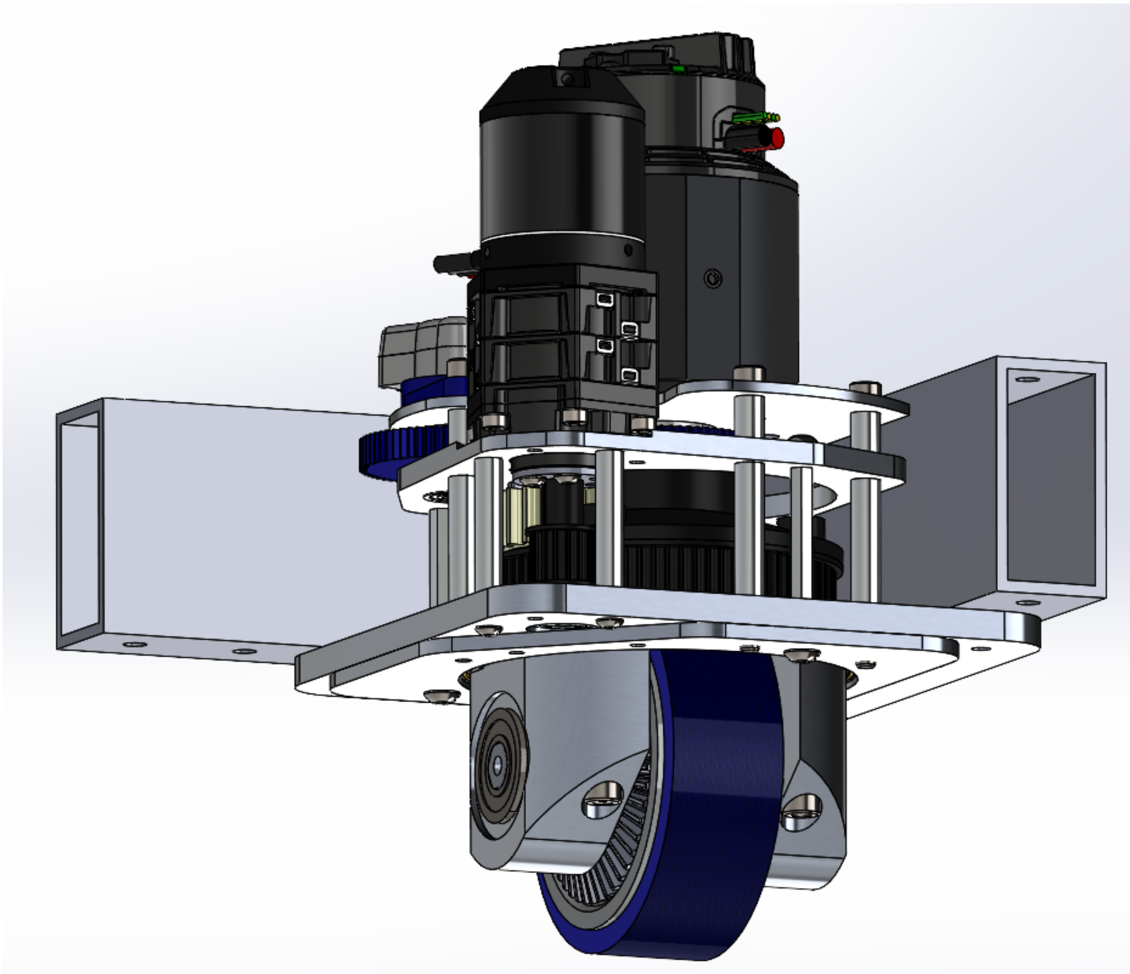

Coaxial Swerve module V23

40 amp FRC motor + 30 amp FRC motor (Document specific: Falcon 500 + Neo 550)

CTRE CanCoder used for azimuth encoder

Designed for use within FRC
Team 3176
Purple Precision
Brownsburg Indiana
Smallest Active Swerve Pod In FRC

— Nathan Louck | Chief Engineer | Team 3176 | 9/6/2022

Overview

The purpose of this document is to review the workings of the V23 swerve module, the design and fabrication process, provide an assembly manual, and give context into information regarding the module.

This document is also from a design/fabrication/electrical perspective. This document does not contain any detailed information on kinematics or control systems, just abstract concepts and features.

Goals

1. Provide the team and other teams with information regarding the module
2. Give future generations knowledge into thought process
3. Provide clear and distinct assembly instructions and repair guide
4. Allow previous module's success to be repeated with different individuals

Swerve Drive Abstract

Swerve drive is a type of drivetrain that involves all wheels being independently driven and steered. This allows the drive train to translate and rotate simultaneously, with neither action having an effect on the other. Coaxial swerve specifically uses a 2 axle system, with an independent motor driving each axle. Swerve drive has specific advantages and disadvantages compared to other teams.

Advantages

High Maneuverability

- Helps mid match, especially when being defended or attempting defense. When being defended, we can spin around one wheel, "locked in place" in order to orbit defending bots. When defending it also allows us to defend multiple sides of the bot quickly, aiding in useful defense.

High traction wheels can be used (opposed to mecanum)

- Ability to use nitrile tread allows us to gain more contact with the ground, especially when using a 1in wide wheel. This means that we can accelerate faster, aiding in maneuverability, and it gives us more pushing power when in stalemates with opposing robots.

Stealth (Other teams interpretation of actions)

- Ability to transform and rotate means that we can be extremely unpredictable when traversing the field, especially regarding shooting actions and game piece attainment. While other drivetrain styles such as tank drive have to complete a specific order of actions in order to turn, swerve can be mobilized in a direction as fast as we can accelerate.

Modularity and ease of service

- Having individual and addressable pods allows us to quickly identify which section of our drivetrain is causing the issue, and allows us to quickly swap the broken pod with a new one, meaning that we don't have to address the drivetrain as a whole entity, rather something that can easily be swapped in and out.

More team specific or action specific options while steering

- Don't have to design around specific sides of the bot as much - "no front". This allows drivers to visualize a location and move there, whereas with drive styles such as tanks this requires much more thought or training. In addition, the drivetrain can be aligned to be driven as field centric, meaning the driver does not have to change directional thinking when the bot is in a specific orientation

Weight (When compared to standard chassis)

- Especially with more optimized pods, the weight of the entire chassis can be significantly reduced, allowing for more components to be placed, giving us more of a margin of error for other designs.

Space Claims

- When comparing the footprint of swerve to drive systems such as tanks, swerve takes up a significantly reduced area. In addition to raw space on the xy plane, swerve also allows components to be placed lower to the ground, making a much more stable center of gravity, which can help when attempting climb end games or accelerating/decelerating quickly.

Disadvantages

Complexity (Programming and design)

- While programming has become easier, with the inclusion of many premade libraries and WPiLib support, swerve is extremely program complex. Due to the kinematics required in order to independently drive 4 wheels, swerve is extremely hard to debug and perfect when initially starting, Even with the libraries available, for team specific functions or control systems swerve can still be extremely hard to implement.

Cost (Each module can be 10% or more of total robot budget)

- Every single module is extremely resource intensive, with multiple motors, gears, and encoders. The cost per module can exceed 400$ and many COTS modules can be up to 600$ per module. WIth an assumed robot budget of 5000$, this can be a significant amount for many teams.

Time (CNC, Design, programming, fabrication)

- Every module requires a significant amount of machining time, especially when machining thicker base plates. 3D-printing also will take a significant amount of time, assuming that every component is a high density part with a high temperature material. There also is time required for designing, programming, and testing, which can require a significant amount of man hours, an extremely valuable resource during the offseason and build seasons.

Driver training

- Due to the unique nature of swerve drive, it is rare that it is intuitive to certain individuals. This means that development of swerve drive also requires a driver that has significant training or practice using swerve drive, and understands how to translate and rotate effectively at the same time.

High resource budget (motors, current draw, can resources)

- Swerve requires 8 motors, more than a typical drivetrain. Having all of these takes up 8 spots on the PDH, and requires each of these motors drawing current whenever you need to drive. This amperage draw can often result in lower speeds and significantly decreased voltage throughout the match. Swerve also uses a significant amount of can resources, meaning that the can bus can get extremely noisy very quickly.

Why 3176 uses swerve

While this is a complex answer, like all decisions made, the benefits outweighed the cost. Complexity has been challenging, but over the years we have built a strong understanding of kinematics, and have a solid repository of code and resources in order to build a system off of. In recent years, our team has grown big enough and now operates on a sustainable budget, allowing us to pursue projects like swerve. Dedicated students and mentors and has remained in a consistent supply, allowing us to overcome the time restraints that swerve requires. Driver training is something that we still struggle with as a team, but with the past couple seasons we have found that drivers tend to learn over the course of competitions, code testing, and the time in between competitions. The high resource budget is something that has not been a major concern of our team, but with the introduction of the rev control system, it allows us to be less concerned about budgeting 40 amp devices, and with smarter routing we have significantly limited noise on the can bus.

Coupling these factors with the pros of maneuverability, ease of service, and drive control, Swerve seemed like a viable option for our team to pursue and we have for multiple years now.

However, one thing that sets team 3176 apart is the use of custom modules. While swerve has gained significant popularity, especially in recent seasons, producers such as SDS and WCP have dominated the market, however they have done so at high prices with extreme robustness, in order to protect the manufacturer. By designing our own module, we can use our own mounting system, swerve libraries, and most importantly, make our modules unique to our team and season. This also makes our modules significantly cheaper, with the cost per module in total only being around 350$, significantly lower than the average competition price.

Why 3176 redesigned their swerve

The decision to redesign swerve for the 2022 season was made after particular struggles with available space low to the ground, especially with the 2021 bot in which we had to implement a “drum” design, one that had a significantly limited diameter due to the size of our previous modules. Around this time, SDS and thrifty both released swerve pods, and evaluating these designs led our senior leadership to greenlight a new version of 3176 Swerve. Understanding that swerve is the future, our team made it a priority to develop a module that can compete at the highest level of competition, continuing our team's history of swerve in a sustainable way.

Specifications

This pod was designed to be used with a 30 amp FRC motor and a 40 amp FRC motor. While the Falcon 500/Neo 550 Version is displayed for the majority of the document, the module is equipped to use a neo 500 or a redline/775 pro. This pod was also designed to be used with a CTRE cancoder. The reason for this choice will be specified later, however a SRX mag encoder can also be used.

Fabrication Constraints

When designing the pod, we initially were concerned about development of more complex pieces, such as the wheel forks and azimuth pulley. While 3d printing and remote machining are possibilities, lead times (especially in the pandemic) were too long to reasonably pursue. We have a 2.5 axis CNC, and had only previously cut up to .125in 3003 aluminum. We understood that we reasonably had to work up to .25in plate, and purchased bits and upgrades in order to get to this point. 3d-printing resources were only accessible via student resources, and the highest material capability we had was abs.

Critical Design choices

A long list of things to consider was created in order to meet all things that we as a design team considered necessary.

- Adequate traction
- Easy Wheel Changeability (swap wheel in under 1.5 minutes)
- Easy pod Changeability (mechanically swap pod in under 2 minutes)
- Easy Motor Changeability
- Easy Encoder Changeability

- Low backlash on steering + steering encoder
- High CPS on steering encoder
- Ability to auto home via encoder
- Enough force to win pushing matches
- Over 12ft/s max speed
- Turn efficiency with steering ratio
- Visibility to all moving parts
- 5x5 footprint or less
- Under 5 pounds per module
- Has to be mountable to 2x1 boxtube
- Can sustain loads over long period of time - can't afford azimuth to break ever
- Belt Driven Azimuth
- Wheel close to outside of chassis
- Ability to swap multiple motors for different brands
- All plates must be rigid and confined to each other - mechanism to do so
- A lack of failure point in the middle of a moving system
- Attention to bearing orientation in order to avoid dirt/carpet in bearing
- All shafts captured on multiple sides/points
- Wheel must be as close to the ground as possible
- Need a way to quickly swap in a non driven pod
- Must be slack between azimuth and bearing in order to provide a loaded and unloaded state
- Entire pod must be protected from outside
- Belt must have over ½ pulley contact
- No significant amperage draw on either motor

Coaxial Swerve V23 Breakdown

Coaxial Swerve V23 is a standard coaxial swerve module that uses a falcon 500 and a neo 550. It has a top drive speed of 15 ft/s, and can be operated in field centric or robot centric positioning systems.

Module Features:

- 5inx5inx7in footprint
- 4 pounds per pod
- Wheel close to outside of chassis
- Bevel set integrated into wheel
- 2 Bolt wheel change, can be done in around 1 minute when done smoothly

- 5 bolt motor changes, allowing for specific motors to be easily replaced in case of issue
- Ability to interchange motors with Neo for the drive and a 775 Pro for the Azimuth/Steering
- Implementation of the CTRE CanCoder, allowing for modules to be positioned absolutely or relatively, allowing us to quickly return or set a home position.
- Multiple plate system allowing for easier maintenance - don't have to disable entire pod
- Completely independent of chassis, allowing entire pods to be changed with a series of 5 bolts, making a mechanical pod swap happen in around 1.5-2 minutes.
- 3 In diameter, 1in wide wheel with blue nitrile tread
- 3d printed azimuth in order to shrink form factor and reduce weight

1-Speed Drivetrain

	Free Speed (RPM)	Stall Torque (N*m)	Stall Current (Amp)	Free Current (Amp)	Speed Loss Constant	Drivetrain Efficiency
Falcon 500	6380	4.69	257	1.5	81%	83%
# Gearboxes in Drivetrain	# Motors per Gearbox		Total Weight (lbs)	Weight on Driven Wheels	Wheel Dia. (in)	Wheel Coeff
4	1		154	100%	3	1.1
Driving Gear	Driven Gear	RPS	Drivetrain Free-Speed	Drivetrain Adjusted Speed	"Pushing" Current Draw per Motor	
14	22	67.67	17.72 ft/s	14.70 ft/s	101.43 Amps	
1	1	67.67	4.71 : 1	<-- Overall Gear Ratio		
15	45	22.56				
1	1	22.56				

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