-Red	x2			
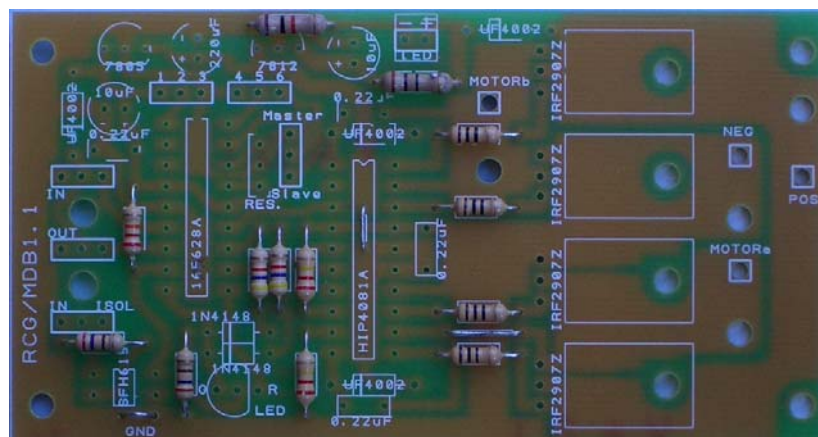
Component Insertion 3 - Diodes

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.
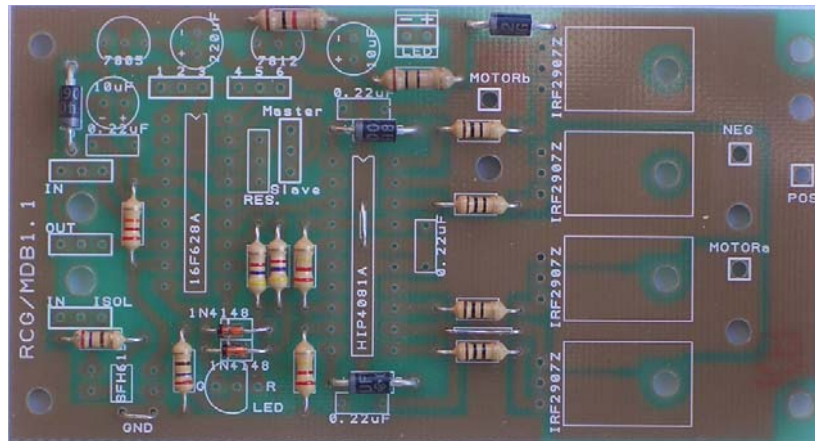
Component Insertion 4 – Radio Control Leads

Insert the radio control wires through the restraint holes from the under side of the board (Black wire to the edge of the board).
Hint: Squeeze the three coloured wires together so that they will fit through the circular hole and push them through about 4 cm so that you can bend over the wire and line the wires up straight with the holes.
Note, It is not easy to get all three wires inserted in these holes.
Solder in the wires with the **CORRECT ORIENTATION** (Black to the edge of board).
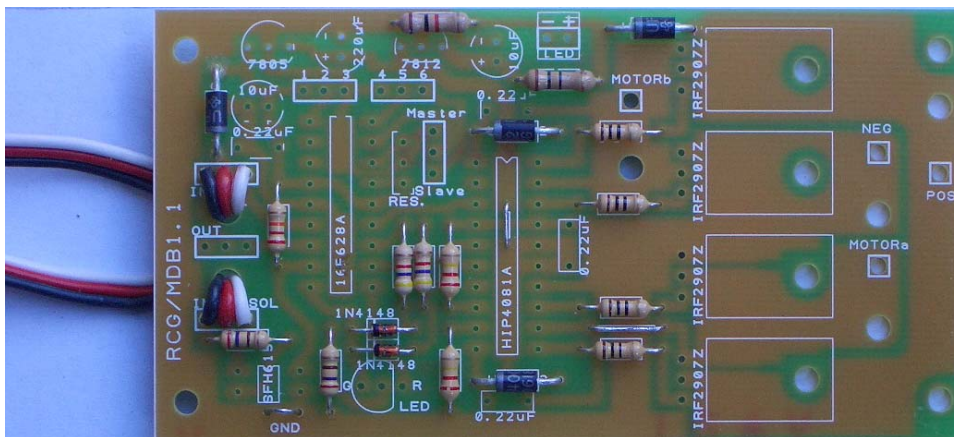
### Component Insertion 5 – IC Sockets, Opto-Isolator and Voltage Regulators

IC Sockets. Insert and solder in the two sockets for the ICs with the small indentation towards the top of the board. The socket must lie flat on the board.
Note: Check that all the contacts are fully down with none sticking up above the plastic.
Hint: Solder two opposite corner pins first and then ensure the socket is flush with the board before soldering the rest of the pins.

Opto Isolator. Insert and solder in the Opto-Isolator with the **CORRECT ORIENTATION** for pin No 1 (Line to the left side of the board).

Voltage Regulators. Insert and solder the 5v and 12v voltage regulators in the **CORRECT POSITIONS with the CORRECT ORIENTATION**

78L05   78L12
5v Reg   12v Reg

Output (. . .) Input
↑
Ground
Voltage Regulator
View from Top

1

Opto Isolator
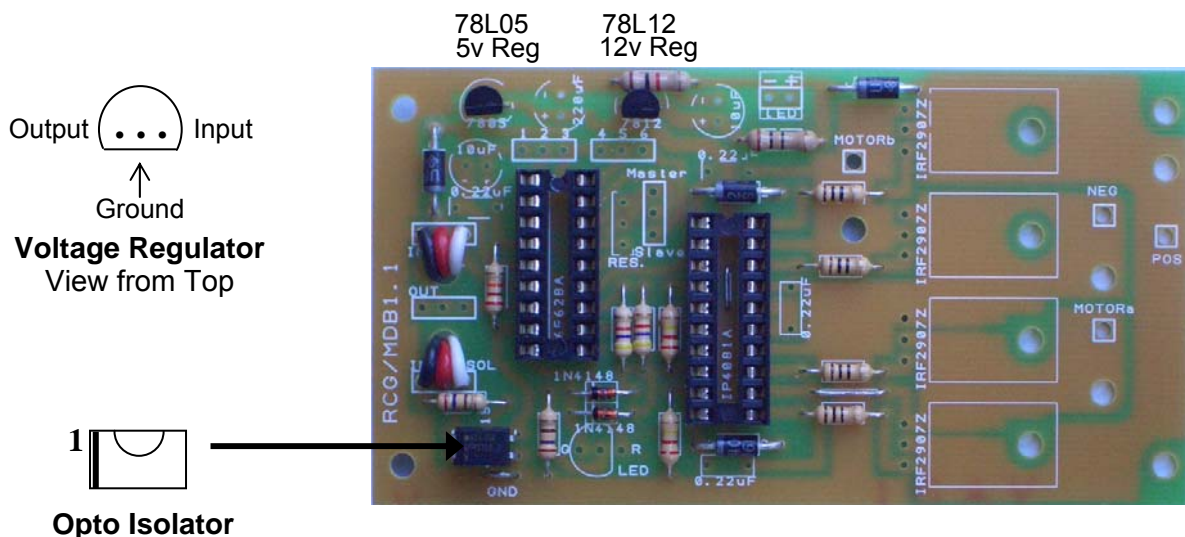
Component Insertion 6 – LED, Resonator, Plugs and Jumper

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

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

Plugs and Jumper.
Insert and solder in the white Output Plug (three pins)
Insert and solder in the three black Jumper Plugs (three pins) with the shorter pins through the PCB
Insert and solder in the white external LED Plug (two pins) with the tab towards the edge of the board.
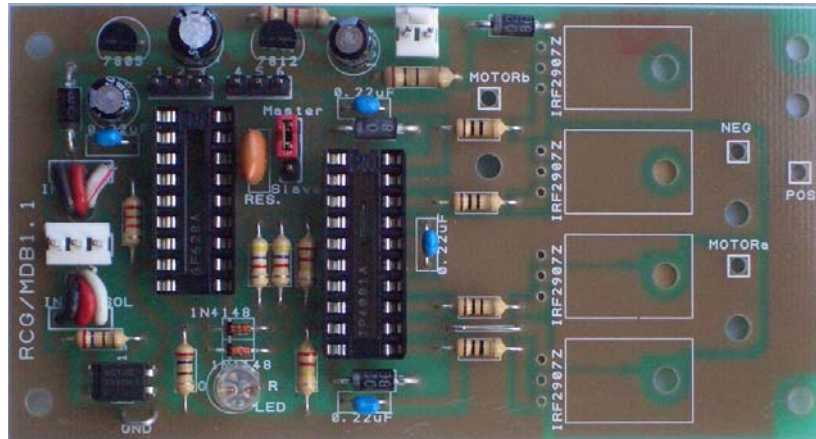Fit the red Jumper to the two top pins as shown.

Green   Red

View from Top
LED
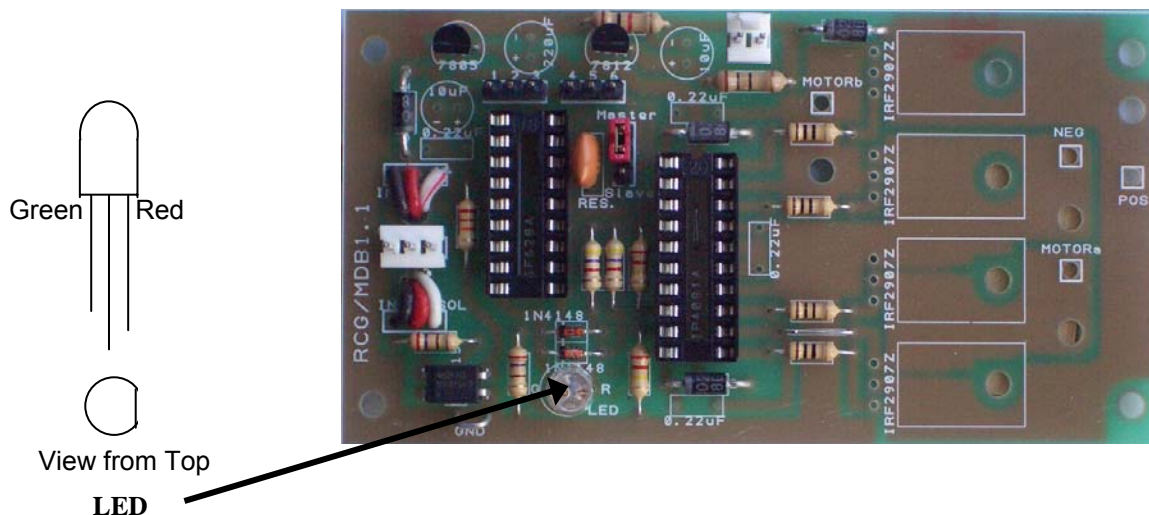
Component Insertion 7 – Capacitors

Insert and solder the four 0.22uF small capacitors.   0.22uF = 224

224

Insert and solder the large capacitors noting their different values and **CORRECT ORIENTATION.**
The white stripe denotes the negative connection of electrolytic capacitors

Component Insertion 8 – Connecting Wires

Twist and tin the ends of the wires, but do not use too much solder or the wires will not go through the holes.
Ensure no strands of copper wire are left on top of the board
Note: The big copper areas will take longer to heat up

Insert the red and black heavy wire connections through the restraint holes and solder to the lower surface (lots of heat required). The red wire is soldered to the copper labelled POS
Insert the two grey heavy wire motor connections through the restraint holes and solder to the lower surface (MOTOR).
Finally, pull these four wires back through the restraint holes whilst pressing the wire flat against the top surface of the board.
Attach (by crimping) red and blue **Male** Spade terminals to the longer red and black power wires.
Attach (by crimping) red and blue **Female** Spade terminals to the grey motor wires.
Note: The colour of the connectors on the grey wires is not important. (We put the red connector on the wire attached to the centre of the board).
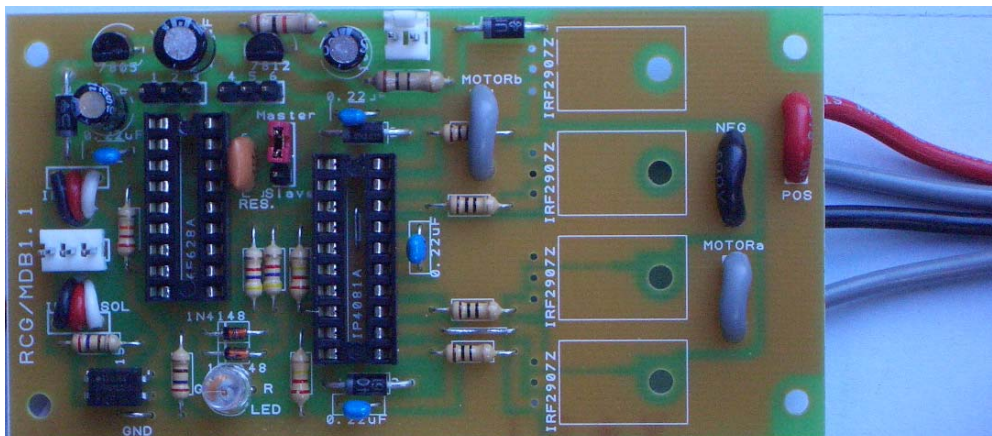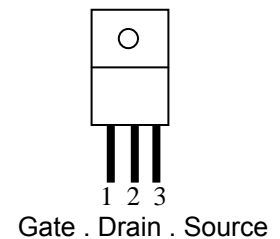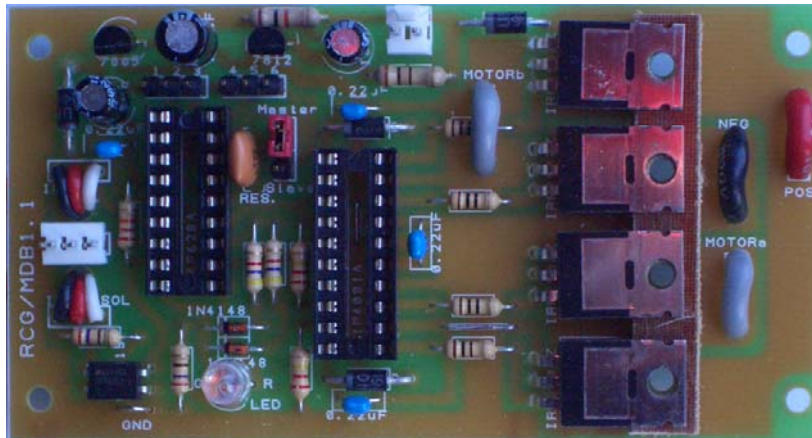
Component Insertion 9 – MOSFETS and Insulation Spacer

Insert the four MOSFETS in the PCB and ensure the MOSFET holes line up with the holes in the PCB.
DO NOT SOLDER THE MOSFET LEGS UNTIL THE HEAT SINK IS BOLTED DOWN.
Note: The MOSFET legs are supplied pre bent through 90 degrees away from their flat side.
Insert the brown insulated spacer under the metal tabs of the MOSFETS and again line up the four holes.

1 2 3
Gate . Drain . Source

Component Insertion 10 – Heat Sink Assembly

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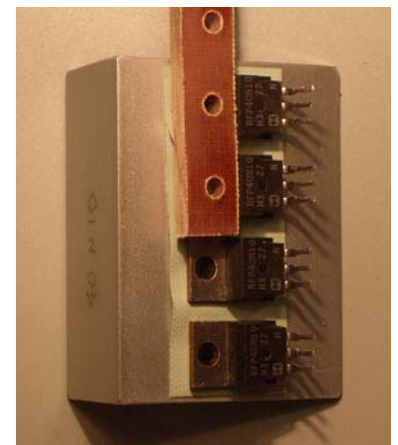

| Heat Sink | Insulation Sheet | Insulated Spacer | Assembly |

Insert the four black top hats in the top of the heat sink.
Fit the green Insulation sheet onto the underside of the heat sink and ensure the four black top hats poke through the holes in the insulation sheet.
Insert the bolts from the underside of the PCB and carefully place the heat sink on top of the MOSFETS.
The assembly should be in the following order from bottom to top: **2.5mm bolt – PCB – Insulating spacer – MOSFET – Insulating sheet – Heat sink plate - Black plastic top hat – Nut on top.**

- Nut
- Plastic Top Hat
- Heat Sink Aluminium Plate
- Insulating Sheet
- MOSFET
- Insulating Strip/Spacer
- PCB
- Bolt
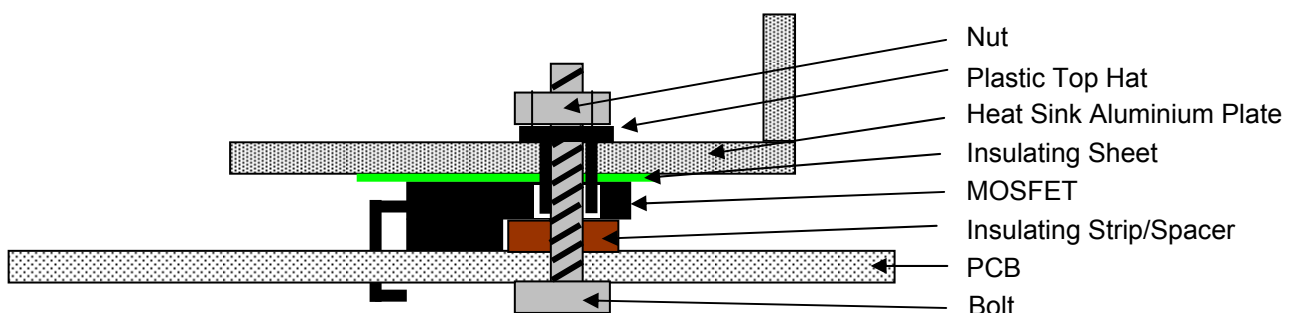
Take great care fitting the heat sink as if you try to force the black top hats into the holes you may squash them and end up with blown MOSFETs caused by an electrical short circuit.

Initially fit all four of the nuts **FINGER TIGHT** on top. Ensure the black plastic top hats are still located in the MOSFET tabs and **the top hats are flush with the top of the heatsink**. This is very important to ensure the screws are insulated from the MOSFETS.

Hint: You may need to remove the black top hat and align the MOSFET and holes with a small screwdriver in order to get the top hats to sit flush with the heat sink.

When all the top hats are correctly seated, tighten the nuts fully ensuring that the MOSFETS are sandwiched flat without touching each other.

Cut off **half the length** of the MOSFET pins protruding through the PCB and **bend over the Drain and Source pins under the board towards the large area of copper (see picture below)**.

This will ensure there is a good high current connection between the MOSFET pins and the large areas of copper.
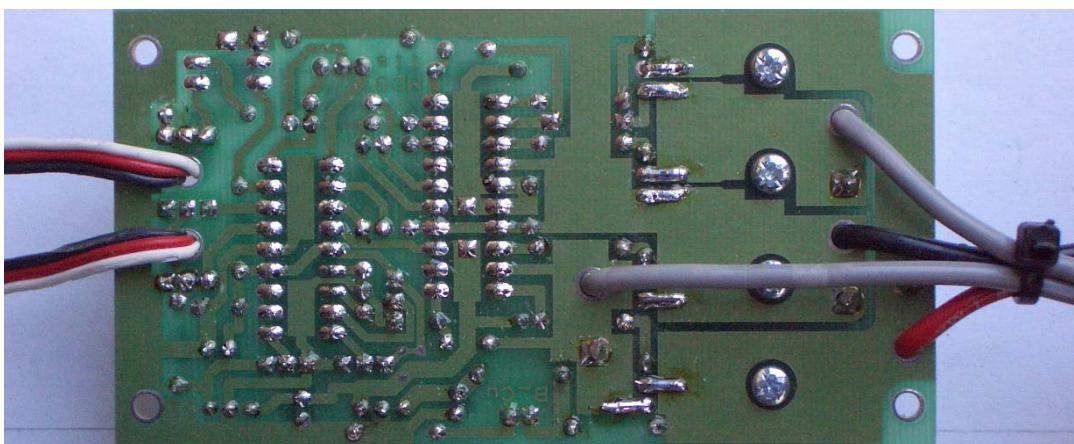
Solder all the pins and then cut off the excess length of the Gate pin.

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

Fit a small cable tie wrap round the four wires near the edge of the board
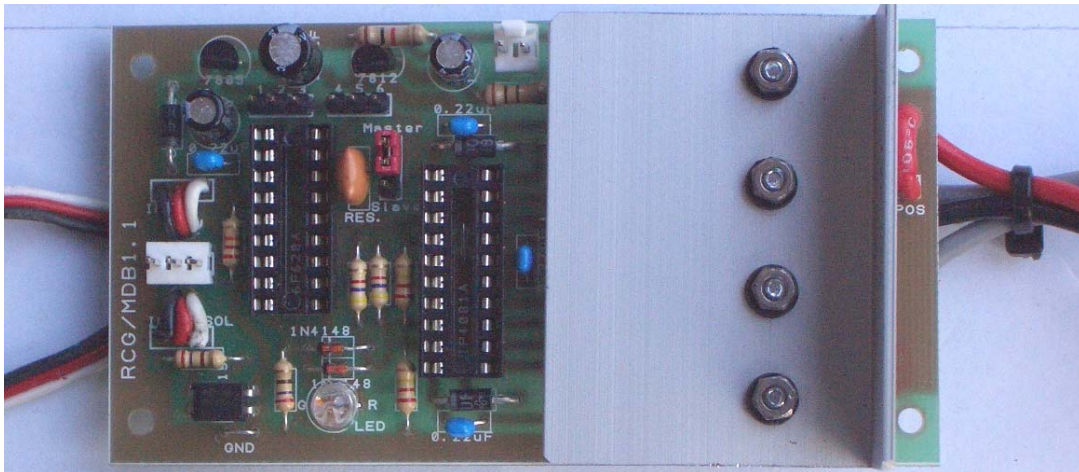
**The Completed Board – Top View**

The Completed Board – Bottom View

Configuring The Boards as Master and 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: The other two sets of jumper pins are for changing the characteristics of the Rampaging Chariot control laws. Jumpers and suitably programmed PICs will be provided by the Guild if you are chosen to represent your country at international competitions.

Channel 4

Channel 2

Master Board
Jumper Connects
Top Two Pins
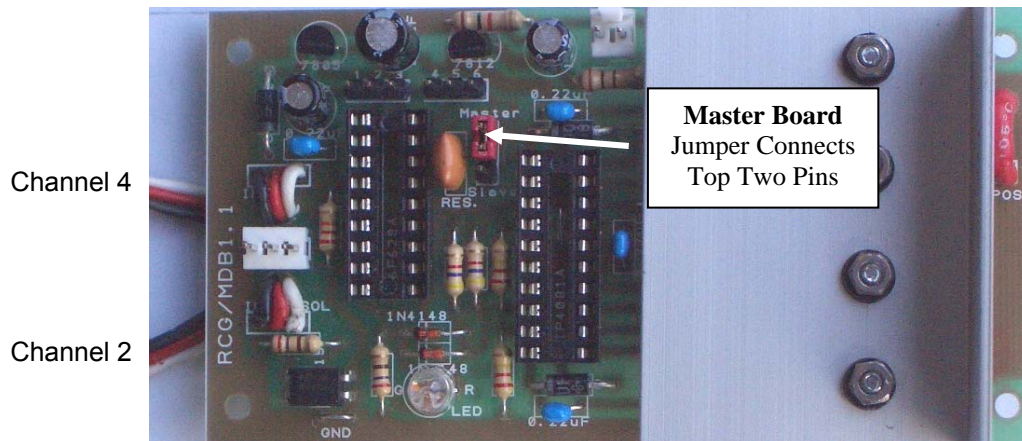
For the Master board both radio control leads are used and these plug into Channel 2 and Channel 4 of the radio receiver.

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

Making the Test Equipment

Connect up the test equipment parts as shown. If there is a major fault the bulb will light and protect the MOSFETS. **Disconnect power immediately as the bulb and resistor will get extremely hot quite quickly and will burn you**.
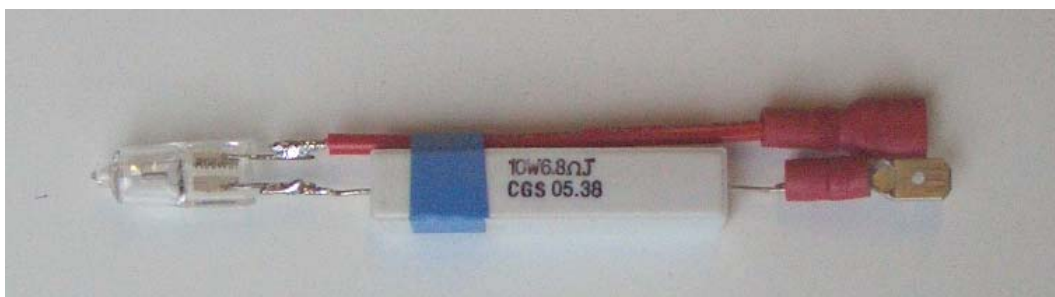
12v Halogen Bulb and 6R8 10W Resistor for Initial Testing of Small Motor

Small 3 volt Motor with 47R Series Resister

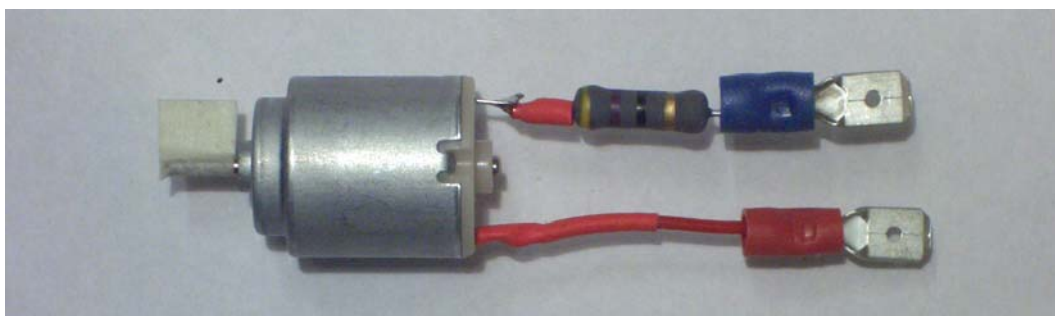# Build 9 – Testing the Motor Control Boards

Test Equipment

To avoid blowing the expensive MOSFETS if there is a fault on the circuit board it is desirable to insert a 12v bulb and 6.8 ohm series resistor between battery and board. This can be removed after testing.
For initial power-on checks also connect the small 3v test motor with a 47 ohm resistor in series.
Hint: Stick a piece of insulation tape on the shaft to show which way it is rotating.
**Warning:** This resistor will heat up with prolonged running.
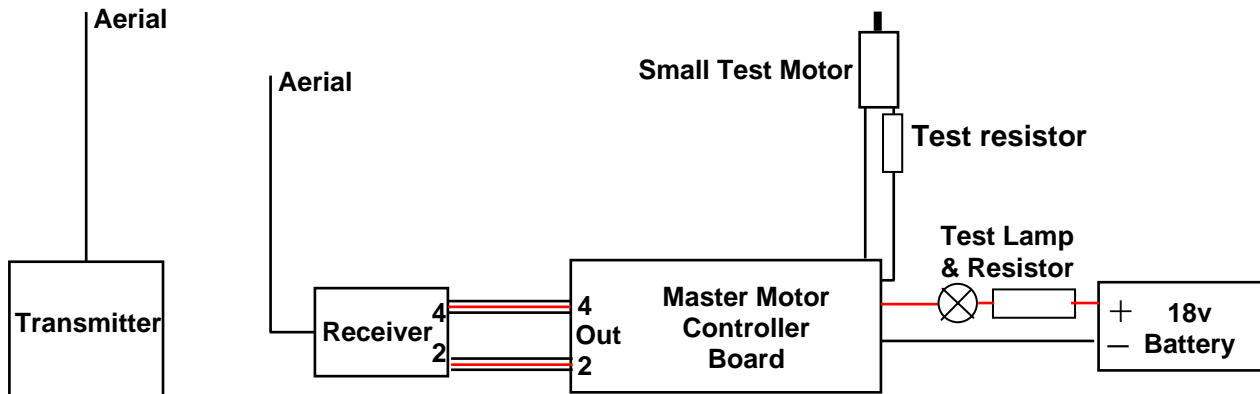
Once you are happy the board is functioning correctly and the small motor can be controlled forwards and backwards at varying speeds, the bulb can be disconnected and the proper drill motors connected. These drill motors can draw currents of up to 40 amps.

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.

With Motor, Receiver, Battery, and both ICs 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, resistors may be fitted where capacitors should be and 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 track bridging. -   This is another major cause of problems.

3   If you can, measure resistance between pins 1 and 3 of each MOSFET.
        Note: The resistance should be greater than 1MΩ.
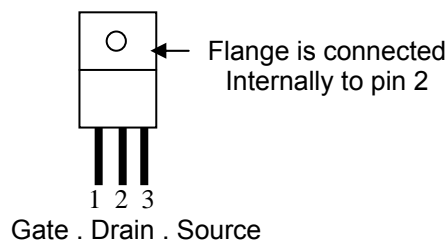
4.   Check the heat sink is isolated (>1MΩ ohms between the **edge** of the heat sink and the large areas of copper on the board).
        Note: The anodised surface of the heat sink is good for heat dissipation but also acts as an insulator so place the test lead on the cut edge of the heat sink which is not anodised.

5.   Check the battery plug is wired the correct way round and the red wire is connected to the positive central 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 try to stop your chariot from a high speed.

Applying Power

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

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.

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 and the charge is likely to leak away in a few minutes.

6.   Connect the Black test lead from your meter to the negative test point.

7.   Apply power to the board from the 18v drill battery through the 12v bulb and series resistor.

8.   Touch the two power regulators to check they are not heating up and be aware of any unusual smell.

9.   Check approx 18v on input to board from the drill battery (End of Resistor)

10.   Check 12v +/-0.5v on output from first regulator

11.   Check 5v +/- 0.2v on output from second regulator (End of Diode)
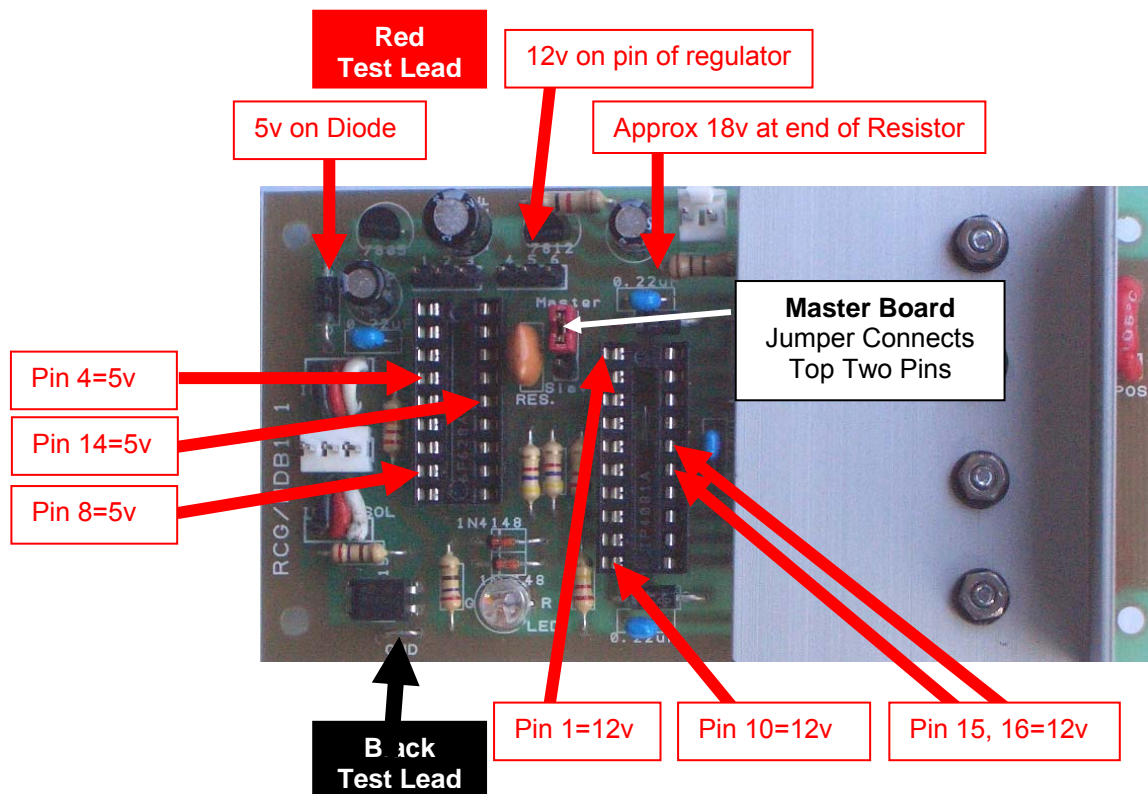
12.   Check voltages on IC1 socket

       All pins<0.1v except

       Pin 4 = 5v

       Pin 8 = 5v

       Pin 14=5v

13.   Check voltages on IC2 socket

       All pins<0.1v except

       Pin 1 =12v

       Pin 10 = 12v

       Pin 12 = Stabilise <0.5v

       Pin 15 = 12v

       Pin 16 = 12v

       Pin 19 = Stabilise <0.5v

Inserting The PIC

14. With the battery disconnected, insert the PIC IC (18 pins) with correct orientation (Pin 1 at top left)
Note: You may need to bend the pins slightly inwards to get it to fit in the socket.
15. Apply power to the board from the 18v battery through the 12v bulb and resistor.

16. Check the dual colour Light Emitting Diode (LED) lights RED (No radio pulses being received). It will light GREEN later to indicate that motor rotation is being demanded.
17. Disconnect Power from board.

18. **Connect the Receiver** (Both Channel 2 and Channel 4 wires must be connected)

19. Switch on Transmitter and ensure that the controls are centred.
20. Apply power to board from the 18v battery through the 12v bulb and resistor.
21. Check the LED lights RED for ½ second and then goes out to indicate pulses being received from receiver.

22. Move transmitter right stick up slowly (Channel 2). The LED should glow GREEN and increase in brightness with control deflection.
23. Move transmitter right stick down slowly (Channel 2). The LED should glow GREEN and increase in brightness with control deflection
24. Move transmitter left stick to left and right (Channel 4). The LED should glow GREEN and increase in brightness with control deflection.
25. If the LED glows GREEN faintly with controls at neutral, adjust the transmitter trims for neutral.

Switch off the Transmitter and disconnect power from the Board.
If steps 22 to 25 give the correct results the first half of the board is working correctly and you can proceed to insert the driver IC.

Inserting The Driver IC - ONLY DO THIS IF STEPS 22 to 25 ABOVE GIVE THE CORRECT RESULTS

26. With the battery disconnected Insert the Driver IC (20 pins) with correct orientation (Pin 1 at top left)
Note: You may need to bend the pins slightly inwards to get it to fit in the socket.
27. Connect the small test motor with its series resistor.
28. Apply power to board from the 18v battery through the 12v bulb and resistor.

29. Touch the two power regulators to check they are not heating up and be aware of any unusual smell.
30. Check the LED is RED (No radio pulses being received)
31. Check the test motor is not rotating.

32. **Switch on the Transmitter** and check the LED goes out to indicate pulses are being received from the receiver.
33. If the LED glows GREEN (the motor may also be rotating slowly) adjust the transmitter trims for neutral.
34. 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
35. 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
36. 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.

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

Eureka It Works!

Switch off the Transmitter and disconnect power from the Board.
Now test the other board configured as a master board in exactly the same way.

When both boards are working correctly and identically as master boards, configure one as a Slave.
Neatly tape up the lead of the Slave board Channel 4 plug as this is not used on a Slave board.
Remove the 12v bulb and series resistor from the circuit.

<u>Troubleshooting</u>

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

With the PIC IC inserted 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?
    Symptoms:
    Are12v and 5v indicated at the correct places on the board?
    Does the control board LED shine red when the battery is connected?
    Does the control board LED go out when the Transmitter is turned on?
    Does the control board LED light GREEN when either control stick is moved?
    Is the brightness of the GREEN LED proportional to the speed demanded?

NB: Do not insert the Driver IC if the LED is not giving the correct indications 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 MAGNIFING GLASS.
    RESIST THE TEMPTATION TO TRY THE NEXT STAGE OF TESTING.
    DO NOT SUBSTITUTE COMPONENTS FROM YOUR OTHER BOARD.
    DO NOT REMOVE THE TEST BULB.
SOME TEAMS HAVE IGNORED THIS ADVICE, DESTROYED EXPENSIVE COMPONENTS AND MADE OUR TROUBLESHOOTING TASK MUCH MORE DIFFICULT.

<u>Advice</u>
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.

For advice contact   technical@rampagingchariots.org.uk   Please describe your problem and supply as much detail as possible about the symptoms.
   a. State whether you have checked the board for solder bridges, components in correct place and correct component orientation.
    b. State which numbered steps above you have completed with the voltage values obtained.
    c. State which steps gave unexpected or confusing results with the voltage values if applicable.

Build 10 - Wiring up Your Robot

Fitting the Motor Controller Boards

The board you have configured as a master board is fitted at the rear of the chariot nearest to the receiver.

You should already have marked on the chassis the positions of the four holes in the two PCBs and drilled through the MDF with a 2.5mm drill.

1. Insert 3mm x 20mm pan head machine bolts through the circuit board and fit the plastic spacers. Screw the four bolts into the MDF, but not too tight.

Hint: Hold the board firmly down onto the spacers as you tighten the screws or you may distort or crack the circuit board.
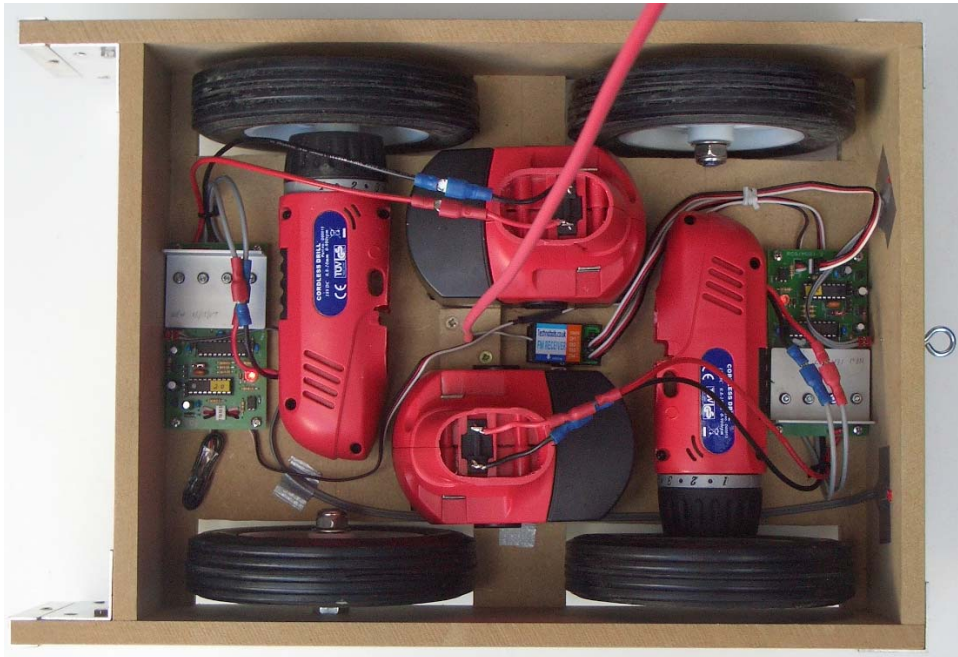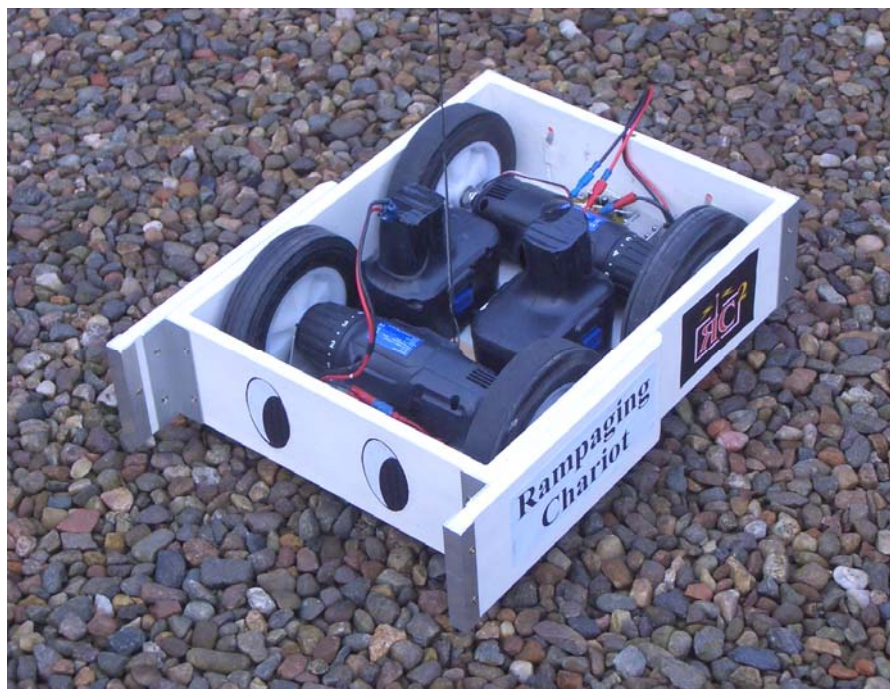

Interconnections
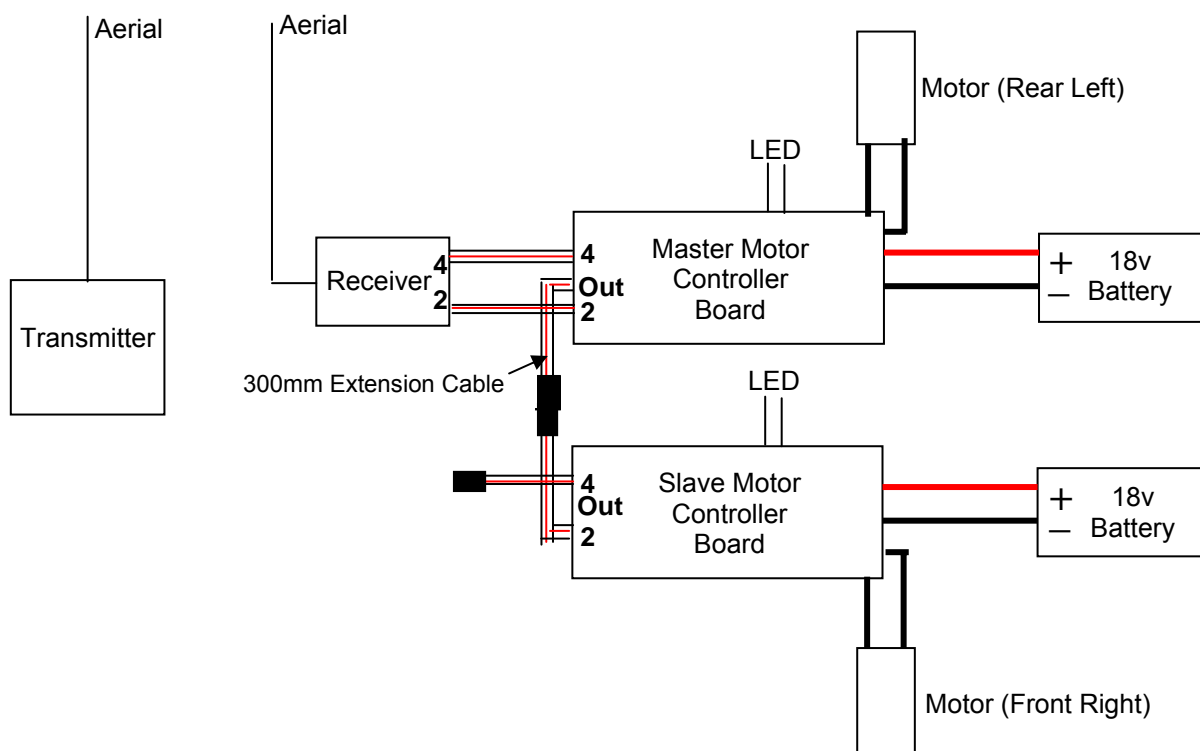
Build 11 – Testing the Completed Robot

2006 Model Rampaging Chariot

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 transmitter and receiver crystals are the same frequency. 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 the 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 switch over the channel 4 reverse switch on the front of the transmitter.
4. Trim the control system by slowly selecting forwards on the right stick and adjusting the left trim (Channel 4) until both wheels just start to turn at the same time.

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 therefore get the exact zero position on both trims by adjusting them until the robot is silent.

Check the system that is required by the rules to stop the drive motors if it senses a loss of radio signal.
1. Select half speed forward and switch off the transmitter. The motors should stop (with RED LED).
2. Select half left stick and switch off the transmitter. The motors should stop (with RED LED).

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 includes video clips of the 2007 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 will also 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.

The batteries may also come loose. We have supplied you with cable ties to tie them down to the chassis, but there may be other problems that will need ingenuity and engineering thought to overcome. Think through the consequences and discuss each idea with your team members before you cut anything. You must leave easy access to the battery release for safety reasons.

3.   Traction

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

4.   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 8.2 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 Torque settings are at maximum.

2. Why do my batteries break loose when I am playing football?
   A. The Velcro battery fixing is not strong enough if you insist on playing 'Robot Wars'. Devise a stronger way to attach the batteries to the chassis.

3. Should the aerial be straight up?
   A. Yes the aerial should be straight and vertical for best performance and range, but at the distances you normally control the Rampaging Chariot we find it is acceptable to loop the aerial over, provided you keep it well away from the motors and control boards which are sources of electromagnetic interference.

4. Can I shorten the aerial?
   A. The aerial has to be exactly the length supplied for best performance and range. We don't recommend shortening it at all.

5. I can trim my transmitter to get my Chariot moving forward in a straight line, but it always reverses in a curve; even when the batteries are fully charged. Can I correct this?
   A. This is a rare problem, but could be caused by one drill motor being more efficient than the other in one direction. One solution is to reduce the power of one motor by a small electrical resistance or a mechanical friction brake. A further way is to angle the wheels in the chassis. Failing all else use extra skill when reversing.

6. 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.

7. 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.

8. Does the Rampaging Chariot have Fail Safes in both channels?
   A. The Rampaging Chariot motor control boards incorporate 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. This satisfies the rules of the UK Robotic Games.
   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.

9. 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.

10. 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.

11. 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

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.
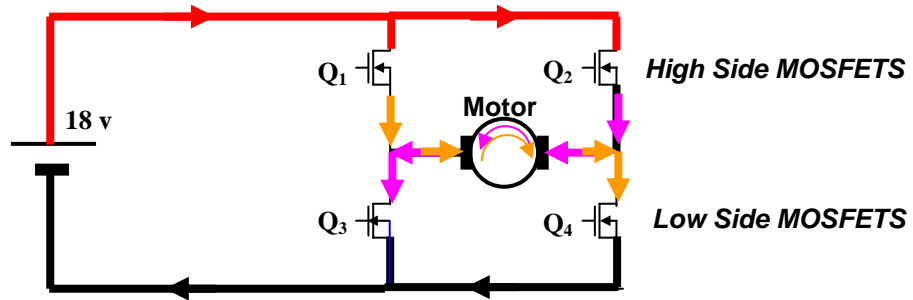

Fig 2 MOSFET Bridge

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
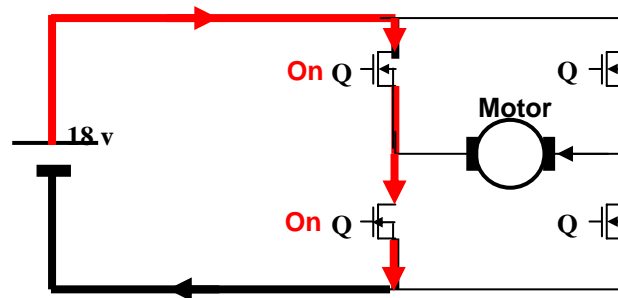

**Fig 3 Shoot-Through Causing Burnt Out MOSFETS**

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.
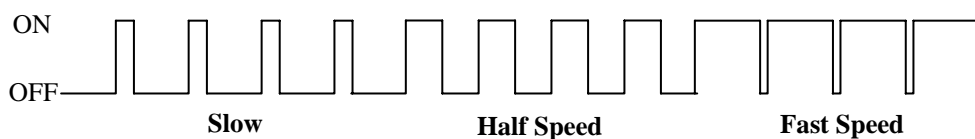
Gate Voltage

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.
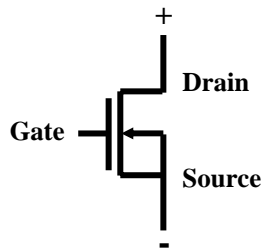
MOSFET

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.
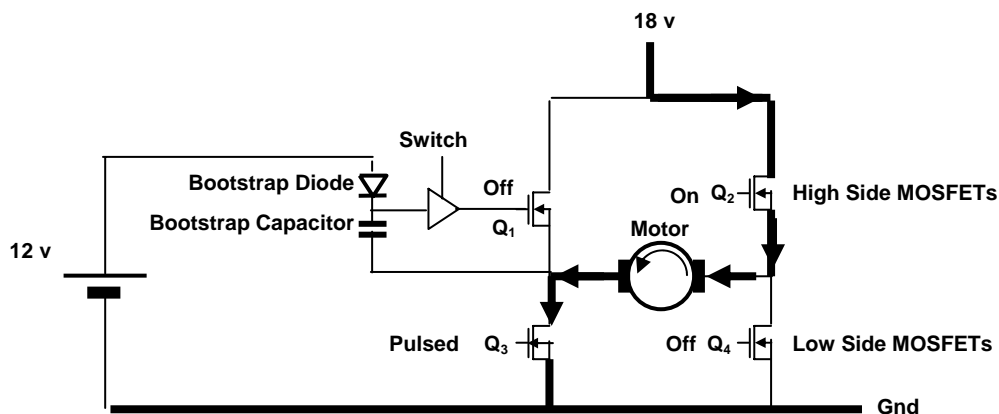

Bootstrap Circuit

Charge Pump

Another circuit (within the IC) called a charge pump is able to supply a very small current (about 50 µA) 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.

Voltage Doubler

Voltage Quadrupler
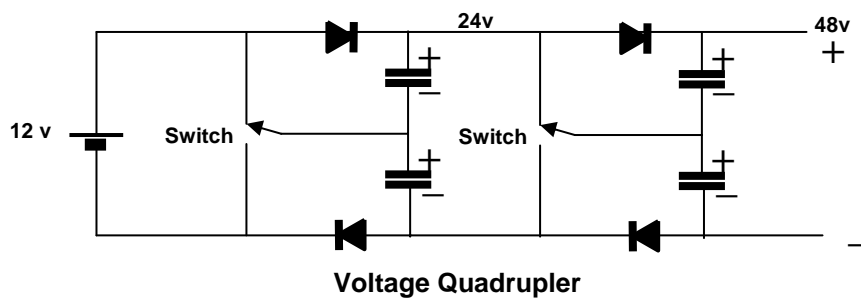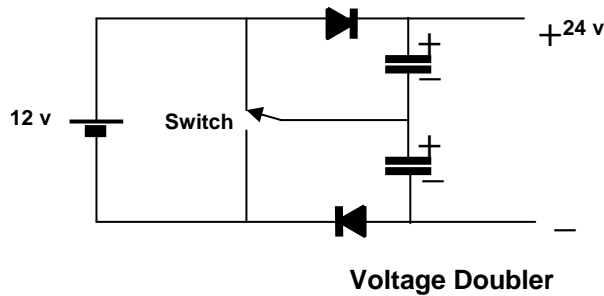
Motor Control Board Circuit Diagram Voltage Regulation Section
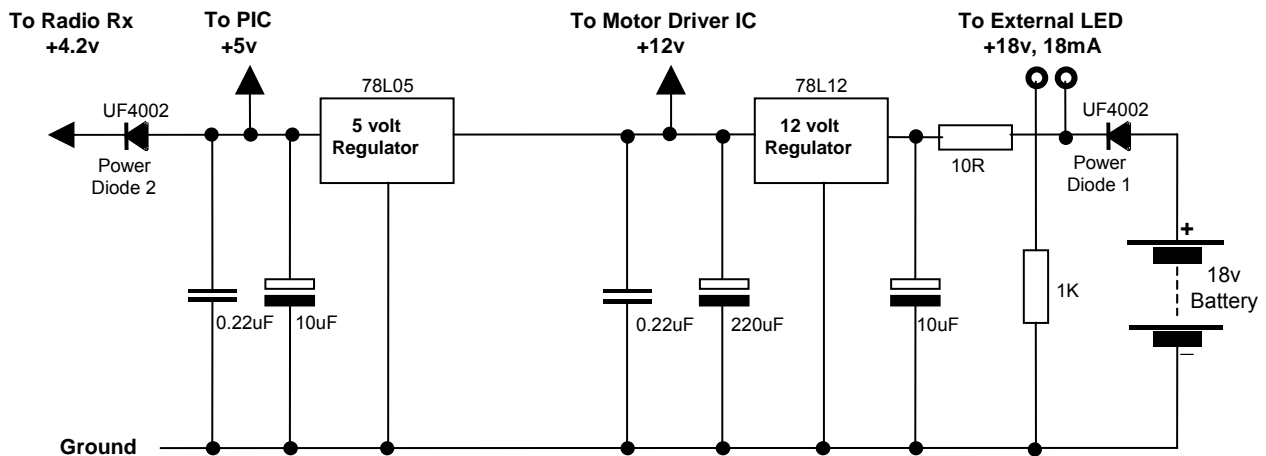
Power diode 1 protects the voltage regulation section against reverse connection of the battery.
In conjunction with the 10uF reservoir capacitor this diode also maintains the voltage at the input of the 12 volt regulator during fluctuations of battery volts caused by pulsing of the drive motors.
At 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.
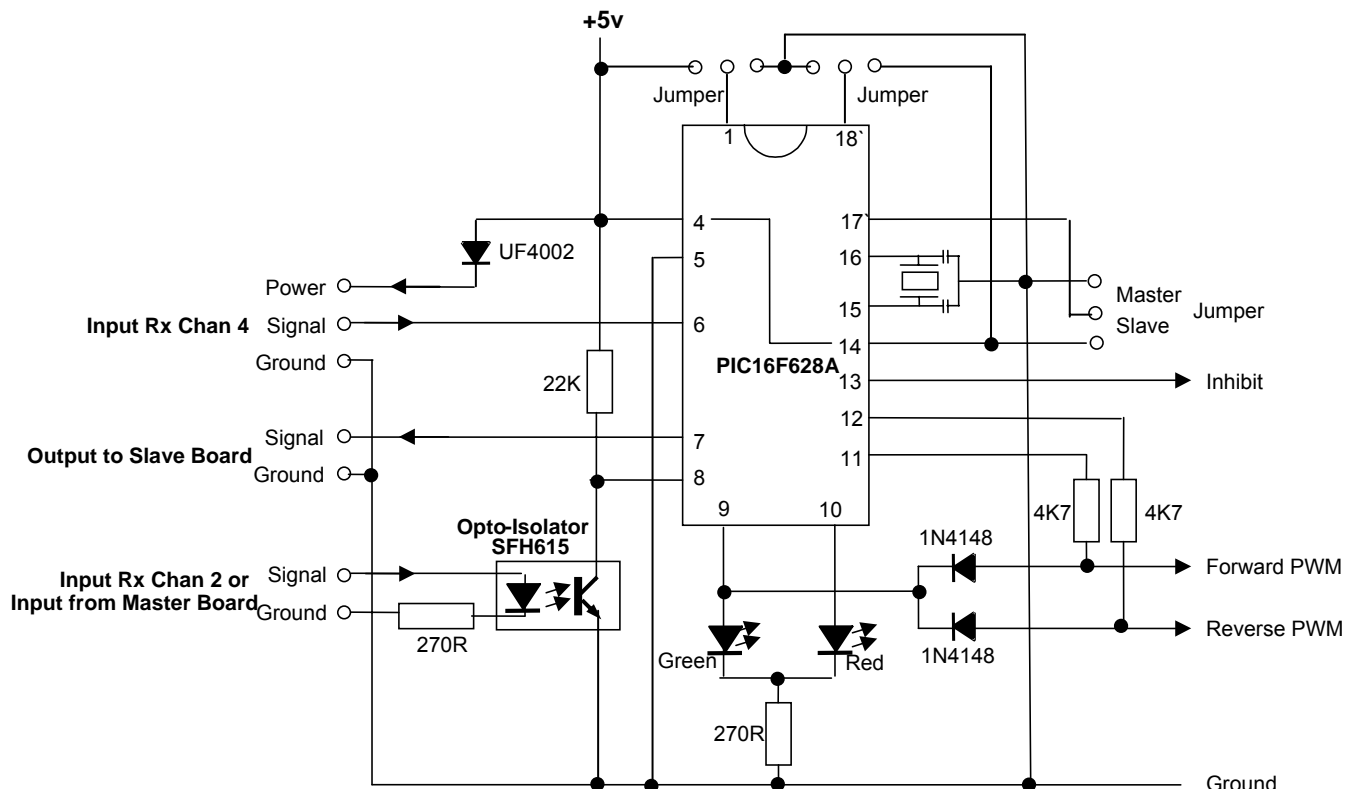A socket is provided for an external high brightness LED to indicate that the robot is powered up and the circuits are live.

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.

Two additional jumpers are provided to allow selection of different control laws.

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.

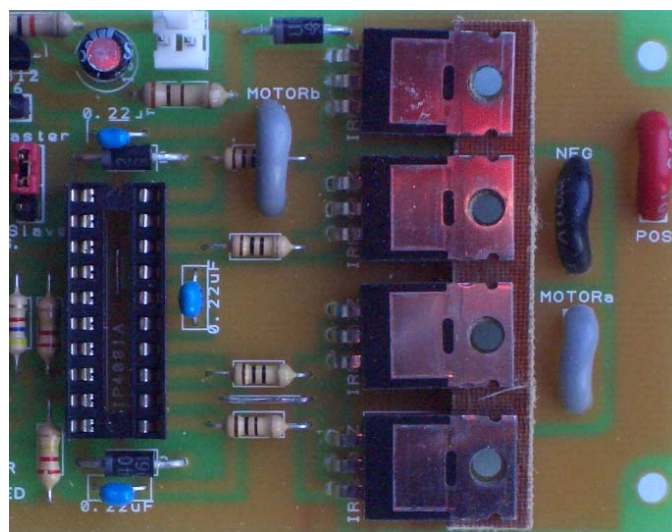The opto-isolator on the Master Board is not strictly required.
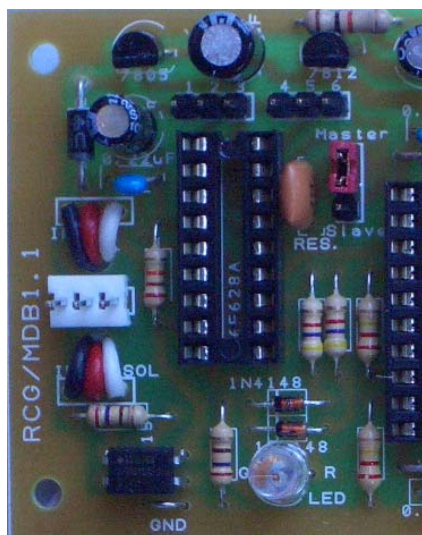
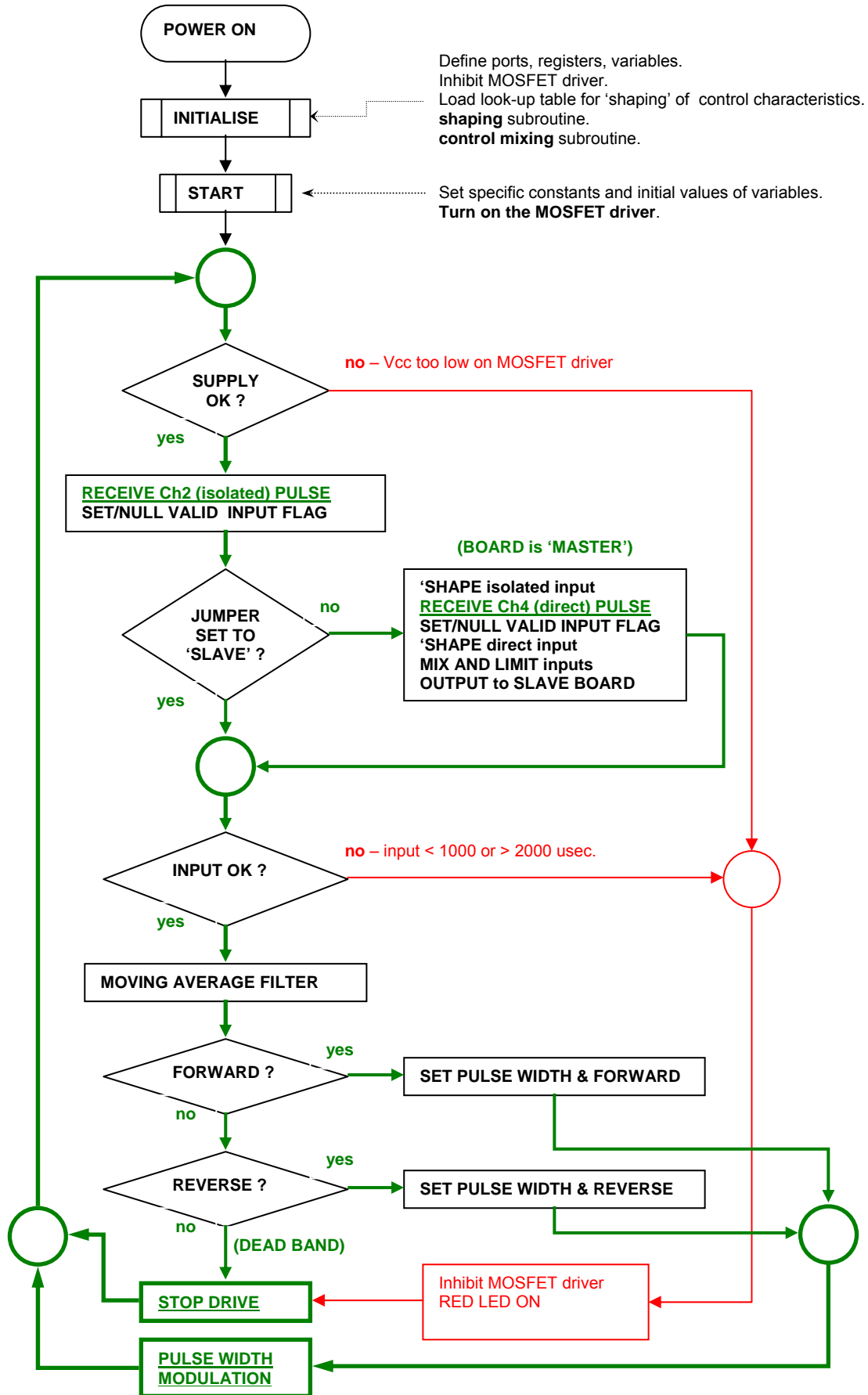# Motor Control Board Circuit Diagram Motor Drive Section
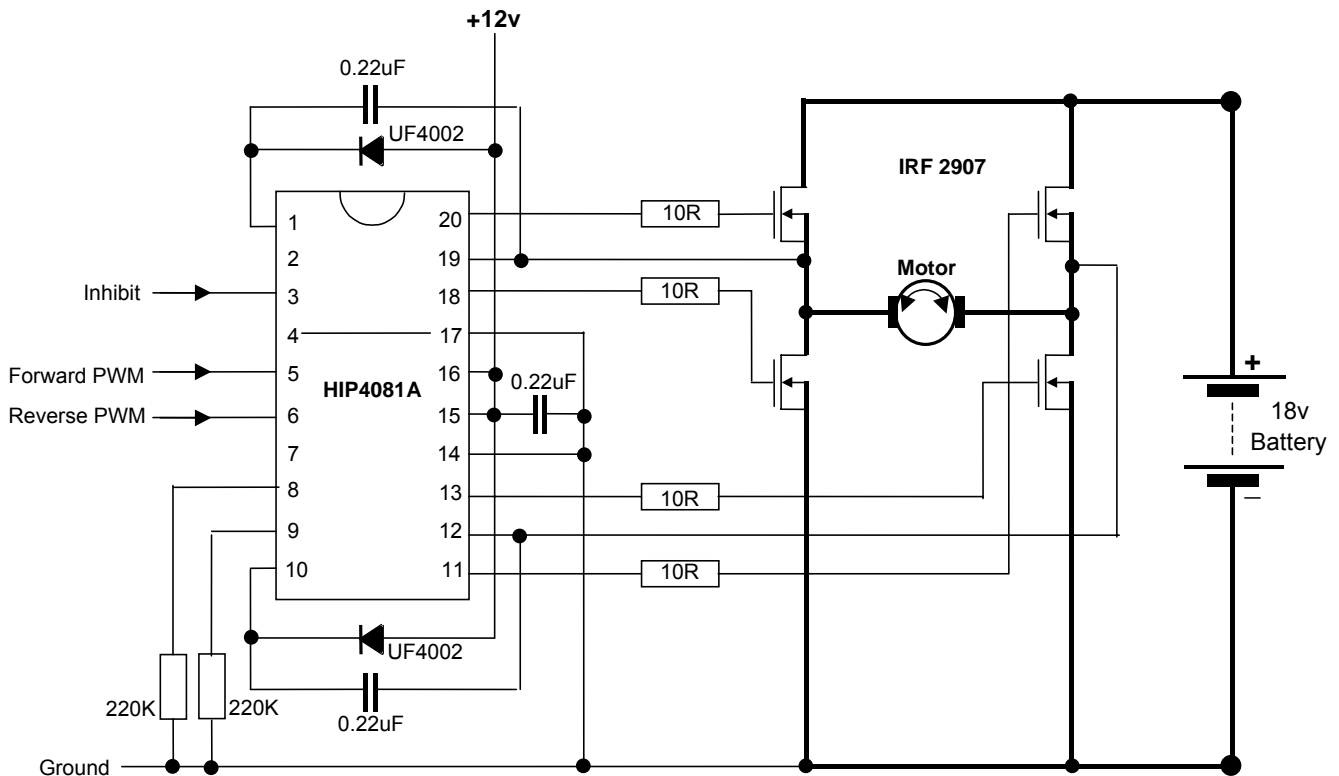
The Motor Control IC switches the MOSFET bridge and prevents 'shoot through' (a direct short between the battery terminals). Either a forward or a reverse PWM signal is received from the PIC and this is translated into appropriate turn-on signals to the four MOSFET Gates. The required high side MOSFET 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 V3.2

POWER ON

Define ports, registers, variables.
Inhibit MOSFET driver.
Load look-up table for 'shaping' of control characteristics.
shaping subroutine.
control mixing subroutine.

INITIALISE

START

Set specific constants and initial values of variables.
Turn on the MOSFET driver.

SUPPLY OK ?

no – Vcc too low on MOSFET driver

yes

**RECEIVE Ch2 (isolated) PULSE
SET/NULL VALID INPUT FLAG**

(BOARD is 'MASTER')

JUMPER SET TO 'SLAVE' ?

no

'SHAPE isolated input
RECEIVE Ch4 (direct) PULSE
SET/NULL VALID INPUT FLAG
'SHAPE direct input
MIX AND LIMIT inputs
OUTPUT to SLAVE BOARD

yes

INPUT OK ?

no – input < 1000 or > 2000 usec.

yes

MOVING AVERAGE FILTER

FORWARD ?

yes

SET PULSE WIDTH & FORWARD

no

REVERSE ?

yes

SET PULSE WIDTH & REVERSE

no

(DEAD BAND)

STOP DRIVE

Inhibit MOSFET driver
RED LED ON

PULSE WIDTH MODULATION

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Appendix B – ATC Risk Assessment Example

Unit: ……………………………………….   Activity / Exercise: Robotic Games

Risk Assessment Number:	GENERIC RA: NO

Relevant Publications / Pamphlets/Procedures: 1 Construction Booklet Chapter 2 - Safety 2 3 The following steps relate to the Risk Assessment Process.	Assessor Date: Review Date	Related RAs (e.g. Manual Handling) 1. Use of Tools 2. Soldering 3. Manual Handling

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 10 MPH.

The robots are controlled by commercial 40 MHz radio links (This band is for ground vehicles). They have fail-safe circuitry incorporated in each channel.

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 in Pits	Robot runaway	Battery connectors are only to be inserted when the robot is off the ground with wheels free to rotate.	Yes		
2	Maintenance in Pits	Internal Fire	Fire extinguisher to be readily available	Yes		
3	Maintenance in Pits	Radio signal failure	Internal failsafe circuitry cause electrical outputs to revert to zero	Yes		

4	Maintenance in pits	Electrical fault	Removing battery connectors isolates all electrics.	Yes		
5	Maintenance in pits	Injury from tools	Maintenance involving the use of sharp tools is only to be undertaken by cadets under the direct supervision of an adult engineer or staff member.	Yes		
6	Maintenance in pits	Electric shock	Robot electrical voltage is approximately 18 volts. Batteries are charged using commercial 18v chargers supplied with the cordless drills.	Yes		
7	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		
8	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		
9	Robot Competition and Practice	Robot runaway, Collision damage 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

CONTROLS	NAME (print)	POST	DATE	SIGNATURE
Existing & Additional Controls Agreed – **Sqn Cdr, Wing, Region**				
Additional Controls Implemented – **Activity Commander**				

Appendix C - Parts List

No	Item
1	Instruction Booklet
2	Rampaging Chariot & Sponsors Logos
1	Packing List
	Radio Control System
1	Skysport 4, 4Ch 40MHz Transmitter
1	40MHz FM Receiver
1	40MHz Tx and Rx Crystals
8	AA Batteries
1	Piano Wire 1.5mm x 3ft (Aerial)
1	Heat Shrink Red 3.2x820mm (Aerial)
NA	MDF 12mm Aerial housing 32x32mm (Chassis Offcut)
	Chassis
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 12x12x182mm(2x90mm)
1	Aluminium Angle Plates 25x25x406mm(4x100mm)
1	Aluminium Angle Centre Plates 25x25x90mm(2x45mm)
2	Cable Ties 5 x 370mm (Battery tie down)
38	Wood GoldScrews CS 3x12mm (Plates)
16	Wood Goldscrews CS 3.5x30mm (Chassis)
4	Bolts C/S M4x20mm (front brackets)
2	Bolts Pan M4x25mm (Wheel Hub)
8	Bolts Pan M3x20mm (Motor Casings)
8	Bolts Pan M3x16mm (PCB)
4	Hex Nuts M4
8	Hex Nuts M3
8	Nylon Spacers Circ 6mm (PCB)
1	Towing Eye 40mm
	Motors and Batteries
2	18v Cordless Electric Drill: (Duratool D00013)
2	18v NiCad Batteries
2	Mains Battery Charger
2	Crimp Connector Male Red
2	Crimp Connector Male Blue
2	Crimp Connector Female Red
2	Crimp Connector Female Blue
1	Velcro Loop (Receiver & Batteries) 20x450mm
1	Velcro Hook (Receiver & Batteries) 20x450mm
	Wheels
4	Rubber Wheels 38x153mm (Machine Mart ML605-1)
2	Aluminium Drive Axles 3/8"x24 UNF (In wheel)
2	Full Thread Coach Bolts M10 x75mm (Axle)
2	Plastic Tubing - Free Wheel Axles 13x33mm.
2	Hex Nuts M10
4	Flat Washers M10
2	Nylon Nuts M10
1	MDF 6mm Drive Wheel Spacer Plate 50x50mm
	Red Safety Lights
2	LED 5mm Ultra Red 3500mcd 30deg 20mA,
2	2 Way 0.1" Pitch MTA Housing 22 AWG Red
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 80mm (4x20)

Bd1	Bd2	Item
		Motor Drive Boards
1	1	PC Board 53x100mm
4	4	FET, IRF 2907
1	1	Full Bridge Driver IC, HIP 4081A
1	1	Controller, PIC 16F628A
1	1	IC socket, 18pin
1	1	IC socket, 20pin
1	1	Opto Isolator SFH 615A-2
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.,
2	2	10uF 50v Elec. 2.5mm lead.sp. 5mm dia
1	1	220uF 16v 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
2	2	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, 8MHz. Ceramic,
1	1	5mm LED Tricolour Red/Green
1	1	2 Way 0.1" Pitch Polarised Str Header (for LEDs)
1	1	3 Way 0.1" Pitch Polarised Str Header (Output)
3	3	3 pin Jumper Plug -Single row Pin Header
2	2	Jumper (one spare)
1	1	Crimp Connector Male Red
1	1	Crimp Connector Male Blue
1	1	Crimp Connector Female Red
1	1	Crimp Connector Female Blue
2	2	Cable tie 2.5mm x 100mm (one spare)
1	1	Aluminium Angle 40x20x53mm long (Heatsink)
1	1	Insulation sheet (50x20mm)(MOSFETS)
1	1	Insulator Whale Sheet 4x10x50mm (MOSFETS)
4	4	Insulation bushes TO220
4	4	Bolts Pan Head M2.5 x 12mm
4	4	Hex Nuts M2.5
1	1	Wire, Black 30core 18A 1.0 x 250mm
1	1	Wire, Red 30core 18A 1.0 x 250mm
2	2	Wire, Grey 30core 18A 1.0 x 150mm
2	2	Futaba servo leads and connector 200mm
	1	Futaba servo lead extension 300mm
		Test Equipment
	1	Small Motor 3v 340mA
	1	Halogen Capsule Bulb 12v 20W
	1	Double Screw connector 3A (spare)
	1	6R8 Wirewound Resistor 10W
	1	47R Large Resistor 3 watt
	1	Wire, Red 30core 18A 1.0 x 80mm
	1	Red Flex 1.6 dia 16/0.2 80mm
	2	Crimp Connector Male Red
	1	Crimp Connector Male Blue
	1	Crimp Connector Female Red
	1	Heat Shrink Red 2.4mm x 20mm

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Appendix D – Parts Manufactured or Modified by 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.

Thread 3/8 x 24 UNF Min length 15

8.5   5.5   9   13.3

18   3   12
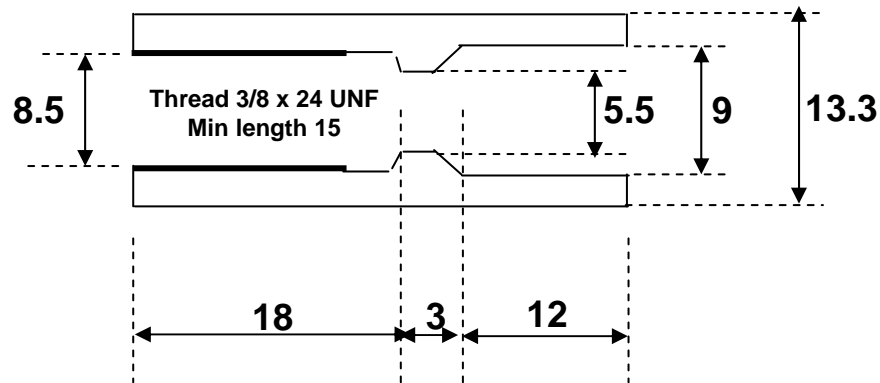
Section Through Aluminium Wheel Axle

Heat Sink, Insulation Sheet and Spacer

The heat sink is cut to fit the width of the PCB. Holes are 3.5mm diameter

The insulation sheet is heat resistant with good thermal conductivity. The holes are punched at the positions shown for the black plastic top hat insulators to poke through.

The Insulation Strip/spacer is cut the width of the PCB. Holes are 3.5mm diameter.
Note: The insulating strip could be manufactured from three pieces of Veroboard glued together.

Heat Sink   **Insulation Sheet**   **Insulated Spacer**
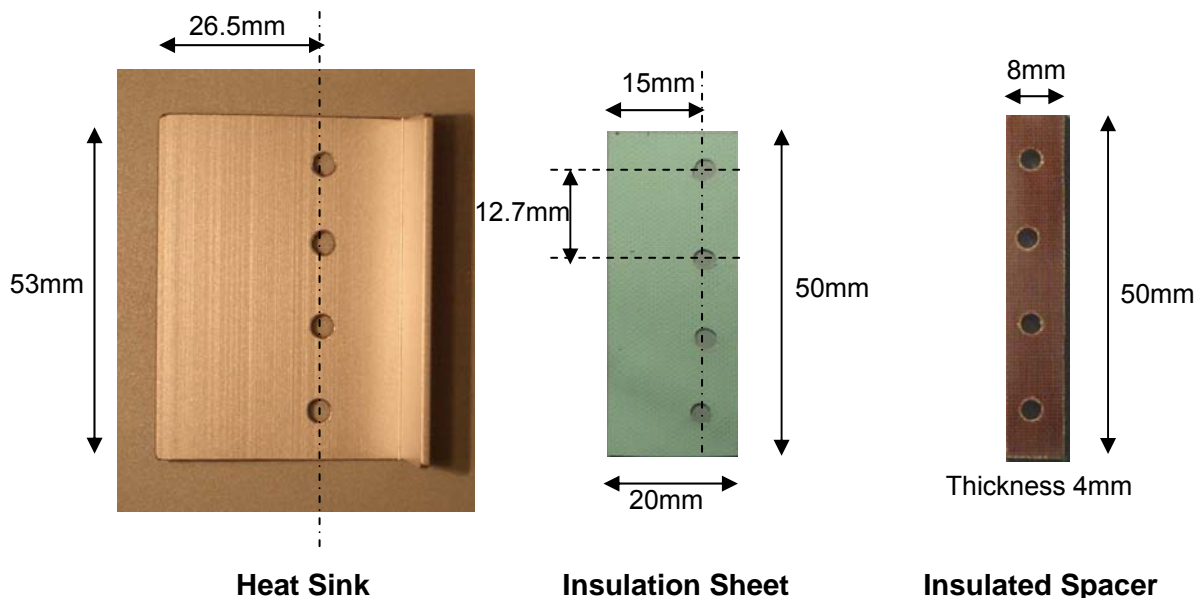
Build 8 – Constructing The Motor Controllers (Duplicate tear-out sheet)

Identifying Components
Identify all your components and lay them out over the diagrams to ensure you have them all.

Wire Links
(Cut from resistors)
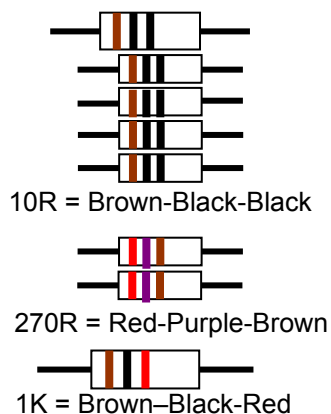
Resistors

Resistance Colour Code
0 = Black
1 = Brown
2 = Red
3 = Orange
4 = Yellow
6 = Green
6 = Blue
7 = Purple
8 = Grey
9 = White
Band 1 = First Digit
Band 2 = Second Digit
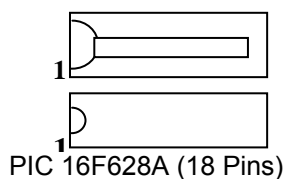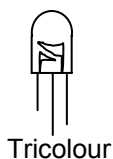Band 3 = No of following zeros
Separate Gold Band =
5% Tolerance

10R = Brown-Black-Black

270R = Red-Purple-Brown

1K = Brown–Black-Red

4K7 = Yellow-Purple-Red

22K = Red-Red-Orange

220K = Red-Red-Yellow

Diodes

UF4002

1N4148

IC Sockets

1

1

ICs

1

PIC 16F628A (18 Pins)

1

HIP 4081A (20 Pins)

1

SHF615 (4 Pins)

LEDs

Tricolour
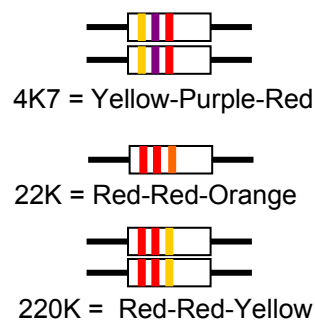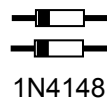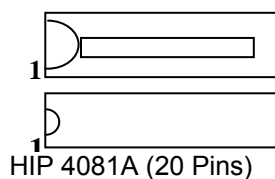
Voltage Regulators

12 volts

5 volts

78L12

78L05

Resonator

Capacitors

| 224 | 224 | 224 | 224 |

Ceramic 0.22uF

Electrolytic 10uF

Electrolytic 220uF

MOSFET

IRF 2907

Radio Control Leads

LED Plug

Output Plug

Jumper Plugs

Jumper
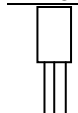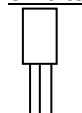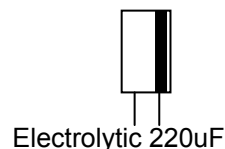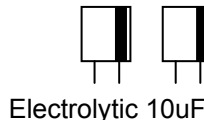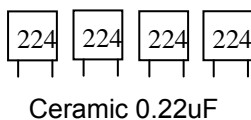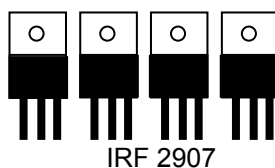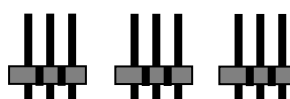
Notes

Appendix E - Rampaging Chariots Robotic Games 2006 Arena

Football Arena

Arena Walls
220mm High

Goal
1m wide

Goal
1m wide

Plywood Base
Mat Paint

5m

5m
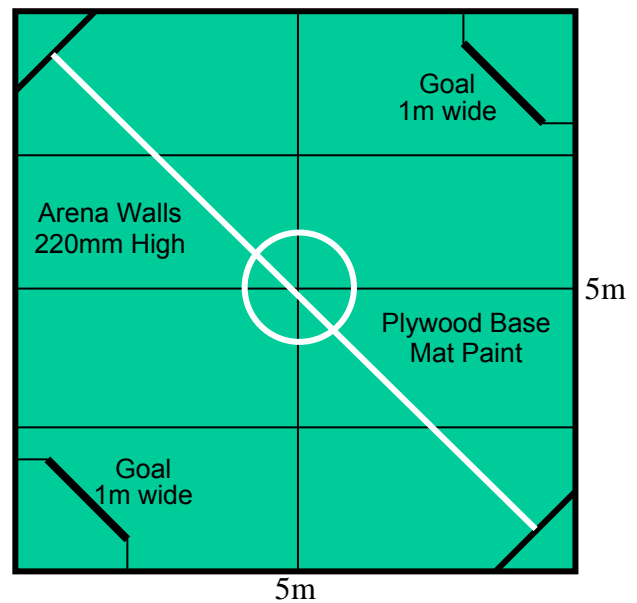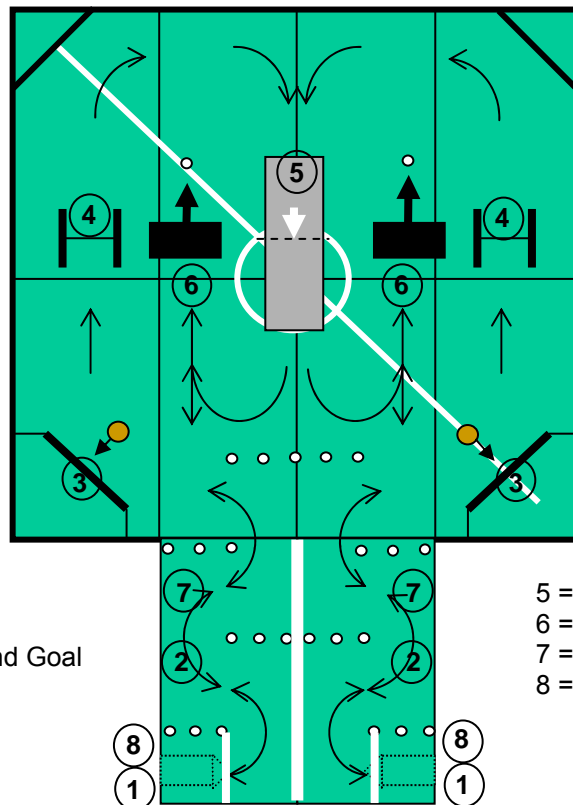
Sumo table is 6ft (1829mm) diameter and placed in centre of arena
Tug of War is conducted across centre of arena

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

If you are having difficulties please contact the team at: 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.

Our web site   www.rampagingchariots.org.uk   includes a frequently asked questions section.

Rampaging Chariot Spare Parts and Kits

You will find a list of spare parts in this booklet.
Additional kits of parts for the electronic motor controller boards are available @ £20 each plus p&p.
Additional full kits of Rampaging Chariot parts are available whilst stocks last @ £100 each plus p&p.

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.
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 Chariots Robotic Games

The full rules of the Rampaging Chariots Robotic Games are available on our website:
www.rampagingchariots.org.uk
This site also includes pictures and video clips of the 2007 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.

We are very grateful to the Scottish Prison Service for their help in the manufacture and packing of components for Rampaging Chariot kits.

Version 3.0 January 2008