Russell's Slot Cars

CHASSIS DESIGN AND MOTORS

Technically, modern mass produced ready-to-run slot cars are hardly inspiring and poor chassis handling, due mainly to a lack of quality control and precision (with the notable exception of cars produced by NSR, Slot.it and TSRF). Unfortunately, the simple addition of traction magnets by the manufacturers hides most of these faults; remove the magnets and you will find that in most cases you have a badly handling car that is difficult to control. The motors used in these cars are not particularly powerful either, so the difference in handling between a sidewinder and an inline configured ‘ready-to-run’ (r-t-r) production car is hardly noticeable. Personally, I prefer to scratch-build my own chassis.

The Chassis

In a 1/32 scale non “magnet-traction” car, the chassis is undoubtedly the most important part.

A glance at the modern sports car chassis shows that the motor is fitted across the car but at a slight angle to the back axle. The reason for crossways fitting is mainly the gyroscopic action of the armature when the car is cornering; the gyroscopic force concerned is precession, which is the reaction of a rotating mass at 90 degrees to the force applied. With the traditional in-line design chassis, precession causes a weight transfer from one end of the car to the other, producing a tendency to de-slot when turning one way and excessive tail-slide turning the other.

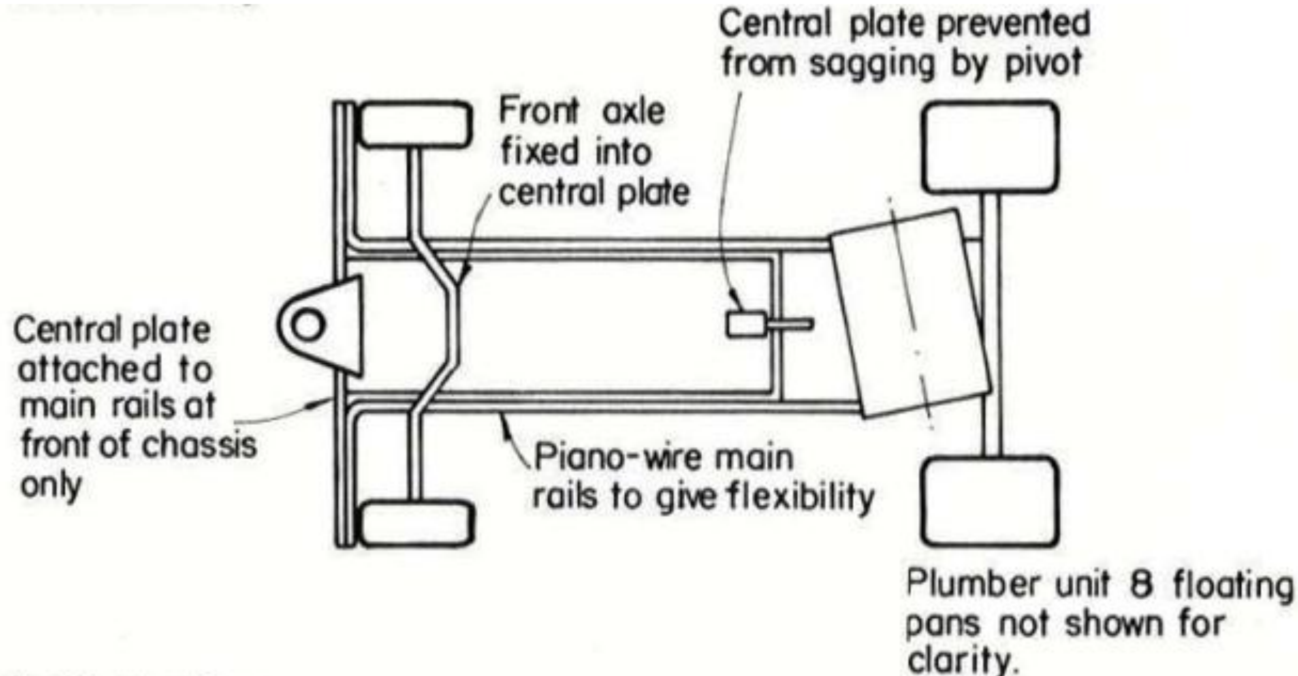
With the motor across the car, the weight transfer is also across the car and with the armature turning in the opposite direction to the wheels (due to the gears), the weight transfer is always toward the inside of the corner, which helps to keep the car stable and reduces tendency to tip.

In order to use reasonable diameter rear wheels, the motor is set at a slight angle to allow space for the brush gear. The 'anglewinder,' as it is known, represents the best compromise between the conflicting requirements of theory and practicality.

Forward of the motor the chassis may be constructed along several different approaches. In general, these are piano-wire rails, several wire and tube hinges and wide brass pans. All this metal is as low as possible and the ground clearance will also be set as low as possible. Some clubs restrict ground clearance to 1/16 inch minimum, but at others the front of the chassis in particular is dropped to be only a few thousandths clear of the track, in the constant search for greater stability and hence higher cornering speeds.

Detailed descriptions of different types of chassis can be confusing, especially as there is no proven best design and, indeed, many of the most successful racers find it difficult to analyze why a particular car is fast. The main approach today is a “flexi-iso” or “flexi-board” chassis.

The "flexi-board" design, pioneered by Ian Fisher in the late '70s or early '80s, is a good all-round design which works well on most tracks.



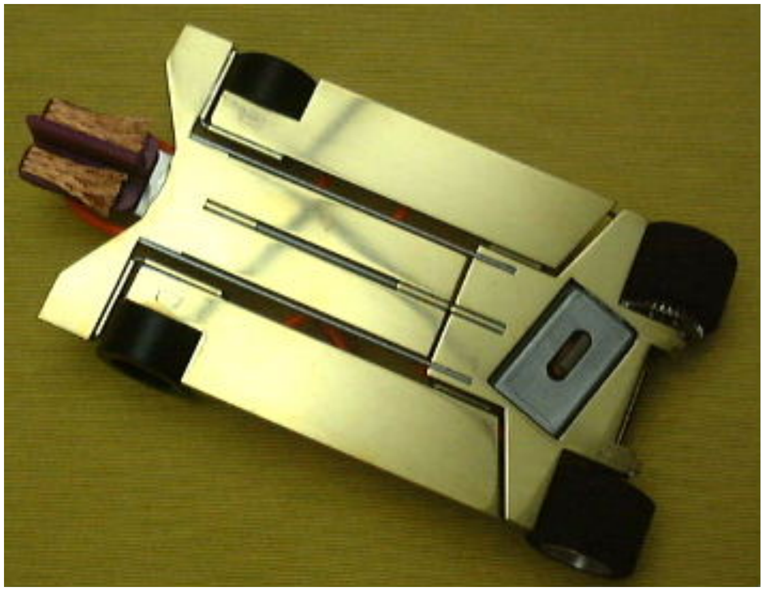
Basic flexi-board frame.

When entering a corner at speed, due to its momentum, a slot car tends to want to go straight. If the chassis is too stiff, it will react stiffly and resist the change in direction. Flex 'dampens' this to a degree, as well as enabling the chassis to generate more traction.

The "flexi-board" allows the front and back ends of the chassis to flex or twist independently by means of the central longitudinal pivot, called the "flexi hinge". This effectively absorbs some of the cornering forces, while the side rails dampen longitudinal twisting, helping to keep the guide blade vertical without being affected by what's happening at the rear, since the front end of the chassis remains relatively fixed.

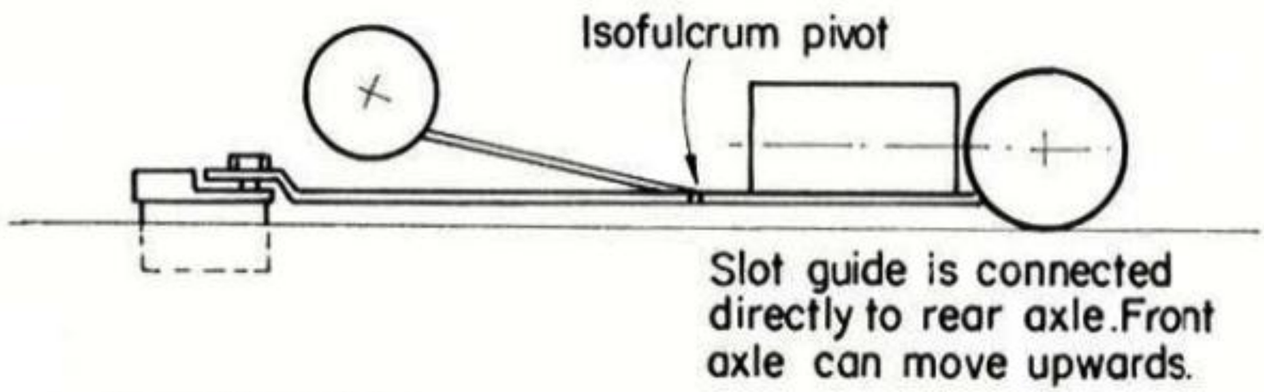
The side rails contribute to the torsional stiffness of the chassis, controlling the degree to which the rear end can twist. Too much traction or 'grip' causes the car to want to tip over when cornering and adjusting the stiffness or degree of flex can be achieved by experimenting with different thicknesses of side rails. I've found 18 gauge piano wire works well.

The side rails, or "torsion bars", do not contribute much to the beam stiffness of the chassis - in fact if you press down in the middle of the central spine, it doesn’t take much force to make it touch the track. To overcome this to some degree, I extend the central "spine" all the way to the front, as pictured below:-



This set up is most effective if the chassis has a degree of "plumber" movement. The more 'weight' or force on the guide under braking and during cornering, the harder it is for the guide to come out of the slot. "Plumber" movement allows the transfer of weight to the front of the chassis under braking, by allowing the rear of the pans and body to lift slightly. This is achieved through upwards hinging, to assist the weight transfer.

The "plumber" effect is best illustrated by the way that dragsters lift their front wheels off the ground when accelerating; the opposite torque effect - when decelerating - is not so obvious but it is there in a big way. The "flexi-iso" design is particularly good at transferring these forces.



Basic isofulcrum design

Some people prefer to set up their chassis as a "tripod". With a "tripod" set up, the front wheels are slightly clear of the track surface, so as not to cause drag on the straights, and the full weight of the chassis is supported by the guide/braids in the front and the tyres at the rear. The front wheels should however rotate independently and freely, as weight transfer will cause them to touch in the corners, acting as outriggers.

Some chassis are designed so that the side-pans have a small amount of additional sliding motion, allowing the body to move forwards and backwards in relation to the centre section, guide and rear wheels. This also has the effect, under braking, of transferring weight to the front and, under acceleration, towards the back, aiding traction.

Side or "bat pans" are hinged to aid the weight transfer (lifting) of the body from one side of the chassis to the other, caused by cornering forces. If weight is transferred to the outside tyre, it will provide more traction, reducing excessive sliding to the outside of the corner.

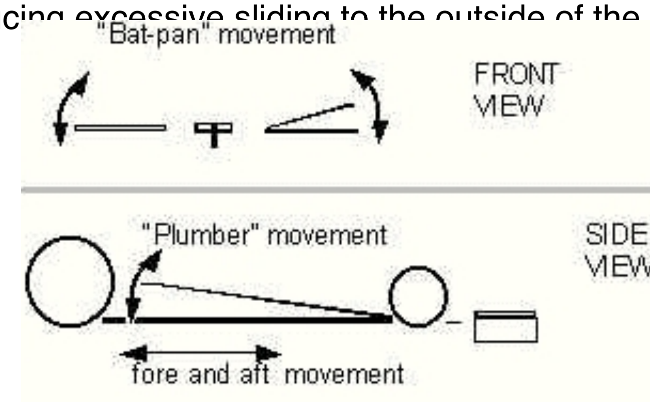


Image courtesy of Chris Frost

The relative movement of the various sections is always very restricted. The effect is to provide a degree of controlled isolation of the guide, motor/rear axle and body.

Modern Eurosport chassis are of course laser or EDM cut spring steel, which does away with the need for piano wire and hinges to achieve dampening or flex. Current Eurosport designs are designed so that the motor-box/rear axle unit is free to move slightly from side to side. With this arrangement, often called "rear-end steering", the rear of the chassis and body is allowed to move out slightly, being pulled back into line as the car straightens up when accelerating out of the corner.

With brass and wire chassis, the gauge or thickness of the piano-wire I use for the main rails depends on how flexible or how stiff I want the chassis to be, which in turn depends on a combination of factors. It's really all about getting the power down so that the car can be driven close to the limit in a manageable way; i.e. having the "right" amount of grip or traction.

The combination of motor and tyres (often predetermined by the rules), the length of the chassis -- the critical measurement being from the centreline of the rear axle to the centre of the guide swivel -- and the intended weight of the car, plus of course the track design, are all factors to consider.

I generally use two single pieces of 16 gauge wire (0.047") for chassis in classes that require "hard" bodies, such as injection-moulded plastic or resin bodies, and where no hinges are permitted. I've found that slightly stiff chassis work best when there is a high mass, such as with a "hard" body. Of course, how far apart the rails are spaced also affects the amount of flex.

My preferred wire and brass design -- i.e. the design that I've found works on most tracks, not necessarily the best design for the track -- is the basic 25 year old "flexi-iso" chassis, which dates back to the late 70s or early 80s and was pioneered by North London's Ian Fisher, such as the one pictured below. I generally use 18 gauge wire (0.040") for the outer rails and 16 gauge wire for the central pivot.

I must again stress that detailed descriptions of different types of chassis can be confusing, especially as there is no proven best design and, indeed, most people, myself included, find it difficult to analyse why a particular car is fast!

MOTORS

Assuming that everything else is equal (armature, timing, magnets, etc.), spending some time fiddling with spring tension is the one area where tremendous gains can be achieved in motor performance.

The first step is to ensure that the brush hoods are properly aligned. The face of the brush should sit perfectly on the centre of the commutator (aligned with the armature shaft) or you will get uneven brush wear. Any variation in the alignment will affect the timing of the armature. Use a brush alignment tool to do this, such as Slick-7's Brush and Bushing Alignment Tool (ref. S7163).

For 1/32nd scale low power racing, I use Camen light tension double overhead springs (ref. #1620.20). Insulate both ends of the spring using Pro Slot Teflon Spring Insulation (ref. PS-611). This will ensure that the heat from the brush hoods and endbell plates is not transferred to the springs. The cooler you can keep the springs, the more consistent the tension.

Onto the brushes. I always use Pro Slot PS-900 Goldust Pro Motor Brushes and consider them the best available. Polish all four sides of the brush by rubbing it against a Crocus cloth or just use a piece of paper placed on a flat surface and lightly rub the brush surfaces up and down it. This will ensure that the brushes slide smoothly inside the brush holders. Make sure that the brushes don't wobble in the brush holders, though. If you use a break-in tool on the face of the brush, make sure that it isn't too rough. I don't use one as I feel it puts too rough a finish on the face. If you do use one, Pro Slot makes a very nice Diamond Brush Radius Tool (ref PS-654) which has an anodized knurled knob for easy use.

The next thing to do is to widen the slot in the brush where the short leg of the spring sits, so that you can use shunt wire. Shunt wire helps to transfer the electrical current to the brushes directly. If you don’t use the proper tool for this it can be tricky and you may end up with lots of broken brushes. The width of the slot should be able to accommodate the shunt wire and the insulted spring in such a way that the spring seats properly. Use a small round jeweller's diamond file or better yet, a special brush slotting tool like the one made by Magnehone. I use Pro Slot PS-613 Silver Shunt Wire. The silver content assures good contact and conductivity.

Before installing the brushes, clean them off with contact cleaner. Any electrical contact cleaner will do. Slip the first brush into its hood, attach its spring and check that there is no binding and that the insulator on the short leg clears the brush hood. Now, attach the shunt wire. I bend a 'U' in the end of a length of shunt wire. Place the short end of this 'U' into the brush spring slot and latch the spring down onto it, making sure to get all the strand ends tucked neatly under the spring insulator. The shunt, like the insulator, should cover the entire length of the brush slot for maximum contact but not interfere with the brush hood. Now route the shunt to the buss bar; using as little wire as possible but leaving enough slack for the brush to move during wear, also allowing clearance for spring removal and making all this look as neat as possible. Solder the buss bar end of the shunt in place. Do not use too much solder as it will flow into the shunt and restrict movement. Repeat this process for the other brush.

Bend the springs to 90 degrees, by placing a tight fitting tube through the coils and with your thumb against the short leg of the spring, lightly squeezing the long leg with your forefinger. Never adjust the angle of the short leg as this is set to correctly seat in the slot of the brush. Now you need to bed in the brushes. Install the springs and fit lead-wires, lightly oil the bearings and place the motor in a glass of water. Slowly increase the power of the power supply to about 5-volts with the motor running under water. Let the motor run for about minute. The water will discolour from the carbon of the brushes. Remove and blow dry the motor. Don't forget to re-oil the bearings.

Now onto adjusting the spring tension. You really can't do this without a decent power supply which has a volt and ammeter. I use a Slick-7 Motor Analyser, but Camen, Koford, BSP and Wrightway all make good power supplies. They are a good investment and you need one anyway for your tyre-truer. Run the motor at 3 to 5 volts for about twenty minutes. When you see uniform arcing under the trailing edge of the brushes it will indicate they are fully seated. You will notice that the amp draw will initially be high, then gradually come down as the brushes become fully seated and stabilize in the range of 1.5 to 2.5 amps.

Bear in mind that the brushes generate friction against the commutator. Logically, less friction should mean greater performance. This is true to a point but just the opposite can happen. Too little spring tension can increase arcing, which generates heat and heat reduces spring tension. A certain amount of spring tension must therefore be maintained to provide the optimum conductivity between the brush and the commutator. Since heat will reduce spring tension, you need to actually load the spring with a little more tension than actually needed, since we're setting the tension while the motor is cold.

One of the best tools you can use for measuring spring tension is a Fiddlestick, made by Sonic. It will allow you to take spring tension readings. Without these readings you will only be guessing. Experimentation is the only way to find the right tension. Reduce the tension until the motor starts getting hot, then raise it back up. Camen light springs usually have a little too much tension. I try to get my motors to run at around an amp to an amp and a half at 7 volts for low power tracks. But as mentioned, it's a matter of experimentation.

Now install the motor in the chassis with gears and wheels. Check for drag or binds. The amp draw with the car ready to run should not be more than .5 amps higher than with no load. More than that and you need to check for binding by checking the axle and bearing alignment and getting the gear mesh perfect.

Generic designations based on Mabuchi designations:
FC-130 is the standard slot car motor, sometimes called Mabuchi or S type.
FK-130 is the Fox or TSRF type.
FK-180 is the Boxer or long can type.
FF-050 is the slim, long can F1 type.
FF-030 is the slim, short can F1 type.
SH-030 is the small open frame box type used mainly in HO.

General armature specifications:

Euro motors
Pro Slot Puppy Dog – 75t, 31 ga
JK Hawk 6 - 72t, 30 ga, 20 deg, .390-.400", .513" dia., small comm
Raptor - 65t, 30 ga, 25 deg, .390-.400", .513" dia., large comm, tie wrap, tagged
Koford M646 – 75t, 31 ga

16D
16-D 70 turns of 30 AWG 0.600" long, 0.513" diameter stack
S-16-D 60 turns of 28 AWG 0.490" long, 0.520" diameter stack
S-16-D Outlaw 60 turns of 28 AWG 0.490" long, 0.520" diameter stack

C-Can Super 16C 55 turns of 28 AWG 0.490" long, 0.513" diameter stack

Group 12
Group 12 50 turns of 29 AWG 0.350" long, 0.513" diameter stack

X-12 50 turns of 29 AWG 0.350" stack
Outlaw G12 50 turns of 29 AWG 0.350” long, 0.500” diameter stack

Group 27: 38 turns of 27 ga .440" stack
Group 20: 38 turns of 27 ga .440" stack

FK-130 size motors:
JK Falcon V: 75 turns of 31 ga. 5* timing
Plafit Cheetah/TSRF: 95 turns of 31 ga.
Plafit Fox: 130 turns of 33 ga.

FC-130 size motors:
Rabbit, Carrera: 150 turns of 35 ga.
Fly, Scalextric: 180 turns of 38 ga.

MOTORS: Armature Balancing

The process of reducing the out-of-balance forces that cause vibration in rotating machinery is called balancing. The reason for balancing an armature is to reduce excessive vibration, because vibration causes inefficiency. The unbalance is caused by the displacement of the armature's mass centre-line from its true axis, usually due to some mass eccentricity in the windings.

The process of balancing is the removal (or addition, rarely done these days) of weight to the armature, so that the effective mass centre-line approaches the true axis, i.e. the armature shaft.

The simplest form of balancing is static balancing, i.e. placing the armature on low friction bearings (such as done with razor blades back in the '60s) and allowing it to rotate and settle with the heaviest point falling to the bottom. Material is then removed from this point (or added at the top point) and the armature is gently rotated again until, when stopping, the new heavy point again falls to the bottom. This process is then repeated until no obvious heavy point exists.

Nowadays balancing is done using purpose-built dynamic balancing machines. The bearings that the armature shaft runs in are connected to sensors that detect the heavy point while the armature is being rotated.

Dynamic balancing is relatively cheap. I get my armatures balanced by Missile Products in the UK. For £4.75 you get the comm ultrasonically cleaned and diamond trued and the armature balanced.

MOTORS: Magnets

Most, if not all, magnets used in motors suitable for slot cars are of the sintered ferrite, or ceramic - whichever you prefer - type. In the 1960's, cast Alnico magnets were mostly used. Cast magnets are manufactured by pouring a molten metal alloy into a mold and then further processing it through various heat-treat cycles. The resulting magnet has a dark gray exterior appearance. Sintered magnets are manufactured by compacting fine Alnico powder in a press, and then sintering the compacted powder into a solid magnet. Ferrite magnets are sintered permanent magnets, composed of Barium or Strontium Ferrite. This class of magnets, aside from good resistance to demagnetisation, has the advantage of low cost.

The very powerful "rare earth" or “Cobalt” types of magnets, as used in Eurosport “strap” motors, are a hybrid of casting and sintering but because of the many special steps involved in manufacturing they tend to be somewhat expensive. As with everything, you pay for performance!

Magnets are easily demagnetised if not handled with care. Special care should be taken to ensure that the magnets are not subjected to adverse repelling fields, since this could partially demagnetise the magnets. Magnetised magnets should be stored in such a way as to reduce the possibility of partial demagnetisation.

Also, bear in mind that magnetic flux density (field strength) is affected by many external forces. Heat is not as serious as one might expect. Typically, a ferrite magnet will lose 3-5% of its strength by being elevated from room temperature to 100 decrees Celsius, the boiling point of water. When it cools, the strength returns to very near normal, so this is a reversible effect. There is a point where a magnet will lose all of its strength, never to return until re-magnetised. This is called the "Curie temperature." For a ferrite magnet, this is somewhere around 450 degrees C, about 850 degrees Fahrenheit. Cobalt curies at about 800 degrees C.

The silent killer of magnets is called "contact demagnetisation." Every time you allow a magnet to stick to something, the magnet loses energy! The effect is not as serious
on the poles as it is on the sides or ends. The worst possible way to package magnets is in a poly bag, stapled to a card where they are allowed to contact everything and stick together. Even sliding the magnets in the can will lose some flux density. By removing the armature, the flux path will be partially opened and the magnets will be weakened to a degree. Impact has an effect on the flux strength, but it really isn't significant.

If magnets are partially demagnetised, they may be easily re-magnetised, or “zapped”.

Can the magnetic strength be increased through “zapping”? With, for example, Mabuchi motor magnets, it is more an issue of "saturation". I have found that the magnets are
mostly pretty much saturated, anyway. I've tried "zapping" them but there was no marked difference. When a magnet is saturated, it contains all of the magnetic field it can hold and will be as strong as it can and ever will be.