Vehicle steering and centering systems

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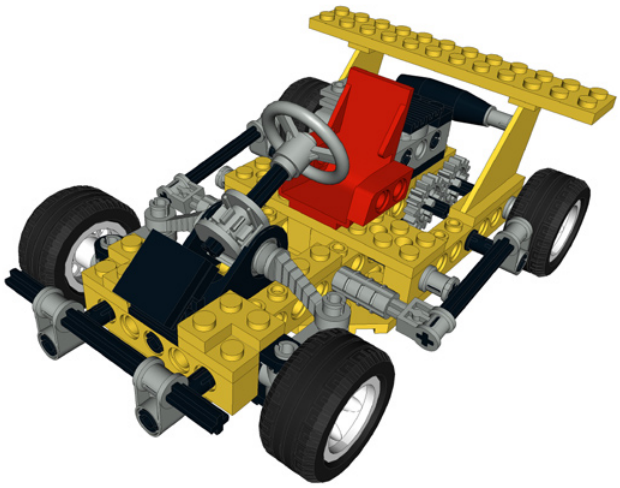
Apart from the smallest which simply don't offer enough space, most LEGO® vehicles rely on some sort of a steering system to allow smooth turning. They span from very simple cars with just a couple of moving parts, to complex multi-axle chassis with asymmetric steering locks, suspension and Ackermann geometry. In this article we shall focus on a few handy tips for building simple steering and centering systems, whereas those interested in advanced or "exotic" steering mechanisms can easily find plenty of further information online and in the literature.

In principle, the aim of a steering system is simple — letting a desired pair of wheels rotate along the vertical axis in a controlled fashion. Things can get slightly more complex if these wheels also need to be driven or suspended, but let us begin with the simplest case.

Among the many possible approaches, decades of experience in the automotive industry have singled out the rack-and-pinion steering as the simplest and the most reliable design, making it by far the most common in today's road cars as well as their LEGO counterparts. This is the design we will therefore aim our focus at.



An older set 8225 is an example of a compact steering using only a few specialized parts.

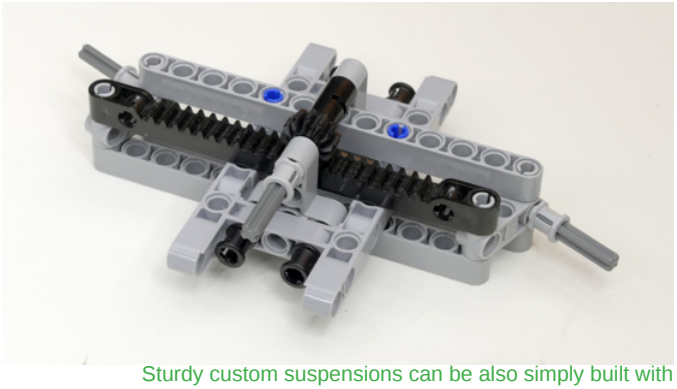
Fortunately, LEGO has provided a considerable amount of parts with steering in mind. They are adapted for various levels of complexity, but if steering is all you need your wheels to do, a solution is rather simple: taking advantage of highly specialized parts 2790-2792, as done in over a dozen official sets, lets you build an entire suspension along with adjustable steering wheel angle, using just a couple of parts.

Its obvious disadvantage, however, is its fixed width, allowing just a narrow range of possible vehicle scales. For a cost of only a few more parts, this can be solved by using parts 32068 and 32069, as shown in the photo. It lets you choose an arbitrary width of the structure

Using ready-made parts for simple steering allows for a very narrow chassis.

between the wheels, and therefore of the entire vehicle. Although relying on only two pins and smallish joints, they are actually pretty sturdy and capable of carrying significant loads, at least on a smooth surface.

Should you prefer the “custom” approach and build the steering using regular parts, or simply don’t have the specialized ones available, there are multiple possibilities. A rather practical one takes advantage of a widely available part 48989, a few standard studless beams, and either a compact or a custom rack. The basic concept is identical in all these cases, as well as the upcoming ones: the wheels are mounted on steering arms which are allowed to pivot around a static point of the chassis. Their rotation is controlled via movement of a single control arm which slides to either side as driven by the rack and pinion.

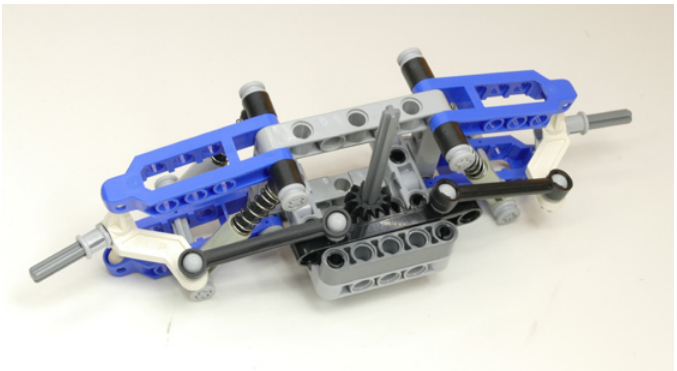


Sturdy custom suspensions can be also simply built with “standard”, widely available Technic parts.

The next step, at which things tend to require more parts, is the introduction of independent wheel suspension along with the steering. By letting the entire steering structure for both wheels stay independent from the rest of the chassis (i.e. a pendular or a floating-axle suspension), one can use the same designs as before. However, independent suspension, particularly favoured by road cars, introduces more complexity.

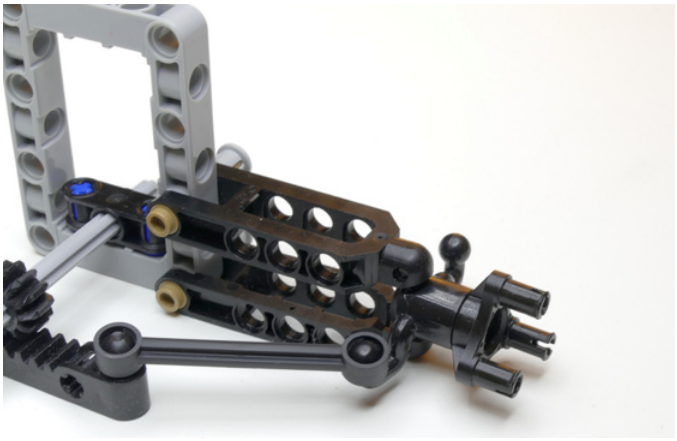
Again, LEGO® has created some pretty useful parts for this exact purpose which can, fortunately, be found in many sets. One can build a custom steered suspension with just regular Technic parts, and while this is a rewarding and occasionally a difficult task, particularly if plenty of mechanical strain is exerted on the wheels, if you are still dipping your toes into steered suspensions it is safer to go with the specialized parts.

First such parts were used in the 8865, a Test Car which was the flagship Technic set of 1988, and though somewhat rare, they are still pretty useful today, and fine as a showcase model. As the wheels need to be able to move in two ways simultaneously (steered and suspended), the steering arms are connected to the control rod via the ball links, as in most real cars.



Parts brought out in the late 80’s allowed the wheels to be both steered and suspended.

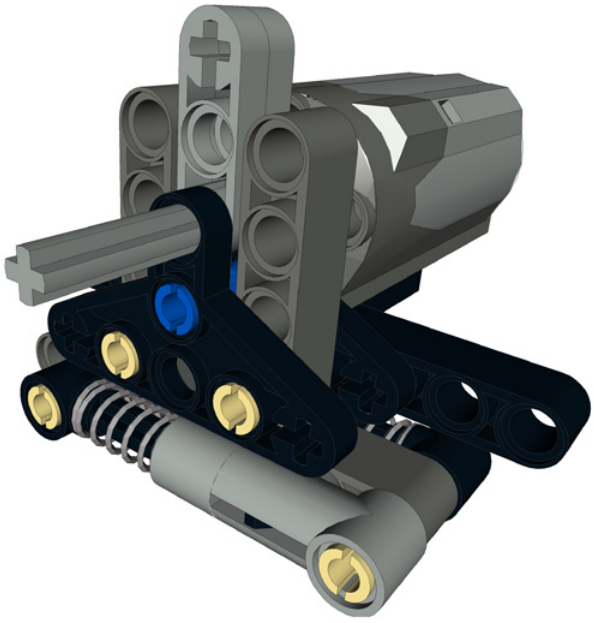
These parts are notable for one other property worth pointing out: they introduced the so-called Ackermann geometry. Note on the photo that, as opposed to the previous examples where the widths were identical, the total width of the control arm here is slightly, by one stud, narrower than the full width between the steering arm pivot points. This detail makes the wheels turn at slightly different angles when the control rod, i.e. the rack and pinion, is moved. Namely, during the turns, the wheel at the inner side of the curve steers slightly more than the outer, as it indeed should: the inner wheel actually turns through the narrower radius than the outer. That makes the steering significantly more stable in turns for real cars, although in LEGO it is more of a mechanical curiosity than something that would yield an obvious effect.



The new suspension parts offer drive and steering, and are seen in many newer Technic vehicles.

The widely acclaimed flagship Super car 8880 from 1994 went a step further, adding wheel drive to the mix. The new parts for driven steered suspension design, though ingenious, were short-lived and are nowadays rather rare. Instead, a new design has emerged and is in use for some time already, based around the steering arm part x873c01. It allows the entire driven, steered suspension package to fit on a smaller space, requires less control rod movement, and is easily built, as displayed; however, its frequently criticized weakness is its displacement. That is, the wheel is somewhat further from the steering arm pivot point, thereby making the wheel move significantly about when steered, in turn requiring more careful chassis design, wider arches, etc.

A simple return-to-centre system, with the “L” beams serving as spring-loaded pushers.



Servo Motor, a recent addition to the Power Functions family, is a very convenient and simple, though not the cheapest, recentering option.

Of course, there are various other suspension parts from other sets and Technic eras you may want to take advantage of.

While the steering system alone is sufficient if the model is built for manual steering, intending to motorize it, simply by connecting a motor to a pinion axle, typically requires some kind of a return-to-centre mechanism which of course straightens the direction of the vehicle once the motor is not engaged anymore.

True, LEGO® has already solved this problem by introducing the Power Functions Servo Motor, but it still isn’t cheap nor widely available. Another ready-made solution is a part dedicated for the very purpose, a colloquially called “hockey spring”, which can be easily attached to any axle.

But again, such recentering mechanisms can be built using standard Technic parts, at the expense of requiring slightly more space. At their cores, most such mechanisms rely on a lever attached to a steering axle which pushes against spring-loaded surfaces if turned. Specific design, especially the recentering forces, depend on the motor in use: they should be small enough to let the motor overcome it with ease, yet sufficient to push the axle back to a central position once the motor is inactive. Though the premise isn’t particularly difficult, the challenge lies in tuning the aforementioned force, and building this mechanism as compact as possible. The pictured example relies on standard Technic shock absorber spring to produce the recentering force; using a rubber band allows for smaller mechanisms, though slightly more difficult to tune and run reliably.

LEGO steering and recentering in a nutshell:

- Regardless of whether you need only the steering, steering with suspension or drive, steering and suspension, LEGO offers a selection specialized parts from different eras which are suitable for the purpose.
- Most designs, both from ready-made parts and custom, follow the simplest, most reliable idea found on real cars: steering arms rotating around fixed pivots and turned by a common control arm via rack and pinion.
- Ackermann geometry is a feature found nearly all real cars, but in LEGO it is more of a curiosity and rarely affects vehicle performance visibly.
- When designing a return-to-centre mechanism, try to build it in a way which allows its force to be easily changed or tuned on-the-fly.

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