FSAE Electric Dual Motor Powertrain Design

Department of Mechanical Engineering, The University of Utah

Jon Chua, Will Graham, Jeff Gubler, Luke McDivitt,
Karianne Moe, Zach Orton, Dan Sturm

Formula U racing

INTRODUCTION

Each year the Formula U team designs an electric race vehicle to compete in the National Formula SAE competition. To increase the performance of the vehicle, the Formula U team is moving to a dual motor drive train. Doing so increases the power of the vehicle and allows for the capability of torque vectoring, improving the handling of the vehicle. This team was tasked with the design of the dual motor drive train as well as the design of torque vectoring system controller. Table 1 includes the components selected for the dual motor design that meet the design criteria of 80 kW (107 hp) of power, under 400 pounds of weight, and complies with Formula SAE rules.

Unfortunately, due to unexpected financial concerns within the Formula U club, ordering the full-scale vehicle parts has been delayed. Therefore, the emphasis of this project is perfecting the system controller.

Table 1. Components of the full-scale system.

Budget-SAE Formula One							
Full Scale Model							
Proposed Budget	$20,000						
Type	Part Name	Part Number	Supplier	QTY	Price	Total price	% of Budget
Motor & Controls	MGM Reb 50	Reb 50	MGM	2	$4,500.00	$9,000.00	45.00%
	Motor controller	N/A	MGM	2	$5,000.00	$10,000.00	50.00%
	Raspberry Pi 3+	N/A	Raspberrypi.com	1	$45.00	$45.00	0.23%
Power transmission	Shaft	2672N28	Mcmaster	2	$60.00	$120.00	0.60%
	Bearing	2780T25	Mcmaster	2	$25.35	$50.70	0.25%
	Motor mount	N/A		2	TBD	$150.00	0.75%
	Belt	5MGT-425-15	Gates	2	$33.00	$66.00	0.33%
	Pulley-1	TBD	Gates	2	$50.00	$100.00	0.50%
	Pulley-2	TBD	Gates	2	$50.00	$100.00	0.50%
					Total	$19,631.70	98.16%
					Remaining	$368.30	1.84%

OBJECTIVE

Providing the Formula U team with a complete, robust system controller is the main objective of this project. This will be accomplished through the sub-objectives listed below:

- The controller provides functional torque vectoring logic that improves the handling of the vehicle
- Vehicle parameters that influence torque vectoring logic can be easily altered later by the Formula U club
- Controller outputs are regulated by PID control
- Controller outputs can be limited to meet Formula SAE power requirements.

METHODS

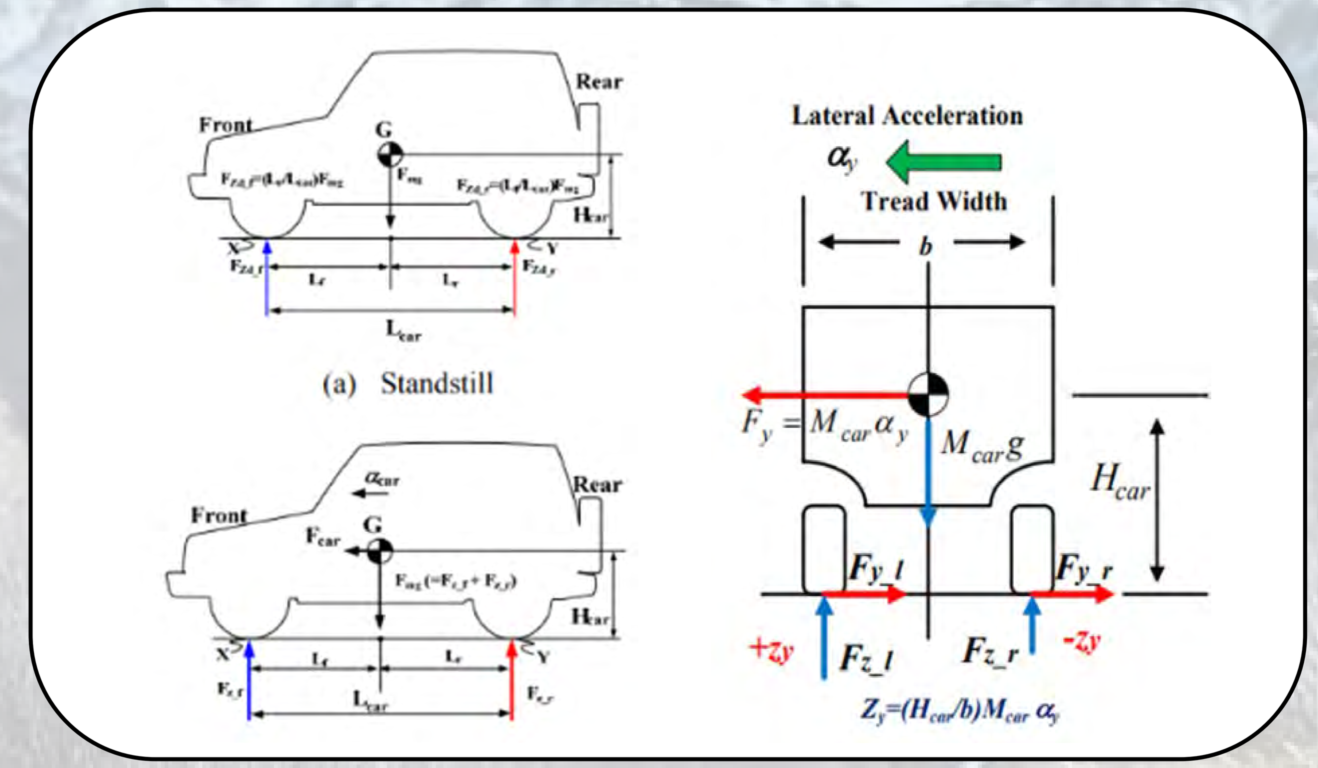

Figure 1. Free body diagrams used to develop the torque vectoring equations [1].

The torque vectoring logic of the controller was designed using the free body diagrams in Figure 1. To verify the functionality and viability of the controller, the testing was broken into two steps, a benchtop prototype and a go-kart style test vehicle.

BENCHTOP PROTOTYPE

The benchtop prototype, shown in Figure 2, consisted of the motors attached to wheels resisted by magnetic bike trainers. With resistance, the PID could be properly tuned and verified. The torque vectoring could also be verified by setting the motor velocity and steering angle with potentiometers while the input currents to the motors are monitored in real time. This setup also revealed the need for filtering due to noisy data from the individual motor controllers and a 20-point moving average was utilized.

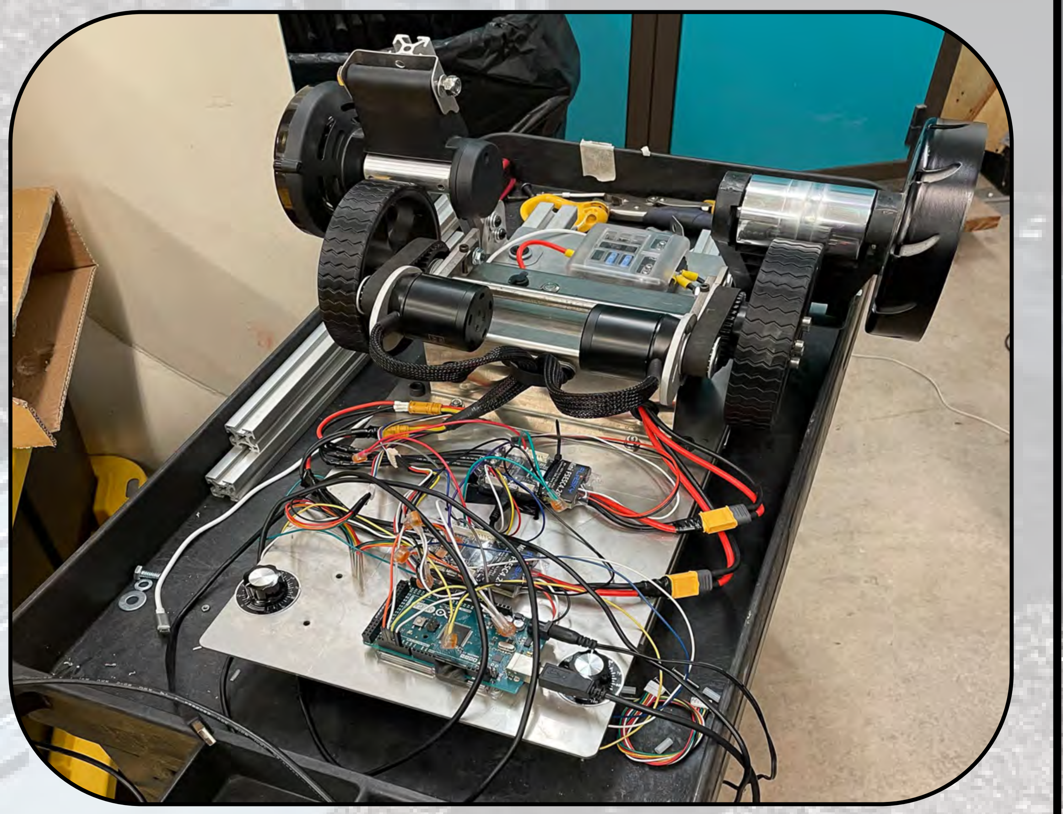

Figure 2. The benchtop prototype used for torque vectoring and PID code development

GO-KART TEST VEHICLE

Figure 3. Complete go-kart test vehicle.

To verify that the torque vectoring logic would improve the handling of the vehicle, a test vehicle was required. The complete vehicle is shown in Figure 3. This vehicle contains scaled down components that are equivalent to the full-scale Formula U vehicle listed in Table 1. The vehicle's performance can verify the effectiveness of the torque vectoring logic through a "cornering" test. The cornering test consisted of analyzing the path as well as the entry and exit velocities of the vehicle in a single high-speed corner.

RESULTS

The go-kart was tested by executing the same turn with and without torque vectoring code running. On-board sensors took measurements of motor speeds, torques, and steering angle. This data was used to analyze entrance and exit velocities shown in Figure 4. The data revealed an average exit to entrance velocity ratio of 89%, with torque vectoring and 66% without, suggesting an improvement in turn speed. A drone was also used to film from above and visually show the difference in handling. This is shown in Figure 5, the red, smaller radius curves are the torque vectoring turns, indicating a tighter turn radius.

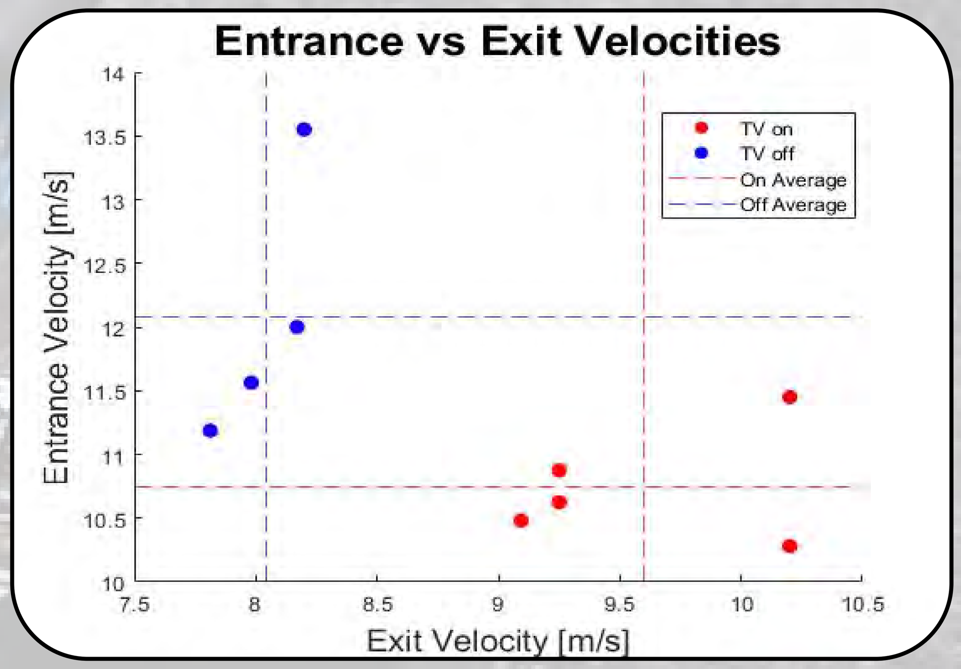

Figure 4. This graph shows the Exit vs the Entrance velocity.

Figure 5. Path lines of the vehicle during testing.

CONCLUSION

The results revealed both an increase in turn velocity and a decrease in turn radius through each turn with torque vectoring on. Together, these results indicate that the torque vectoring logic improves the handling of the vehicle. Additionally, outputs are regulated by a stable PID controller and have a built-in limit to meet Formula SAE requirements. Finally, the code is easily understood and alterable to a specific vehicle's parameters. Therefore, all objectives were met, and a complete, a robust system controller has been produced.

SOURCES CITED

[1] Mutoh, Nobuyoshi, et al. "Driving Torque Distribution Method for Front-and- Rear- Wheel-Independent-Drive-Type Electric Vehicles (Frid EVs) at the Time of Cornering." *World Electric Vehicle Journal*, vol. 4, no. 3, 2010, pp. 558–566.