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1. preliminary research design considerations

1.1. Type of car

There are different types of RC-cars with each type having different use cases. As seen in the table below, there are different types listed with their intended purposes and the terrain they can be used on.

Table 1: Types of Nitro RC-cars

Type	Best Use	Speed	Terrain
Buggies	Racing	High	Mixed
Trucks	Off-road	Medium	Rough
Truggies	Versatile	High	Mixed
On-road	Paved	Very High	Roads
Monster	Climbing	Medium	Trails

The use of the car is mainly for entertainment purposes, nothing special further. That means that the monster-, truck- and buggy types already drop out. Between the truggies and on-road types is the truggies the most versatile car, so that will be the type of car that will be designed.

Another thing to consider is the scale of the car. There are different kinds of scales like a 1/5, 1/8, 10 but also smaller sizes like 1/16 or 1/24, the most common scale is 1/10. Because of the versatile parts that come with the 1/10, will that be also the choice for the dimensional design guidelines for the length/width/height

1.2. The Chassis

The design of the chassis is a bit harder and takes a bit more to get right. That's because the chassis consists of multiple areas that need to be defined properly. Some of those points are Toe-in or toe-out, Setup positive of negative camber, The ackermann-principle, the wheel axle, the scrub radius and the King Pin Inclination (KPI).

1.2.1. Toe-in or toe-out

If the car is viewed from above, the toe is the way the wheels face to. By that definition, Toe-out is if the wheels face outwards and toe-in is if the wheels face inwards. The tires will in general heat up more and can degrade because of wear and tear, that is because the tires are constantly slipping. If a toe-in setup is used, there will be more wear seen on the outside of the tires and for a toe-out setup, the inner side of the tire will have more wear.

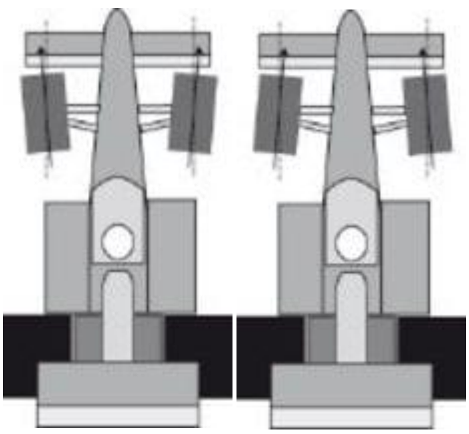


Figure 1: Left is toe-out, right is toe-in

Some pros of the toe-out on the front wheel is that it improves turn-in response (it will become easier to turn) and helps to reduce understeer but also increases oversteer. It's common in lower speeds and frequent changes in direction. The downside is that it will also create instability in the steering at high speed, because the steering wheel tries to change direction without any input. Toe-in on the other hand creates more stability but will be more prone to understeer.

It's also possible to give the rear wheels a toe-in or toe-out. If the car has a front-wheel drive, it tends to have more understeer. To resolve the problem, the rear wheels can be adjusted to a toe-out setup but not by too much. Otherwise (the same with the front wheels) the car will be less stable and is more difficult to drive. It's the other way around with a rear wheel drive, the car tends to have more oversteer. Therefore, a car with a RWD will have more toe-in to provide for more stability in a straight line and especially in corners.

It's always good to have a way of adjusting the toe, even when the car is finished building. It should be noted that in the design phase, it's recommended to design an option that will adjust the toe.

1.2.2. Positive or negative camber

When it comes to the camber, it must be noted that there is a negative, neutral and a positive camber, both with its pros and cons.

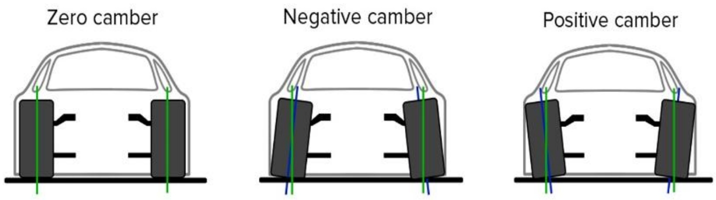


Figure 2: Camber as seen from the front of the car

First, the camber is viewed from the front of the car and is the angle between the plane of the wheel and the vertical axis as seen in Figure 2. When talked about negative camber, the tires are tilted inwards (towards the chassis). Positive camber is the opposite, tilted outwards with the top facing away from the chassis. With zero- or neutral camber, the tires are aligned with vertical axis.

The camber effects the handling characteristics of a suspension system. In general, when a car turns, the centrifugal force will move the car outwards. With negative camber the outer tire will have full contact with the road and the same goes with the inside tires with positive camber.

Some pro's and con's of the different cambers are:

	Pro's	**Con's**	**Use cases**
Neutral or Zero camber	• The tires have full contact with the ground without cornering. • More grip for accelerating and stability	• Reduces stable cornering, because of the lateral creating less contact with the road surface	• Road cars, drag racing, off-roading
Negative camber	• Improves handling when cornering because of the lateral force moving the top of the tire outwards. Which creates more contact grip on the road	• Reduces contact grip on straight lines	• cars with high-speed cornering like f1, indy-cars
Positive camber	• With a high load, the tire will move to a neutral camber for more grip	• Reduces grip because of the lower contact patch with the ground • Barely any contact with the ground when corenering	• Heavy load vehicles like trucks or a few forms of motorsports

1.2.3. King Pin Inclination (KPI)

For wheels to steer from left to right, there needs to be an axis to rotate about. The axis where the wheel rotate around is called the king pin. The name is derived from the heavy steel pin used on agricultural vehicles but is still used today even when no actual 'pin' is used.

The kingpin inclination has two uses, one is the self-centering of the wheels, and the other is for the scrub radius.

Self-centering works as follows: When the wheels are turned left and right around the inclined axis, the tires tend to turn downwards. Because the wheels can't go in the ground, the car instead is pushed up. So, when the tires are turned to either left or right and the steering wheel is let loose, the car goes down and the tires will go to their "highest" point which is straight ahead (if it's aligned properly).

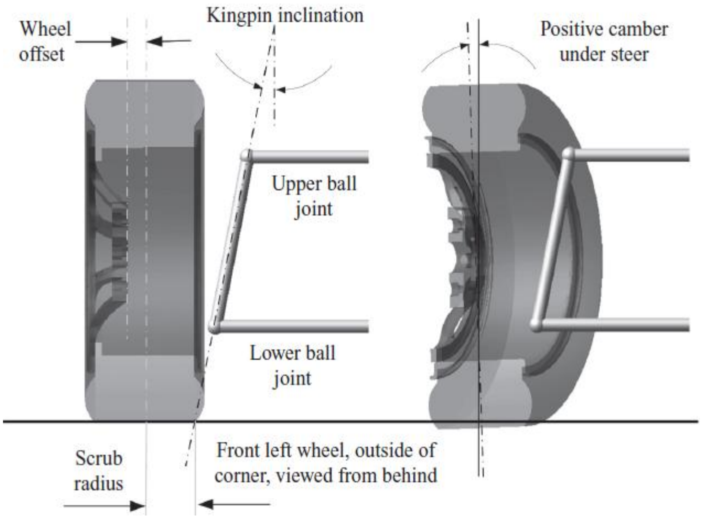


Figure 3: Kingpin inclination

The scrub radius is simply the distance between the center of the wheel and the virtual line where the kingpin intersects with the ground. It affects the tire wear the steering response and the stability while breaking. With a negative scrub radius, the intersection is outboard of the tire center. That reduces the lever arm, providing better stability under braking but often requiring more steering input, especially at low speeds. With a positive scrub radius, the steering axis intersection is inboard of the tire center. This creates a larger turning radius, which can make steering feel heavy and less precise.

1.2.4. Caster

The caster is viewed from the side of the car and is the angle of the steering axis. There are three forms of casters: a negative-, neutral- and a positive caster. The caster influences the way the wheels behave, especially when the car is turning. That's because of the axis on which the wheel rotates around. With a positive caster, the turning point of the wheel is in front of the contact patch of the wheel on the ground. Because of that, the wheel will follow the turning point and wants to straighten up in a turn. The opposite is true for a negative caster, because the contact patch is in front of the steering point. That causes unstable tires in high speeds.

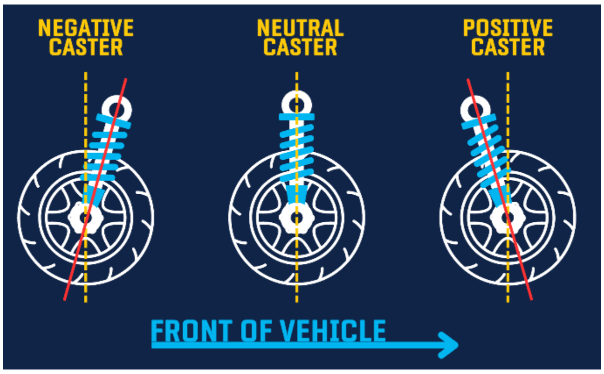


Figure 4: Three types of caster angles

1.2.5. Ackermann steering

When the car is turning, the inner tire covers less distance than the outer tire. That's because the inner tires are closer to the centre-point of the circle than the outer tires. The Ackermann uses the Instant centre of rotation (ICR) for both tires to make a smooth turn.

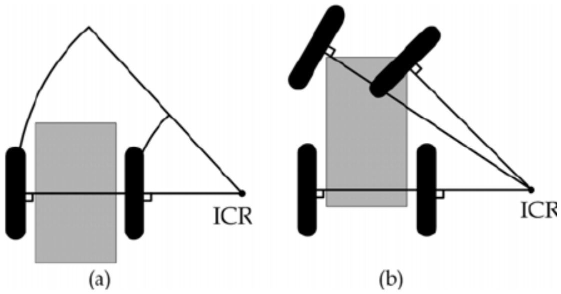
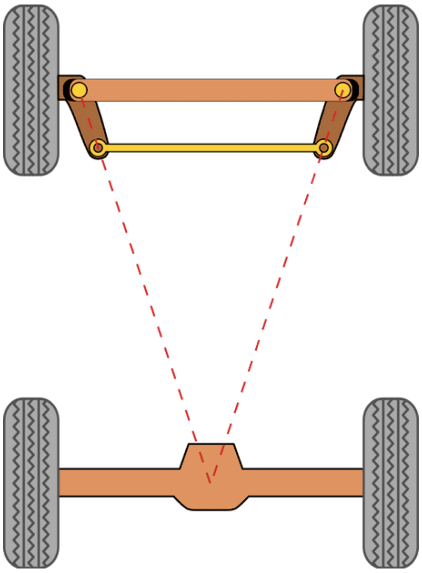


Figure 5: Instant centre of rotation (ICR)

A simple design, like the picture below, can be used as an approximation for the ackermann steering.



1.3. Suspension

The suspension is used for uneven roads. The top of the suspension is connected to the chassis, and the bottom of the suspension is connected to the lower wishbone. It's possible to make an overhang from the chassis to the wishbone, so the suspension can be vertical. Another option is to connect the suspension directly to the chassis. It's then possible to change the angle of the suspension with multiple holes, (figure below)

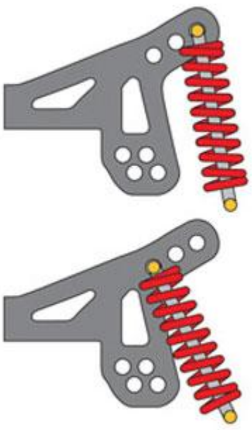


Figure 6: Different mounting holes on the tower

Changing the mounting position will also impacts the behaviour of the vehicle. There are two positions the suspension is mounted on, the tower mount and the arm mount. Both displayed in the figure below.

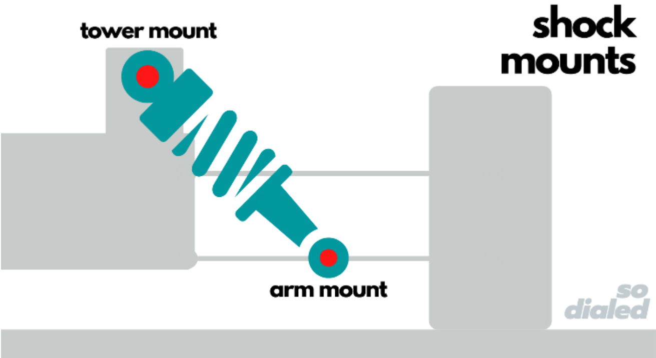


Figure 7: Tower mount and arm mount

Some general effects are described below, but also the difference between the front and rear suspensions:

General effects			
Inward at the tower	**Outward at the tower**	**Inward at the arm**	**Outward at the arm**
• More progressive feel(softer initially, stiffer when compressed) • More responsive • Less side traction • Front: smoother steering response, easier to drive • Rear: more mid-corner traction	• More linear feel (constant stiffness during compression) • More initial chassis roll • More side traction • Easier to drive • Front: better handling on bumpy tracks • Rear: more corner-entry traction	• Softer suspension feel • More responsive • More traction • Less rotation in corners • Outward at the arm	• Stiffer suspension feel • More stable • More side traction • Easier to drive

Front shocks		Rear shocks	
Front shocks more upright	**Front shocks more angled**	**Rear shocks more upright**	**Rear shocks more angled**
• More reactive • More initial turn-in • More front roll • Stiffer feel	• Less reactive • Less initial turn-in • Less front roll • More stable on bumpy tracks	• Stiffer suspension • More steering response • Less stable over bumps	• Softer suspension • Less steering response • More stable over bumps

1.4. Braking system

The braking system is normally a brake-disc with pads connected, it's relatable with disc-brake system on a bicycle. A wire is connected between a servomotor and two pads; the pads will be pulled together on a brake disc that's connected to the central shaft.

There are RC-cars that have a brake disc for each wheel but is harder to design. Therefore, within this project, the braking system will exist of a brake disc, connected to the central shaft.

1.5. Centre of gravity

The centre of gravity must be as close in the middle of the vehicle. The reason for that is because of the balance of the car on the road as well for in the air. The car will lose grip on the right side if the centre of gravity is more on the left side of the car, the same goes for the other way around.

Because it's hard to design a vehicle with the centre of gravity exactly in the middle of the vehicle, the general principle will be that engine will be positioned in the middle, the exhaust will be on one side and on the exhaust will be on the other side. The position of the servo's has yet to be determined, that has to do with the space left on the vehicle.

1.6. Drivetrain

The drivetrain of the RC-car will exist of a nitro engine, central transmission and a differential with the driven wheels connected to it.

1.6.1. Nitro engine (MAX-18TZ SERIES)

The nitro engine will be a smaller engine with around 0,12-0,18cc displacement. The preference goes to the 0,18cc because of more power :). Out of the engine goes a crankshaft with a gear on it, the gear is supposed to be connect with the central transmission.

The engine also has a carburettor, for mixing the air and the fuel. The Carburettor can be opened to send more air into the combustion chamber and because of a venturi effect in the intake stroke. When the carburettor is opened, more air and more fuel will go into the engine.

Therefore, to make the vehicle move, the carburettor must be opened. That will be done by a servo, the same one that controls the brake pads. That means if the actuator does not work, the engine will only stay idling. That is if the engine is set-up properly.

1.6.2. Central transmission

Out of the engine comes a cranks shaft. At the end of the crank shaft is a clutch bell mounted. The clutch bell is then connected with the central transmission.

The central transmission can be a one-speed or two-speed transmission. As a one-speed transmission speaks for itself, the two-speed transmission works with a centrifugal force. The two-speed transmission consist of two gears, one larger than the other. The largest gear is connected to the smallest gear on the crank shaft. Therefore, the vehicle can be driven without asking for a lot of power from the engine. When the largest gear is up to speed, some mechanism will lock the smaller gear that is connected to the larger gear on the crankshaft. The vehicle will than move faster because of the lower gear ratio.

1.6.3. Differential

When turning, the outer wheel will move a further distance in comparison to the inner wheel. With the differential, the power will shift more towards the outer wheel to cause it to move faster.

1.6.4. Power transmission

For the power transmission, there can be a 4-wheel drive and a 2-wheel drive. The 2-wheel drive comes in two variants, a front-wheel drive and a rear-wheel drive. Because of the complexity of the 4-wheel drive, the need of two differentials, pully or dogbone connections for transferring the power to the wheels, the choice will go to a two wheel drive and the rear-wheel drive variant. Becouse it provides better handling, balance, and acceleration, preferred for performance cars and towing.

1.7. Systems control

A working car is one thing, but controlling the car is the second part of designing an RC car. With out speed and steering control, the car won't move from its place. To control the car, there needs to be a transmitter and receiver but there is also the need of actuators, in this case servo's

1.7.1. Receiver/transmitter/actuators

For sending a signal the vehicle, a transmitter is needed. There are basic modules for sending and receiving. Logically the receiver is placed in the RC-car with the servos connected to it. If the gas/break is connected to the same servo, then there needs to be two servos on the car. One for breaking/give gas and one for steering.

2. Final design ideas

For designing the RC-vehicle, the following design choices are made:

Design choice	**Reason**
1/10th RC car	Versatile in parts
Dimensions:	Length: 43-59cm Width: 21-36cm Height: 13-23cm
Adjustable toe-in/toe-out	Ability to change the stability of the RC-car if needed
Adjustable camber	More stability while cornering with high-speed vehicle
Near zero (slightly negative) scrub radius	1. Because no human is steering the vehicle, but a servo. So the torque doesn't mean anything, unless the servo doesn't like it 2. Because it causes stability while breaking
Positive caster	The tire will "follow" suspension and cause it not to wobble
An Ackermann steering	It causes less resistance because of the wheel
Multiple mounting options for the suspension	Experiment with the different effects of the suspension
One servo for breaking as well for giving gas	Less component to add on the vehicle. It causes the vehicle to be lower in weight
Two-wheel rear wheel drive. With a differential	Cheaper to design. Provides better handling, balance, and acceleration

3. Bronnen

https://www.conrad.nl/nl/inspiratie/diy/chassis-rc-autos-afstellen.html : Outdoor: chassis afstellen van uw RC auto

https://www.mvwautotechniek.nl/wielgeometrie/ : Wielgeometrie

https://suspensionsecrets.co.uk/springs-dampers-and-roll-bars/

https://suspensionsecrets.co.uk/lateral-and-longitudinal-load-transfer/ : Load Transfer

https://www.eurorc.com/news/311/types-of-rc-cars : types of RC cars

https://lj-machine.com/blog/nitro-fuel-rc-cars/ : Nitro fuel RC cars

https://www.rcteam.com/en/blogs/the-rc-model-blog/what-size-scale-should-i-choose-for-my-rc-car : What size scale should I choose for my RC car?

https://brscc.co.uk/suspension-secrets-how-to-tune-toe-settings/ : SUSPENSION SECRETS – HOW TO TUNE TOE SETTINGS

https://suspensionsecrets.co.uk/camber/ : What Is Camber & What's Its Purpose?

PERFORMANCE VEHICLE DYNAMICS : Boek

https://youtu.be/rUwJTqr2JC4 : Intro to Racecar Engineering: 11 King Pin Inclination

https://www.sodialed.com/rc-settings/shock-mounting About shock mounting

https://www.eurorc.com/page/97/rc-nitro-cars---the-complete-guide

https://www.youtube.com/watch?v=_yGX9u2ysIE R/C Truck Rebuild Project - Part 4 - How to Assemble a Nitro Engine and Exhaust

https://www.youtube.com/watch?v=Mg38UiJ4dZo How A Nitro Engine Works. Does Lefty Understand?

https://youtu.be/toVfvRhWbj8 How Does A Carburetor Work? | Transparent Carburetor at 28,546 fps Slow Mo - Smarter Every Day 259

https://www.rcsuperstore.com/blog/rc-scale-car-size-guide/#:~:text=1%2F10%20scale%20RC%20cars,racing%20or%20large%20indoor%20tracks.