

Oakland University
Octagon V3.0; Sponsored by Nabtesco Motion Control Inc.



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Statement: I certify that the design and engineering of Octagon V3.0 by the current listed student team has been significant and equivalent to what would be awarded credit in a senior design course at Oakland University.

Signed - Dr Khalid Mirza

Khalid Mirza

Introduction

For the past three years, Octagon has been a robotic platform providing experience designing and programming autonomous vehicles to Oakland University students, and the modifications made this year have moved it from good to great. For the uninitiated, Octagon is sponsored by Nabtesco, who contributed the robot's flawless 53:1 ratio gearbox. Said gearbox is attached to an 80/20 framed industrial quality chassis with polycarbonate detailing and a brand new tank-style continuous track suspension. Electrical highlights of the robot include a RoboteQ motor controller and an Asus laptop processing inputs from a Hokuyo Lidar, a Ublox GPS, two newly added side-mounted LeddarTech Leddar™ units, and an IDS uEye camera along with two new webcams. Six batteries power the robot, all wired with a thorough recharging, protection, and power distribution circuit, topped off with two easily accessed regulation E-Stops. The Octagon V3.0 team looks forward to submitting their robot to competition this year, and expects it to deliver quality performance.

Innovations

Numerous innovations currently displayed on Octagon had their origin in earlier variants of the robot. For instance, the octagonal base being made of 80/20 allows for easy application and removal of new sensors and structural components. The top portion of the robot, including the sensor tower, is on a hinge with clasps. Lifting the lid via the sensor tower allows for easy access to the otherwise immaculately protected electrical system inside. A six battery system is implemented for maximum runtime, while a built-in battery charging and power distribution system allows for easy recharging anytime the robot is near an AC power source. The software system utilizes high quality sensor data, allowing it to radically modularize the sensor functions, without having to rely on redundant data.

Four major innovations were implemented this year: a reinforced sensor tower is now in effect and is oscillation free, a brand new suspension with tank tracks and a shock absorbing trailer is allowing for the robot to off-road safely, supplementary camera sensors have been employed and coded for to assist with the safe execution of turns, and laser rangefinders installed on the left and right sides of the robot extend Octagon's field of view, ensuring that it does not collide with objects.

Mechanical Design

One of the weakest links in Octagon 2 was the Mechanical Suspension system. The castor wheels proved to be a large issue on obstacles, the sprung mass was not measured or taken into consideration during the spring selection, and the execution was not well manufactured.

The focal point of the suspension design for Octagon 3 was to enable it to be mobile on any terrain and do the math and designing required for a proper suspension. After getting Octagon 3 on corner weight scales, the overall weight is 291 pounds. With that number, proper

springs for the small shocks that were purchased for Octagon 3 could be picked out and implemented on the new system.

To improve traction and mobility, a tank system was designed and implemented to fit the frame as is and replace the initial suspension system. With the load across more surface area on the ground, Octagon 3 becomes more stable than it has been in the past. By picking a drive gear that is one half the diameter of the initial wheeled suspension system, there was a need to change the drive motor speed by exactly 2 times the previous speed. The systems are completely interchangeable, and as the tank system is proven and tested thoroughly, the traditional wheeled system can be bolted on for testing of other systems. It goes without saying that the improved suspension system will greatly improve the robot's ramp climbing ability to above and beyond a competition-ready level.

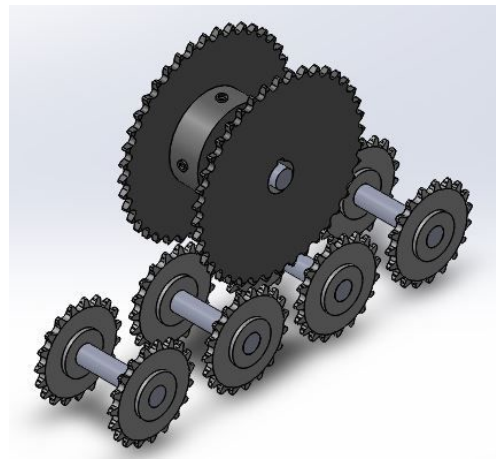
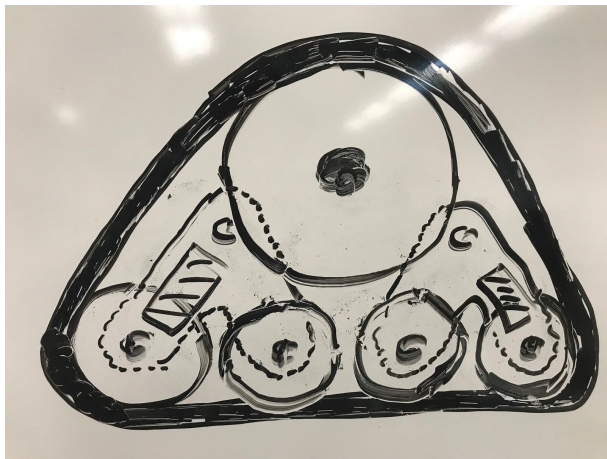


Figure 1 and 2. Track Suspension Brainstorm; Track Drive Assembly Model

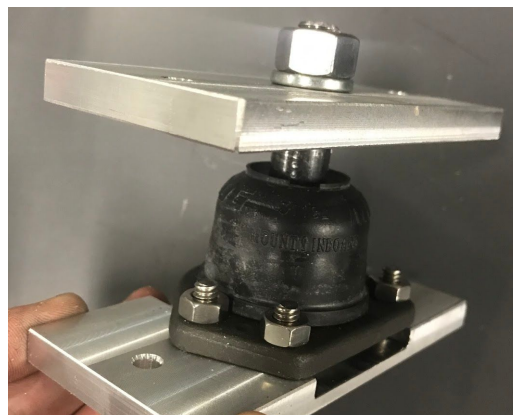
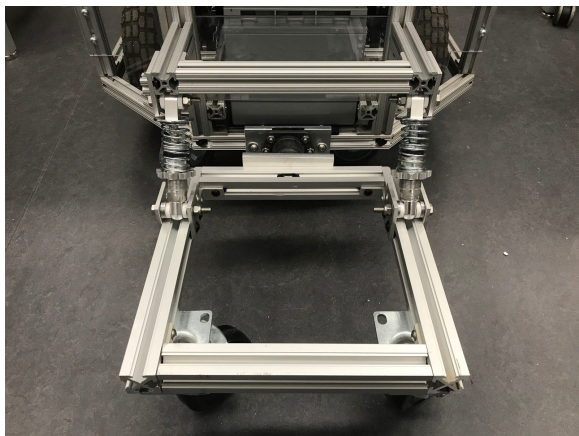
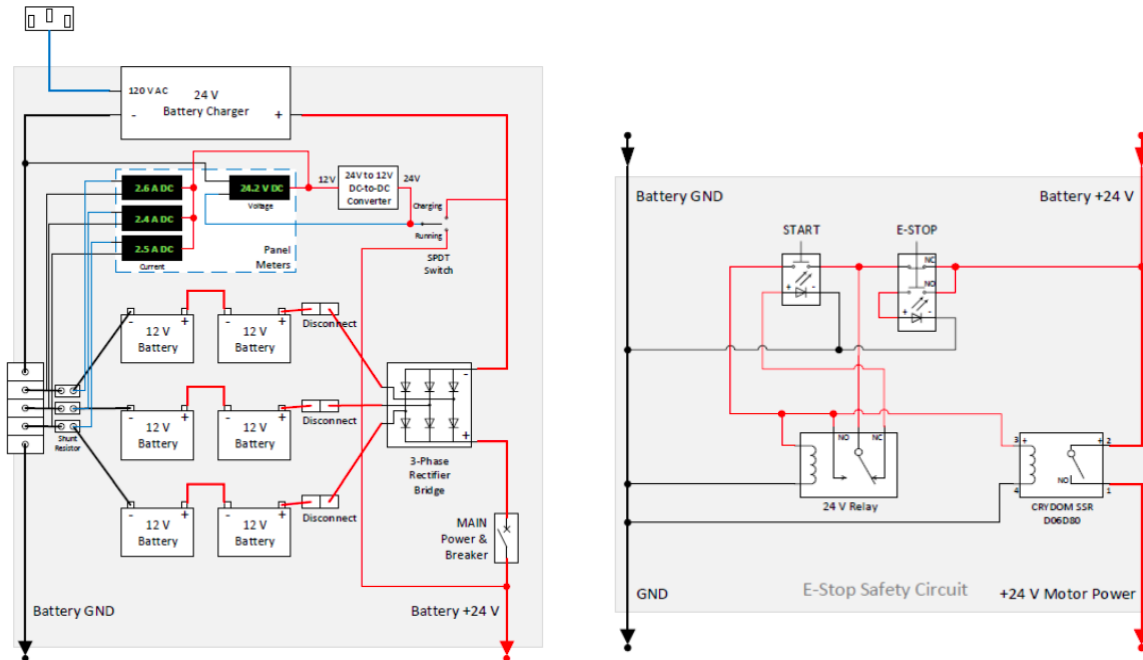


Figure 3 and 4. Suspension System for Wheel Drive; Machined Ball Joint Connection

Electrical Design



Figures 5 and 6. Battery Charging/Power Distribution Circuit; E-Stop Safety Circuit

Six 12V DC batteries serve as the power supply. The battery array is also connected to a 3-Phase Rectifier Bridge which can protect the batteries in normal current. A Noco Genius battery charger also is built into the robot for ease of charging. In addition, the robot has 4 LED displays to show the voltage and one converter for 24V to 12V DC-DC, allowing the battery circuit to be easily monitored and the output to be applied directly to the motor controller, respectively.

A great deal of the electrical complexity of the robot is contained in the RoboteQ motor controller, which was used exactly as supplied by the manufacturer. This unit not only takes in input from the computer directly and outputs directly to the motors, but also utilizes encoder data in its control process out-of-the-box, meaning that the majority of lower-level coding considerations, along with most of the upper level electrical considerations, are eliminated.

Software Design

The software team was tasked with enabling Octagon V3.0 to move and navigate autonomously. To do this they implemented a system called ROS, Robot Operating System. The code developed in ROS allows the robot to navigate autonomously in many different environments. This was accomplished by inputting data from a multitude of sensors including a front LIDAR sensor, two side LIDAR sensors, a front camera, two side cameras, a GPS, an IMU, and wheel encoders. By analysing this data in real time, the robot is able to navigate around obstacles and to destinations autonomously. The sensors utilized all have associated ROS libraries created for them, making implementation seamless

The computer controlling the robot is an Asus laptop running on the Ubuntu 16.4 LTS operating system. These computers are configured specifically to facilitate the continuous operation of Octagon, having all of the ROS packages needed to allow the robot to run autonomously both indoors and outdoors.

The robot has also been coded to navigate autonomously indoors using a map of the area that it would be operating in generated with sensor data. To do this, Octagon is controlled by a joystick and moved around the area, allowing the sensors to obtain information for the most accurate map possible.

The sensors of Octagon V3.0 can be divided up into three distinct categories: line detection, obstacle avoidance, and waypoint navigation. The line detection category consists of the cameras deployed on the robot, what with them being the only sensors that can detect variations in visible light at the precision required in order to ascertain the difference between white lines and grass usefully. The robot's eyes come in three parts, the first being a top-mounted IDS uEye industrial camera. Tried and true libraries have been developed for this camera, and so this component is expected to reliably perform its function of providing frontward-facing vision. In addition to this, two side-facing cameras have been deployed to supplement the primary eye in line detection when completing sharp turns. The addition of these two cameras are an innovation expected to improve curve-navigating performance considerably.

The second suite of sensors, those concerned with object avoidance, is comprised of the three rangefinders on the robot: the Hokuyo UST-10LX lidar mounted at the front of the robot and the two side-mounted m16 multi-sensor Leddars. The function of these three units is to detect objects and track them from when they enter the field of view to when they are passed. The 10 meter, 270 degree range of the Hokuyo rangefinder should allow the robot to sense objects sufficiently far away as to be able to avoid them easily, while the Leddars' 100m, narrow view range more than suffices in effectively detecting side objects with leeway for avoidance.

The final set of sensors, waypoint navigation, revolves around the handling of GPS-related tasks. Naturally this includes of the GPS module itself, but also the IMU, which provides primarily magnetometer data allowing the robot to "place" itself along with the broadcasted GPS waypoints relativistically on the map created by the line detection and object avoidance sensors.

Failure Modes and Avoidance

The primary goal of any robotic platform interfacing with humans must always be, paraphrasing Hippocrates, to "first, do no harm". As a result, the most necessary engineering on the Octagon V3.0 robot is that concerned with ensuring there are enough checks in the control system so as to prevent the robot from harming anything or anyone in its environment. On the mechanical end, this meant improving the suspension system such that the 290 pound robot does not inadvertently fall over or otherwise move erratically as a result of variable terrain. On the electrical end, this meant ensuring the e-stops are correctly implemented, and that autonomous and manual mode are clearly switched between. On the software end, this meant placing measures to stop the robot if sensor data indicates malfunction in autonomous mode, or

if communication between the RC controller and receiver cuts out or becomes unreliable in manual mode. At the same time, the abundance of sensors placed on the robot platform means that the robot may still retain function even with certain sensors malfunctioning. As a result, coding considerations were made ensuring that the robot can not only function given limited sensor data, but also that it will stop before uncorrupted sensor data becomes too limited to safely form the basis of the robot's decisions.

Performance Testing and Initial Assessment

Table 1. Relevant Performance Parameters	
<i>Item</i>	<i>Description</i>
Dimensions	37 x 30 x 66 inches
Safety Considerations	Mechanical and electrical safety measures
Payload	At least 200 lbs
Runtime	2 – 3 hours
Weight	Approximately 290 lbs (w/ IGVC module)
Top Speed	Safe around humans, 5 mph
Operating Environment	Relatively flat all terrain operation

The previous two years of competition have served as a form of testing of utmost importance in the development of Octagon, especially given the deficiency of software simulation testing the team has experienced. From last year's competition, it has been noted that the software was effectively working; the majority of the software issues preventing the robot from being a competitive platform last year were in the integration of and relationship between ROS modules rather than the actual modules themselves. Therefore, having seemed to have worked out the kinks in that regard, the robot's software is functioning well. The other major issue hindering Octagon V2.0 was its suspension, a rather ramshackle set of devices at the time that managed to go untested on the robot until competition, and unsurprisingly failed to work as a result. Considerably more forethought has been applied to the suspension this year, and as a result initial outdoor testing appears favorable, with no fear of the robot, for instance, falling over while rolling up a gentle ramp. Overall, the third iteration of the Octagon platform is a vast improvement over its previous versions, and great results are expected ahead.