Cooling User Manual

ME 498 - Spring 2021

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Abstract

This document is intended to detail the aspects of the cooling system that is used to cool the Motor Controller and Motor 2021 FSAE EV car.

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Executive Summary

Introduction

The cooling system provides cooling for the motor controller and motor. It is divided into three subparts:

1. Cooling system panel
    - Koolance PMP-500 pump
    - Koolance TPL010K temperature sensor
    - YF-S201 flow sensor
2. Yamaha Raptor 660 Radiator w/12V fan
3. One liter reservoir with fill cap

The top level diagram and the connections are shown in Figure 1 below. The cooling system is controlled by TSI such that the fan activates at 38C and deactivates at 35C. While active, the pump and fans run at full speed.

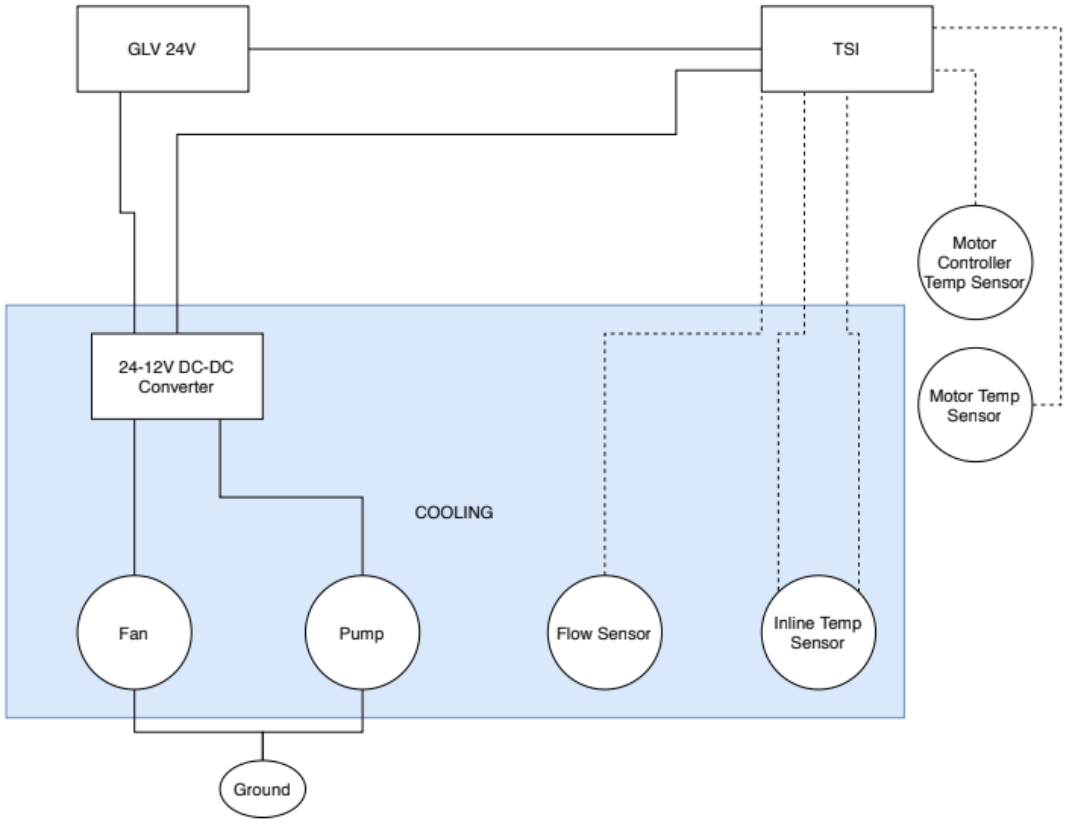


Figure 1 - Cooling system wire diagram

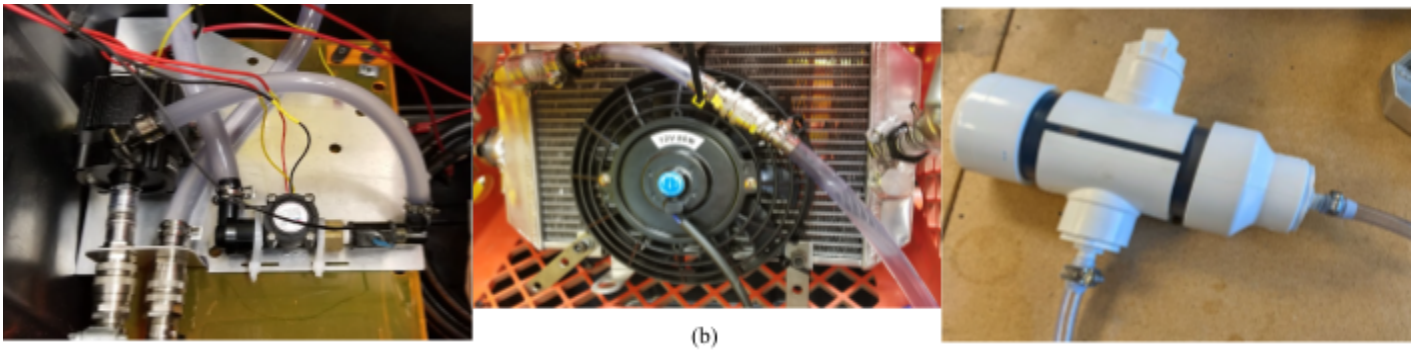
Current State of Design

The cooling system, which currently resides in the dyno room, was designed to have a very high heat capacity and heat dissipation rate. The cooling system is also controlled by TSI such that the fan activates at 38C and deactivates at 35C. The cooling system was initially tested outside of the dyno room by filling it with hot tap water (~40C) and letting it run for 10 minutes. It was found to be very successful in this test. The results of the test can be found here. The cooling system was also tested in the dyno room with the motor controller which is where it currently resides. Recommendations on the design of the cooling system to the future team can be found below.

Cooling System Installation Guide

How to Install

The cooling system was designed to be installed relatively easily in three sections. The cooling system panel is installed on the side of the car between the firewall and drivetrain facing inwards using three u-bolts as seen in Figure 2a. The radiator is also mounted in between the firewall and drivetrain at an angle next to the cooling system panel as seen in Figure 2b with the two u-bolted connections fixing the bottom of the radiator to the bottom of the frame and the mounting tab connection fixing the top of the radiator. The reservoir can be seen in Figure 2c which currently does not have a solution for mounting it to the car. Once all components are mounted to the frame, the components can be linked together with the cooling hoses as specified in Figure 3. It is important to note that all of the components have quick disconnect fittings that follow the same male-female convention in which the male connector is the input and the female connector is the output. Onces all components are connected together to form the cooling loop, the cooling system can be filled by following the subsequent instructions.



(a) (b) (c)

Figure 2: Visual of each cooling system component: Cooling system panel (a), radiator and fan (b) and reservoir (c)

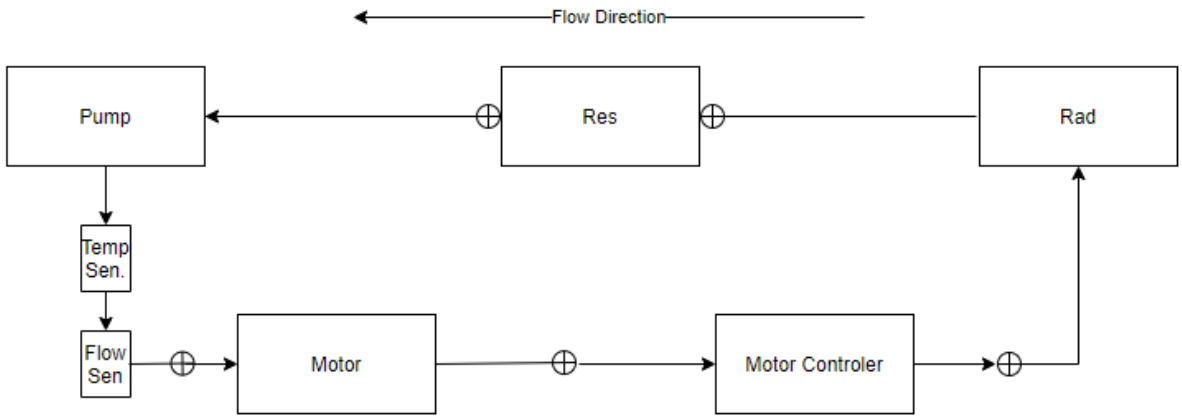


Figure 3 - Cooling loop diagram where the arrows represent a barbed fitting and circles with a cross represent quick disconnect fittings

Emptying and Filling

Filling the system is relatively easy once the system is fully connected to form the cooling loop. To fill the cooling system, one must simply open the reservoir and pour water in until the reservoir is filled completely. Then the pump should be turned on to allow water to propagate through the system. The water level in the reservoir will decrease as a result and more water should be added to compensate. It is important that enough water can be supplied to the pump during this stage as running the pump without water can damage or destroy the pump if caution is not taken. Continue this process until the water level in the reservoir remains constant.

To empty the cooling system, it should first be removed from the car and each component should be disconnected. The reservoir and radiator can be emptied more easily by removing their fill caps and dumping them out. If the cooling system panel needs to be emptied, the easiest way to do so is by attaching a standalone quick disconnect fitting to either the inlet or outlet. Doing so opens the quick disconnect fitting and allows the water to drain and the panel can be rotated as necessary to empty all water from the panel.

IMPORTANT: If the cooling system panel does not have any water in it, it is recommended that you fill the cooling system outside of the car with the connection coming out of the flow sensor jumped to the radiator as it is easier to make sure that water has reached the pump before turning it on.

Future Team Recommendations

The only outstanding issue of the current cooling system is that the reservoir does not have a way of mounting to the frame of the car. The reservoir should be the highest point in the system, therefore it is advised that it be mounted to either the inside of one of the side panels or to the side of CarMan. This was not completed by last year's team due to the fact that the reservoir's location is not a huge matter of concern so long as it is located at the highest point in the system meaning it was decided that the

placement of the reservoir would be considered after the location of all subsystems were determined. Unfortunately, the locations of all the subsystems was not fully realized until later in the semester meaning the location, and by extension mounting solution, of the reservoir was not determined. While this is the only issue preventing the cooling system from being able to be fully integrated onto the frame, there are other small issues that could be addressed but do not hinder the functionality of the cooling system.

One possible issue may be in the location of the radiator which may not be able to draw in enough air in its current location. Possible solutions could be to add ducts from either the sides or the bottom to direct air more directly into the radiator or to relocate the radiator to a more desirable location in the car. It should also be noted that a better solution for mounting the fan to the radiator should be found given that it is currently zip tied to the radiator (radiator doesn't have too many good mounting points so the radiator may need to be modified). Something else to consider would be to control the radiator's fan more gradiently allowing the temperature of the water to be managed more effectively. The radiator also has a vent (found just below the fill cap) that should either have a catch can installed or should be capped in order to be rules compliant (T8.2.2). Because the cooling system cannot operate at temperatures high enough to generate steam (the tubing would melt before this point), capping the radiator should be a suitable solution, as it only serves the purpose of relieving pressure in the event of boil-over.

Algorithms

Heat Loss in a Pipe

$$Q = \frac{2\pi * kL(T_1 - T_2)}{ln(r_2/r_1)}$$

K = heat transfer coefficient of PVC tubing
T1 = Water Temperature
T2 = Ambient Temperature
L = Length Unit
R1 = Inner Pipe Radius (Where water flows)
R2 = Outer Pipe Radius (Insulation)

Energy Lost Due to Heat During Endurance

$$H = \frac{4E_s(1 - eff)}{\frac{3600L}{Speed_{avg}}}$$

Es = Energy per segment (Joules)
Eff = efficiency of system (%)
L = Length of Event (km)

Speedavg = Average speed during event (km/hr)