Supermileage Chassis Dynamometer

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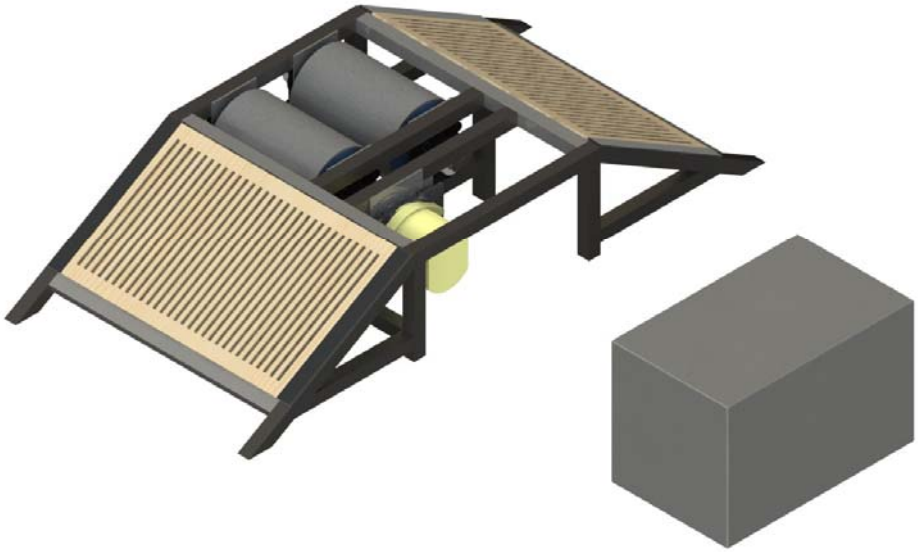

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Abstract

This report describes the final design and analysis of a hydraulic chassis dynamometer as a testing tool for California Polytechnic State University, San Luis Obispo Supermileage Vehicle Team (CPSMV). Literature review was conducted to understand the various types of chassis dynamometers on the market as of the year 2011. After rigorous research, it was determined that a hydraulic system was the best system for a chassis dynamometer in terms of functionality, performance, and cost. Critical study of hydraulics, dynamometers, and data acquisition systems (DAQ) was followed by a complete design of a hydraulic system. The chassis dynamometer proposed in this report tests a vehicle under a load provided by a hydraulic pump. A proportional valve imparts a load on the vehicle by restricting flow and creating a pressure differential. A fluid conditioning loop comprising a strainer is incorporated into the return line to maintain proper fluid cleanliness. This project combined different principles of mechanical, manufacturing, control, and electric and computer engineering to provide a testing tool to aid in the tuning of CPSMV's current and future vehicles.

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Chapter 1: Introduction

The Supermileage Vehicle Team from California Polytechnic State University, San Luis Obispo competes annually at the Shell-Eco marathon. This competition challenges teams all over the United States to design, build, and test energy efficient vehicles. The winners of the competition are the teams that can travel the farthest distance using the least amount of energy. Each year the team develops methods to improve the fuel efficiency of their vehicles. CPSMV has an incredible record of consistently placing well in the Shell- Eco marathon, but they have never had a vehicle at competition with an optimally tuned engine. In addition, the team began using fuel injected engines to achieve better gas mileage and greater performance but they do not have a current method or tool to measure the new performance characteristics of their engines.

As a result, CPSMV has requested the design and manufacturing of a chassis dynamometer to help them test their vehicles under normal road conditions and provide them with engine performance data such as power and torque. The testing of the vehicles will help the team tune their engines accordingly and/or design vehicle drive trains that will allow them to be more competitive.

Senior project team SMV Dynomics will assist CPSMV by designing a chassis dynamometer. SMV Dynomics hopes to provide a specialized tool that will aid in tuning the team's vehicles for maximum fuel efficiency. The goal of the project is to design and construct a portable chassis dynamometer that will test all of CPSMV's vehicles. The main objective of the chassis dynamometer is to measure speed, power output and torque output.

The main constraints facing this project are design constraints, monetary constraints, and time constraints. The design constraints are focused on the portability of the system, the time require to set up and test the vehicles, the safety of operation, as well as the accuracy of the measurements. The budget for this project is of $2,500 while the time constraint is of one academic year for full completion of the project.

The full report provides a detail description of the customer requirements, the research conducted, the ideas generated, and the analysis performed by SMV Dynomics to design the best vehicle testing tool for CPSMV.

Specific Design Requirements

The following requirements list was provided by CPSMV to SMV Dynomics and details the features that the chassis dynamometer must incorporate:

- Must work with 1 wheel drive vehicles
- Must work with both urban concept and prototype vehicles using the dimensions specified in the 2012 Shell EcoMarathon Americas rules
- Needs to fit a tire radius of 6.5 – 15 inches
    - Width between 0.9 inches to 6 inches
- Works with engines between 0.25 hp and 10 hp
- Includes troubleshooting manual, user guide, and schematics
- Real time display of vehicle speed, torque, and power
    - Speed Range: 0-40 mph, resolution: 1 mph
    - Torque Range: 0-25 ft/lbs, resolution: 1 ft-lb
    - Power Range: 0 to 5 HP, resolution: .1 HP
- Accuracy:
    - Speed: ± 1 mph
    - Torque: ± 1 ft/lbs
    - Power: ± 0.1 HP
- Total weight less than 100 pounds
- Collapsed dimensions smaller than 3' x 3' x 3'
    - Dimensions fits in cage, fits in trailer with both vehicles (collapsible)
- Drop and Go Dyno Operation
    - Removal of any vehicle components is unnecessary
    - Physical attachment of dyno and vehicle unnecessary
- Must be able to change engine loads smoothly while engine is running
- Equipped with a wide band O2 sensor and readout display
- Setup time of 8 minutes or less
- Approximately 30 min of maintenance per 25 hours of operation
- Maximum budget of $2500
- Any power is supplied by a standard wall socket (120V 15Amp AC single phase 60hz) or batteries
- Includes easy method of mounting vehicle (eg. Roll up ramp)
- Vehicle must be secured and unable to roll off the dyno while in use
- Instrumentation:
    - Possibly integrate fuel consumption measurement
- Usable Dyno by March 1st 2012. Any of the below requirements do not need to be completed by this deadline
    - Vehicle settings memory
    - Aesthetically pleasing
        - Logos for Supermileage team, Senior Project team, and University
        - All bare metal surfaces painted or anodized
    - No exposed moving parts (excluding rollers)

Design Specifications

The overall goal of SMV Dynomics is to build an effective and easy to use chassis dynamometer for the CPSMV. **Table 1**provides the formal engineering specifications for this project. The table describes the requirement or target that is to be met and how it will be completed. The table is known as a "compliance" method table. The four different types of methods that can be conducted are:

1. Analysis (A)
2. Test (T)
3. Similarity to Existing Designs (S)
4. Inspection (I)

The table also assesess the risk of meeting each of the engineering targets or specifications by assigning a risk level ranging from High (H), Medium (M), and Low (L) to each.

Table 1: Chassis dynamometer formal engineering requirements.

Spec. #	Parameter Description	Requirement or Target (units)	Tolerance	Risk	Compliance
1	Due date	Working design: March 2012 Final design: June 2012	N/A	H	A, T
2	Weight	80 lbs	± 10 lbs	H	A, T
3	Size	3 ft x 3 ft x 3 ft	± 1 ft	H	A, I
4	Production Cost	$2500	Max	H	A
5	Power Handling	1 – 10 HP	Min	M	A, T
6	Torque Handling	0 – 115 ft/lbs	Min	M	A, T
7	Speed Handling	0-40 mph	Min	M	A, T
8	Safety	Not moving parts exposed (except rollers)	N/A	M	I
9	Ergonomics	No previous experience required for use	N/A	L	T, I
10	Maintenance	1 hr maintenance for 100 hr operation	Max	L	A, T
11	Power usage	120V 15Amp AC single phase 60hz) / batteries	Max	L	A, T
12	Setup time	5 minutes or less	± 3 min	L	T
13	Displays	Real time display of vehicle speed, torque, power	N/A	M	A, T
14	Wheel and roller interface	Tire with: Radius: 6.5–15 in Width: 0.9 – 6 in	Radius:± 2'' Width: ± 1''	M	A, T

A high risk was placed on the maximum budget of $2500. This is something that must be kept in mind at all times because it is the limiting factor. Size, weight, and deadline were also important requirements that had to be met in order for successful completion of the project.

The chassis dynamometer must work with both urban concept and prototype vehicles using the dimensions specified in the 2012 Shell EcoMarathon Americas rules. The two vehicles are drastically different in design, so the chassis dynamometer we plan to build must be able to adapt to both vehicles. The Prototype category vehicle is a three-wheel car with a single rear wheel drive. The Urban Concept category is a larger four-wheel, single wheel drive car. It must work for 1 wheel drive vehicles, and support vehicles with 3 and 4 wheels. Due to the difference in wheels for each vehicle the dyno must fit a tire radius of 6.5 to 15 inches with a width between 0.9 inches to 6 inches. Both Supermileage vehicle categories use low power engines; currently the team uses a 2.5 hp Honda GHX 50 engine, and a 4 hp Yamaha 49CC C3 Scooter engine. Therefore the dynamometer needs to work for engines from 0.25 to 6hp.

A troubleshooting manual, user guide, and schematics diagram will be made to allow anyone with minimum vehicle testing experience to set up and test CPSMV's vehicles. There will be no exposed moving parts, excluding rollers. Sharp edges and points will be rounded (1/8 in radius max). A real time display of vehicle speed, torque, and power will allow for easy tuning. The speed will range from 0 to 40 mph, and have a resolution of 1 mph. The torque will range from 0 to 16.6 ft-lbs with a resolution of 1 ft-lb. The power will have a range of 0 to 10 hp with a resolution of 0.1 hp. For additional accuracy the dyno must change engine loads smoothly while the engine is running. Also limit slip of wheels to less than 1% is required for accuracy.

CPSMV informed us that they would like to bring the dyno to competition. This means that it needs to be lightweight, compact (fit into cage and trailer with both vehicles), easy to move, and fast to set up. We were given a goal of weight less than 100 lb, collapsed dimensions smaller than 3' x 3' x 3', and a setup time of five minutes or less. For a fast setup the dynamometer will be "drop and go" with no removal of any vehicle components and no need to directly attach the vehicle to it (except for data cables). It must have an easy method of mounting the vehicle securely and level. Considering the power sources at competition, any power must be supplied by a standard wall socket (120V 15Amp AC single phase 60hz) or batteries. The dyno must have a maximum of approximately 1 hour of maintenance per 100 hours of operations so that it does not need to be serviced at competition.

The current competition driving strategy is the burn and coast method, where the vehicles quickly accelerate at full throttle to 25mph or 30mph before turning off the engine and coasting down to about 8mph. The power and speed requirements are drawn mostly from the current competition and engine setup. SMV Dynomics plans to complete the chassis dynamometer by June 2012.

Chapter 2: Background

This section will provide the user with information regarding the important aspects of chassis dynamometers and existing chassis dynamometers in the market.

Chassis Dynamometers

A chassis dynamometer measures the power delivered to a vehicle's wheel from the engine. The chassis dynamometer collects data through the vehicle's tire rotation. **Figure 1** shows a vehicle parked on rollers that are free to rotate as the vehicle's speed is increased. Chassis dynamometers provide loading to the vehicle's wheel in order to simulate road conditions. The vehicle's response to this loading is what the dynamometer measures in terms of speed, power and torque.

Figure 1: Typical chassis dynamometer.
<http://www.allstates.com/late_model_1999_dyno_with_comput.htm>

Many small engine dynamometers already exist on the market, however none of them fully meet the basic requirements of the Supermileage team. The small chassis dynamometers available do not have a low enough power range and are outside the budget of the team. For example the Land-and-Sea DYNOmite Kart dynamometers seen in **Figure 2** start at $5000 and are not suited for the low power range of the Supermileage vehicles.

Figure 2: Land-and-Sea DYNOmite Kart dynamometer.

<http://www.land-and-sea.com/kart-dyno/kart-chassis-dyno.htm>

Another product that would work for the team's application would be TRIK-DYNO, LLC's TRIK-250A portable RC Engine Dyno (**Figure 3**). It meets the small power requirements for the supermileage vehicles, but it is not a chassis dynamometer. It is also beyond the team's budget at a cost of $3700.

Figure 3: TRIK-DYNO, LLC's TRIK-250A
<http://trik-dyno.com/prod01.htm>

In addition, there are many types of chassis dynamometers and they differentiate by the component that provides the loading to the vehicle's wheels. **Figure 4**shows an eddy current load absorption unit that is used in many modern chassis dynamometers. Even though the eddy current unit is very light when compared to the other systems of loading and provides greater accuracy in terms of the amount of loading provided, it is the most expensive.

Figure 4: Eddy current absorption unit.

<http://www.dynojet.com/motorcycle_dyno/default.aspx>

Another type of system used in chassis dynamometers is water-break loading. Figure **5** shows a typical water-break loading system attached to an engine's shaft to

measure the engine's power output. Water-break systems are relatively inexpensive and versatile. However, they are not portable since a water source needs to be readily available in order to have a working chassis dynamometer.

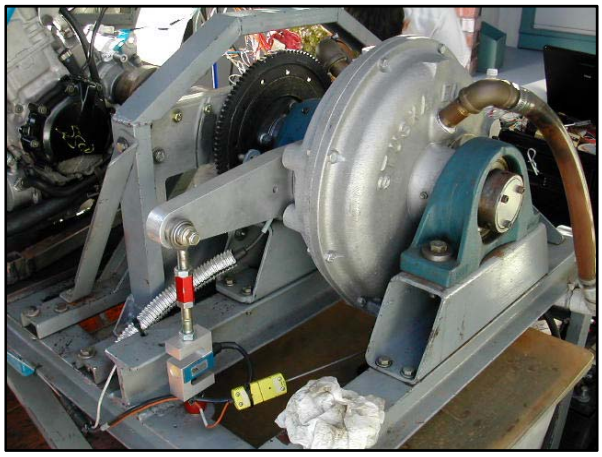


Figure 5: Water-break loading system.
<http://www.me.berkeley.edu/ME102/Past_Proj/f03/Proj11/discuss.htm>

The other popular type of chassis dynamometer utilizes a hydraulic system. Hydraulics is the term used to describe the application of fluid power to produce work. There are several advantages of hydraulics systems over other systems. Hydraulic systems can provide variable speed, high power to weight ratios, low installation space requirements, simple closed-loop controllability, high durability and overload safety, and low maintenance requirements. They are commonly used in engine dynamometers because of their versatility and because they are easy to build. **Figure 6** shows a typical engine dynamometer that utilizes a hydraulic system to load the engine.

Figure 6: Hydraulic dynamometer with pump and valves.

<http://inertiadyno.com/inertia-dyno/inertia-dyno-with-load-sensing-hydraulics/>

Chapter 3: Design Development

The conceptual design of the chassis dynamometer was broken into major subsystems that included the roller frame, the control system, the engine loading, and data measurement (**Table 2**). Top concept models for each subsystem were selected based on the customer requirements. The resulting final concept is the combination of all three top subsystem designs.

Table 2: Possible concept design combinations.

Roller Frame	Control System	Engine Loading	Data Measurement
Tube structure ramp	LabView + Daq	Hydraulic pump	Torque and rpm
Sheet metal structure	Simulink + Daq	Eddy current	Pressure/current and rpm
Stackable units	Microcontroller	Electric motor	
		Disk Brake	

For the frame structure, the most important aspects were weight, cost, ease of manufacturing, and aesthetics. We decided that the best frame would be a tubular structure with a sheet metal skin based on the decision matrix show in **Table 3**. The sheet metal frame was too heavy for our specifications and edges would be difficult to precisely cut, even though it would require much fewer parts. The stackable unit was deemed unnecessarily complex, even though it would make transportation and storage simple.

Table 3: Comparison matrix of top ideas.

Roller Frame	Weight	Cost	Ease of Manufacture	Simplicity	Total
Importance	*0.3*	*0.3*	*0.2*	*0.2*	*100*
Tube structure ramp	100	50	75	75	75
Sheet metal ramp	25	50	100	100	62.5
Stackable units	50	50	50	50	50

Figure 7shows the initial two frame concept designs. The left design shows a tube structure while the right design shows a stackable units model.

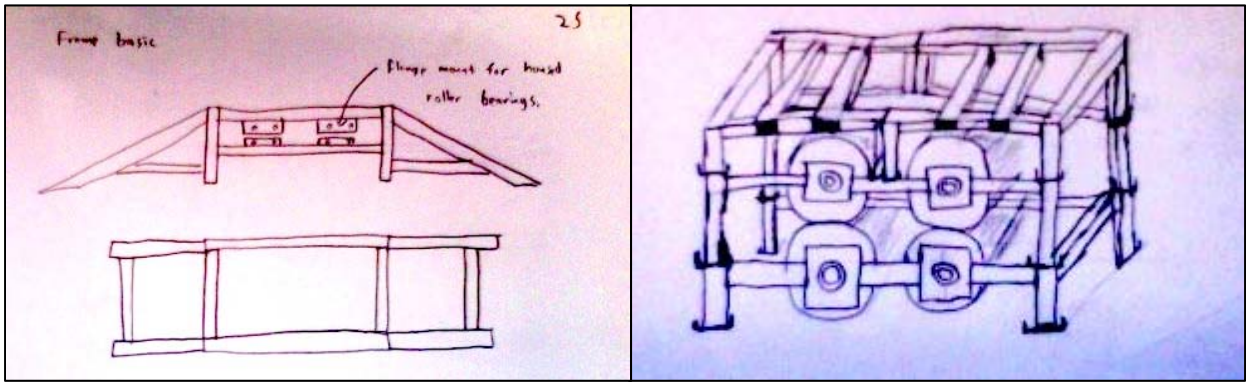


Figure 7: Tube structure ramp (left) stackable units (right).

The most important aspects of the engine loading system were suitability, cost, and ease of implementation. The hydraulic pump and needle valve was chosen as the engine loading system based on the decision matrix in **Table 4**. The disk brake method would be hard to control and would require constant maintenance and calibration. Most chassis dynamometers use eddy current brakes but they are a costly implementation. Using an electric generator would not allow to control the load with accuracy.

Table 4: Engine loading decision matrix.

Engine Loading	Reliability	Cost	Ease of Implementation	Control	Total
Importance	*0.3*	*0.2*	*0.2*	*0.3*	*100*
Hydraulic Pump	100	100	75	100	95
Electric generator	100	100	75	25	80
Eddy Current Brake	100	0	50	100	70
Disk Brake	50	75	100	50	65

Table 5 shows the decision matrix for the Control and DAQ system. The LabView and computer connectable DAQ system had the highest because it was the cheapest and easiest to use with adequate room for customization. Dr. Ridgely will provide us with the DAQ board and give us access to Cal Poly's license of LabView. Using Simulink to control the hydraulic system requires us to purchase expensive equipment. There is also a limit to what we can do with Simulink and we feel that we cannot expand or customize it as much as we would like. Using Dr. Ridgely's Minestrone microcontroller is not time efficient since it would require learning and getting experience working with microcontrollers.

Table 5: Control and DAQ decision matrix.

Control System	Cost	Ease of use	Expansion Capability	Total
Importance	*0.25*	*0.50*	*0.25*	*100*
LabView + DAQ	75	100	75	87.50
Simulink Control	50	75	25	56.25
Microcontroller	50	25	100	50.00

We considered two methods for obtaining the power measurements; measuring torque from the roller shaft and RPM of the rollers, or measuring pressure in the hydraulic system and RPM of the pump. Because the efficiency of the pump varies with fluid viscosity and speed, we determined that taking measurements from the hydraulic or electrical system would be less precise than taking measurements from the mechanical components. In the end, we decided to measure the RPM and torque from the rollers and shaft.

Final Concept Design

The final concept design includes the following features (**Figure 8**):

- A tubular frame structure
- A hydraulic pump to load the engine
- LabView to log data and control the system.
- Power measurements would come from measuring torque and RPM from a roller

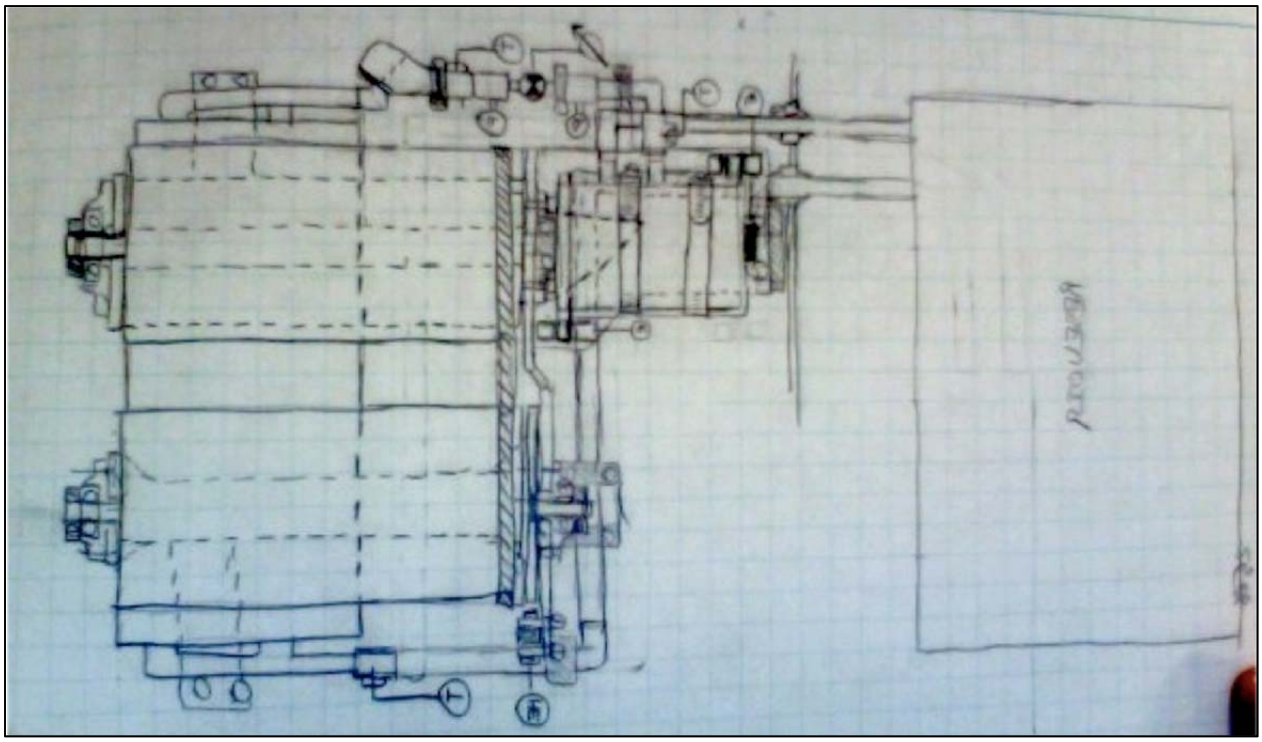


Figure 8: Sample layout of final conceptual chassis dynamometer design (Top View).

Chapter 4: Description of the Final Design

The final design consists of three subsystems, the mechanical system, the hydraulic system, and the data acquisition system. The mechanical system includes the frame, the rollers, and the mechanism that enables the accurate measurement of torque. The hydraulic system is a hydraulic circuit that comprises a pump, a needle valve, strainer, heat exchanger, and reservoir. Its purpose is to load the engine. The DAQ system processes the rpm and torque readings and will control the load on the engine.

The vehicle's drive wheel will be placed on the roller assembly, while the rest of the vehicle is tied down to other blocks. One of the rollers is connected to the hydraulic pump through its shaft by a shaft coupling. When the vehicle applies power to the drive wheel, the hydraulic system places a load onto the vehicle. This load is meant to simulate the vehicle's acceleration and road load under operating conditions.

The rollers are supported by roller bearings on both sides of each roller. The bearings are mounted to the frame.

The power the vehicle delivers to the drive wheel is computed from the measured torque and the measured rpm. RPM measurements are taken by a hall-effect sensor detecting a set of metal plates attached to the rollers. The signals are fed to the control system, where it is processed to give a power reading.

The torque measurements are obtained from the torque the pump exerts onto the rollers. The pump and the pump mount are constrained such that it can "free rotate" about its shaft axis. A load cell is attached to the pump mount such that it constrains the "free rotation" of the pump. This way, the force transducer resists all of the torque provided by the pump. The torque is the calculated by multiplying the force reading from the transducer by its distance to the shaft axis. The load on the engine is controlled by restricting the flow of hydraulic fluid through the hydraulic system.

Final Design

Figure 9 shows the full view of the all in one ramp Dynamometer. The 6 inch rollers are represented as the two black cylinders in the center of the ramp. The ramp design will allow vehicle to be rolled onto the Dynamometer for easy roll on roll off operation.

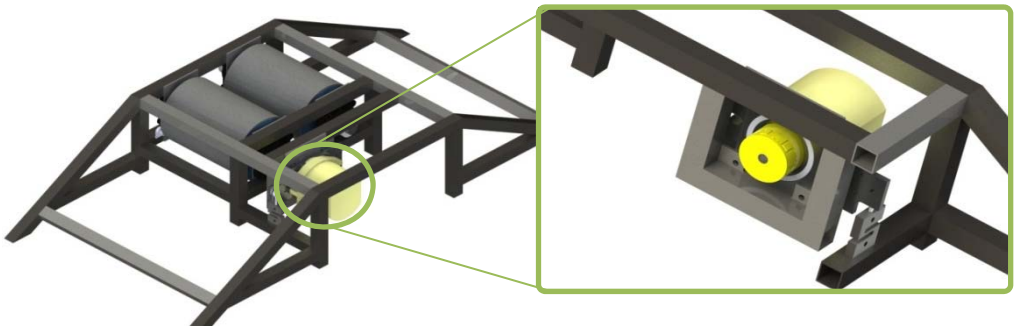


Figure 9: Close view of pump cradle.

Figure 10 shows the exploded view of the drive shaft assembly. The pump is mounted to a free rotating plate, which is attached to the frame. A shaft coupling connects the pump and the roller shaft.

Figure 10: Exploded view of pump and pump cradle.

Figure 11 represents the chassis dynamometer, showing how the parts fit inside the ramp enclosure.

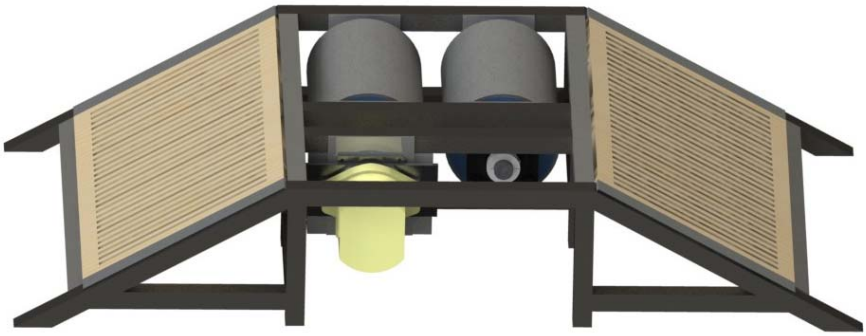


Figure 11: Front view and isometric view of chassis dynamometer.

Figure 12 shows the exploded view of the chassis dynamometer, including all of the hardware that holds the frame together. **Figure 13** shows the full and section view of the chassis dynamometer. **Figure 14** shows the exploded view of the roller assembly, which includes the components used to make each individual roller.

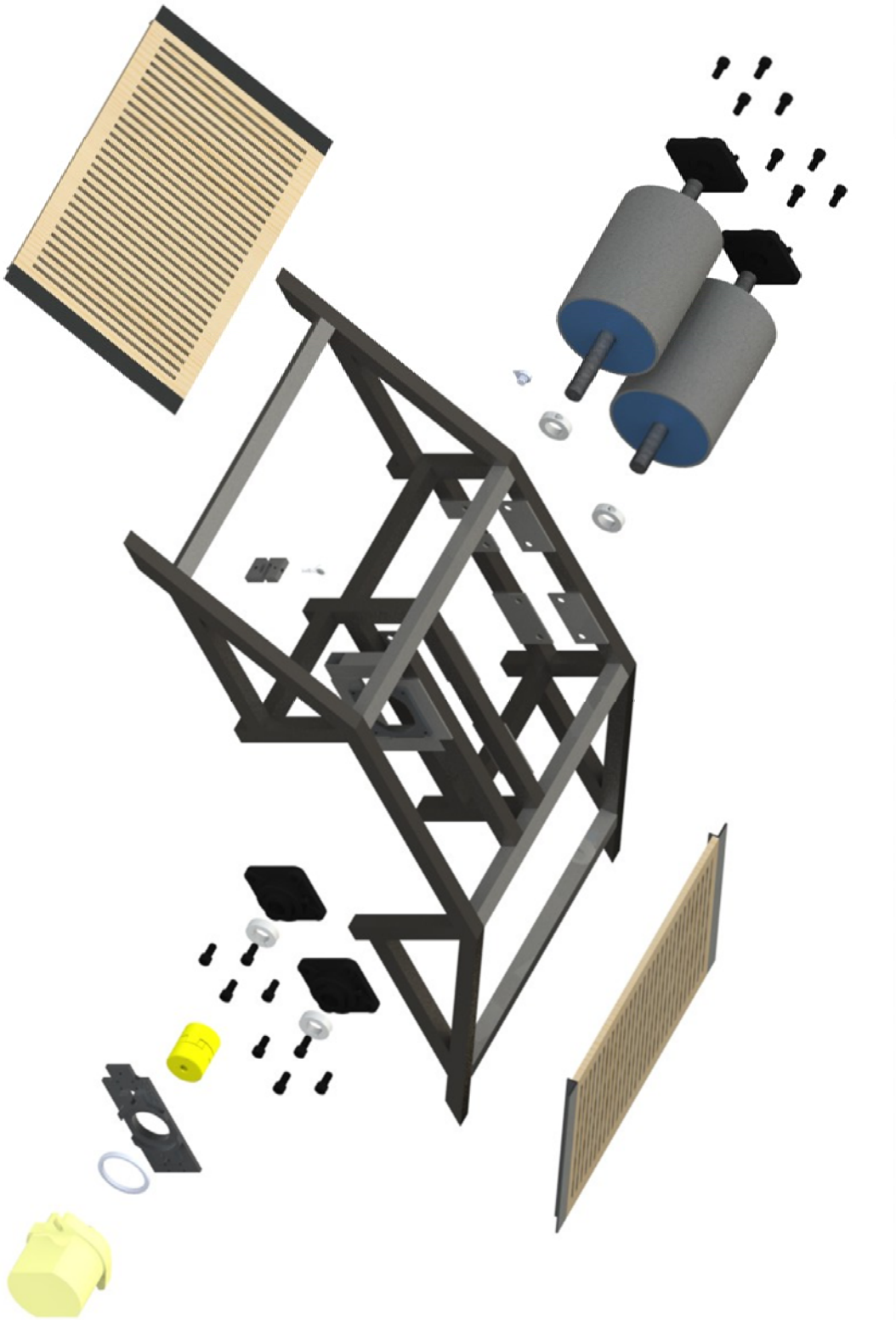


Figure 12: Exploded view of chassis dynamometer.

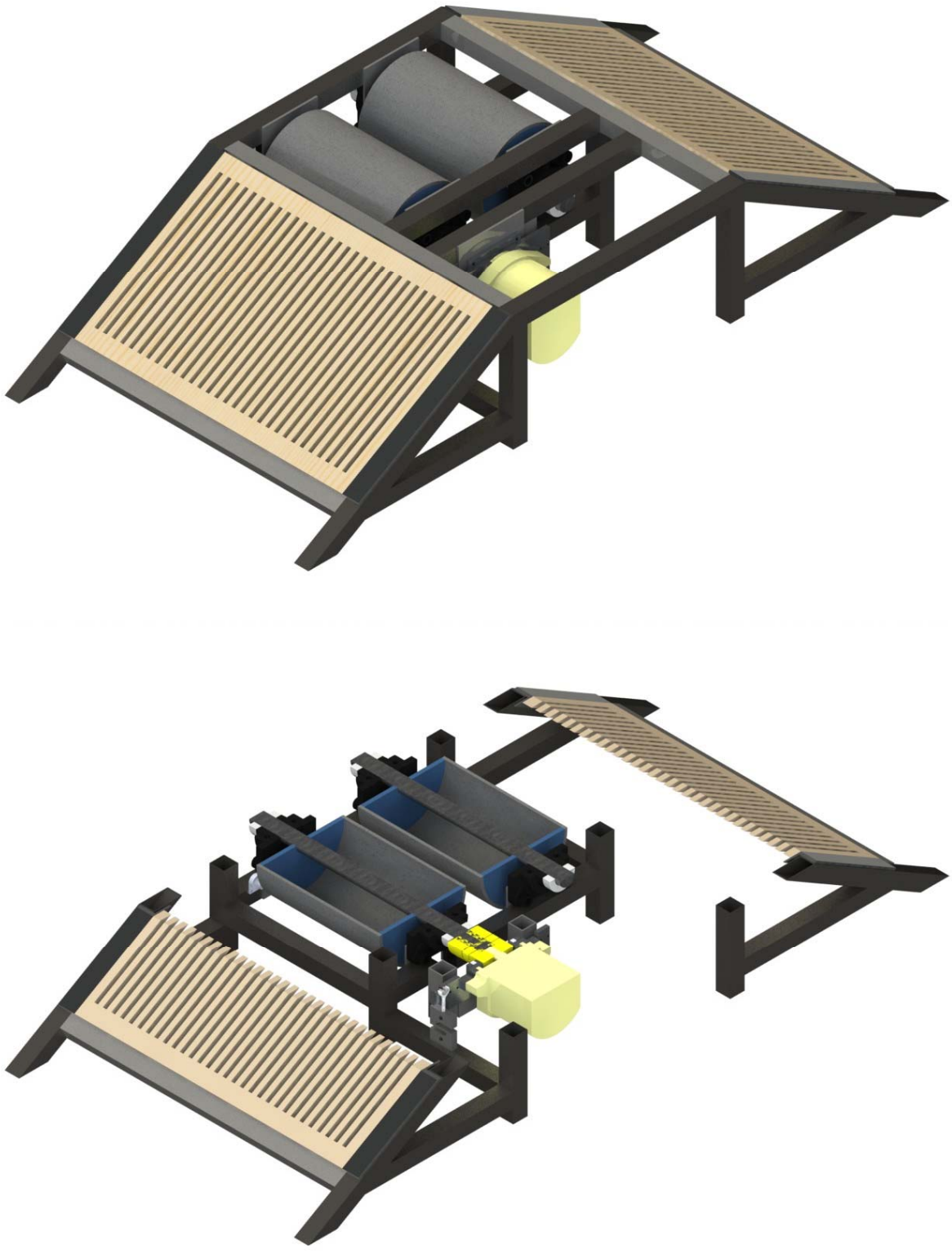


Figure 13: Full view and section view of chassis dynamometer.

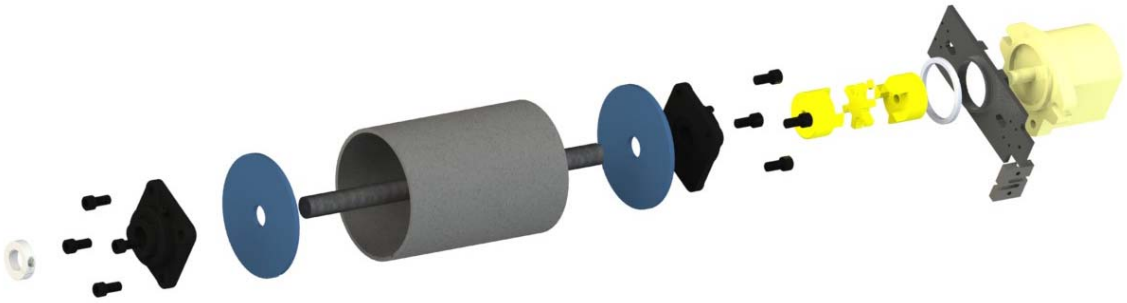


Figure 14: Exploded view of roller assembly.

Figure 15 shows the measurement of the forces and the dynamic effect that the working fluid provides. The torque and power at the wheels is obtained by measuring the pump torque and the RPM of the rollers. Easy access panels are located on both sides of the ramp and above the pump for easy maintenance.

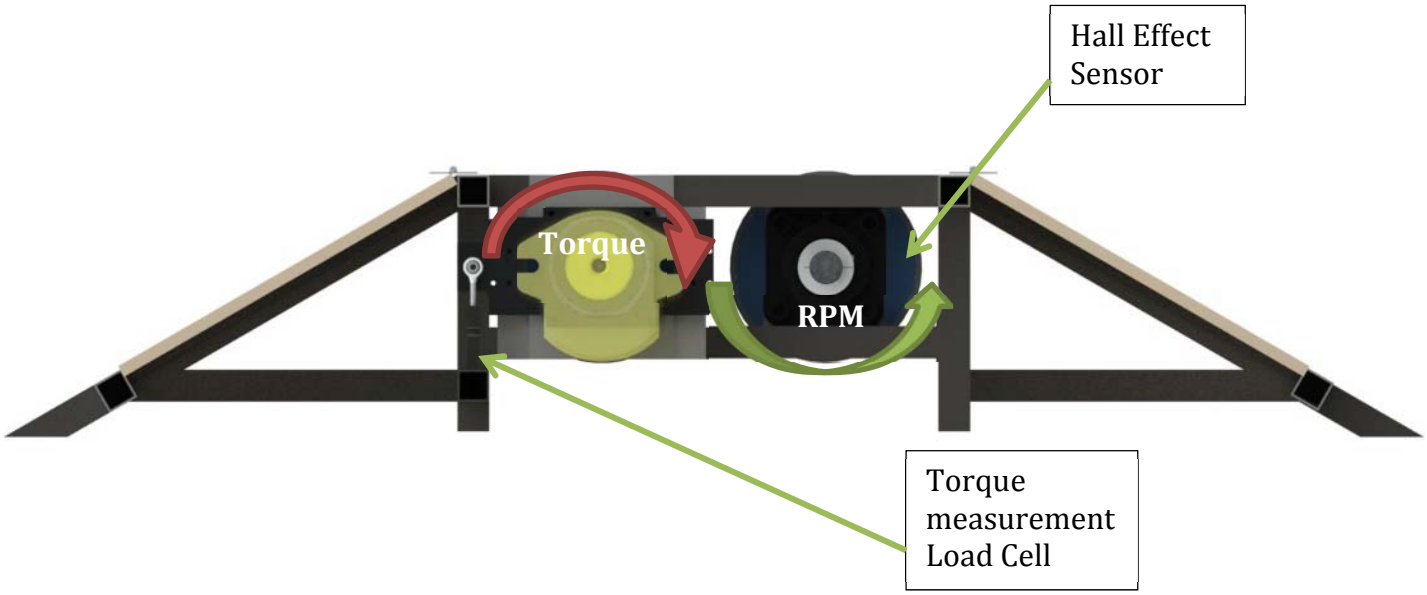


Figure 15: Roller assembly operation.

Hydraulic Loading

One of the subsystems of the chassis dynamometer is the loading subsystem that will simulate normal road conditions by providing a load to the vehicle's wheel. A generic hydraulic system was developed to show how the loading system would operate. **Figure 16** shows the integration of all hydraulic components into a hydraulic circuit. The hydraulic circuit consists of a hydraulic gear pump (1), a pressure gauge (2), a flow control valve (3), a temperature sensor (4), a strainer (5), and a reservoir (6).

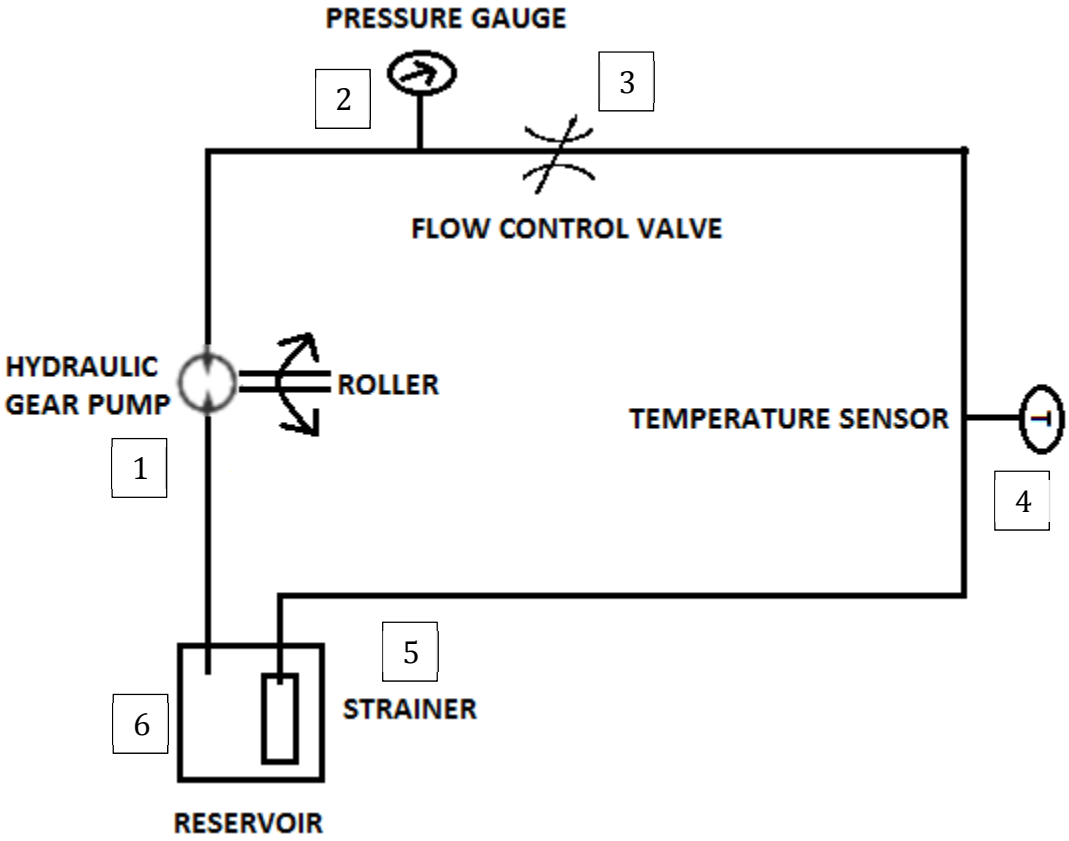


Figure 16: Generic hydraulic system that will simulate road conditions.

Figure 17 shows the basic operation of the hydraulic system, in the correct sequence, at maximum operating conditions.

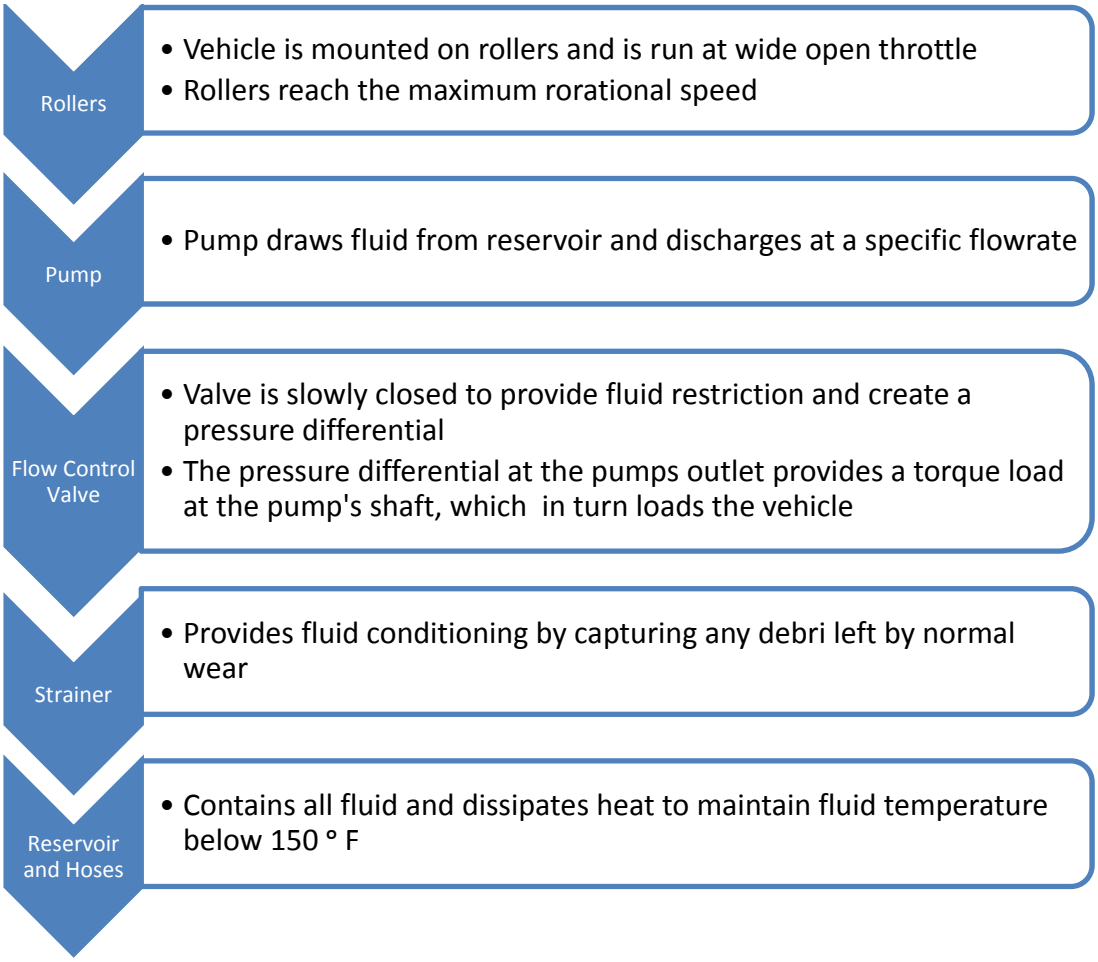


Figure 17: Basic operation of generic hydraulic system.

In addition to the main hydraulic components, a pressure gauge upstream of the flow control valve will allow the user to monitor the pressure. A temperature gauge downstream of the flow control valve will monitor temperature to make sure that temperature stays below 150°F.

The operating conditions of CPSMV's vehicles were analyzed before specifying each hydraulic component. **Table 6** shows the assumed maximum operating conditions for the current vehicles of CPSMV.

Table 6: Performance characteristics for Capax and Prototype vehicles.

Specification	Capax	Prototype
Max Power (HP)	3.0	2.4
Peak Toque (lbf-ft)	3.5	2.0
Max Speed (mph)	35	40
Total weight with driver (lbf)	450	339

Using the maximum speed of 40 mph as the limiting factor, we determine that the maximum rotational speed of the rollers is 2244 rpm. Since the rollers will be directly coupled with the pump's shaft, we can say that the maximum speed the gear pump will operate at is 2244 rpm also. Refer to **Appendix F**: for sample calculation of rotational speed.

Next, the required output flow must be calculated from the pump's operating speed. Utilizing the smallest pump possible (fluid displacement of .40 in^3/rev) in order to achieve the lowest possible output flow, we calculated the actual output flow to be 3.89gpm. Refer to **Appendix F**: for sample calculation of output flow.

In order to calculate the maximum loading required, the maximum weight of the vehicles must be considered. Utilizing 450lbf as the limiting factor, the maximum torque than can be applied to the wheels before slipping occurs is 16lbf-ft. For this calculation a static friction of 1 between tire and rollers was assumed. It was also assumed that there is no slip from the belt connecting the rollers at this load. Refer to **Appendix F**: for sample calculation of maximum torque required.

From the maximum shaft torque of 16lbf-ft, the required pressure loading at the pump's outlet was calculated to be 3016psi. Refer to **Appendix F**: for sample calculation of maximum pressure loading required.

The maximum fluid horsepower developed, which can be calculated from the pressure and flow rate, turns out to be 6.85HP. This translates heat generation of 17,729 Btu/hr. Refer to **Appendix F**: for sample calculation of horsepower developed and heat generated.

Temperature Control

An important consideration of hydraulic systems is heat generation. Flow restrictions create a pressure differential and also increase fluid temperature significantly. Maximum working fluid temperature should not exceed 150°F. Operating temperatures above 150°F will change the properties of the hydraulic fluid. This could lead to oxidation of the oil, deterioration of seals, and changes in viscosity. A drastic change in viscosity could lead to metal-to-metal contact and damage would occur.

The greatest pressure drop in the hydraulic system is across the flow control valve. The equivalent heat generation at this location is of 17,729 Btu/hr, or 6.85HP at continuous operation. However, since the dyno will only be operating at two minute intervals, the operating heat generation that the dyno will see is only 590 Btu/hr. **Figure 18** shows the heat generated in the hydraulic system. See **Appendix F**: for sample calculation.

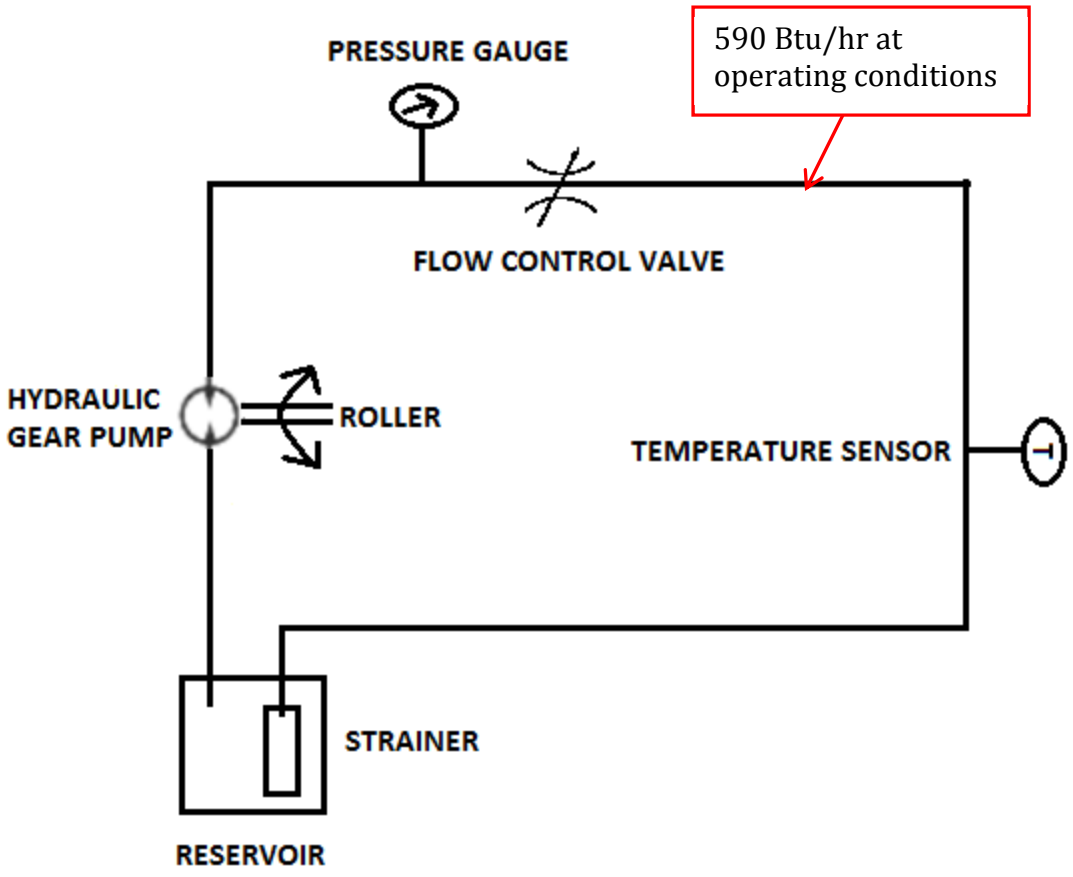


Figure 18: Heat generated by restriction of fluid control valve.

Table 7 shows the total heat generated by the system. A total of 9.98HP is produced by the losses in the system. The reservoir alone is only able to dissipate 759.23Btu/hr, or 0.298HP. See **Appendix F**: for sample calculations. A heat exchanger with a dissipation capacity of 35,897.4 Btu/hr, or 14HP was used in order to keep fluid temperature under 150°F.

Table 7: Total heat generated by system.

Component	Heat Generated (Btu/hr)	(HP)
Pump outlet	17420	6.85
Needle Valve	200	.079
Filter	109	0.04
Total	17729	6.97
Total at Operating Conditions	590	0.23

Structural Integrity of the Frame, Roller, and Pump Mount:
All of the frame and roller components are structurally sound for the intended loading.

The frame has yield safety factor of approximately 5 and a maximum deflection of 0.019 inches. This was found by assuming a vehicle and driver weight of 600 lbf. The weight is equally distributed onto the two rollers, which are supported by two bearings. Each side of the frame sees 300 lbf of loading. Since the structure is statically indeterminate, the problem was simplified by removing the bottom bearing flange support beam. This makes the analysis analogous to a beam supported on two ends. (see **Appendix F**:)

The 1" roller bearings will support a maximum load of 150 lbf. Each bearing is rated to for 500 lbf for a dynamic radial load.

With the stresses induced by the vertical load and the torque, the one-inch roller shaft has a yield safety factor of 4 with maximum designed loading conditions. This was calculated by applying a 150 lbf shear force and adding an 30 ft lb torque (see **Appendix F**:).

The pump mount was analyzed as a cantilevered beam with a point load attached to the end. This effectively represents the anchoring force of the torque transducer. This part has yield safety factor of 3.6 and a maximum deflection of 0.015 inches. This was found by assuming a 30ft-lb torque on the pump shaft (see **Appendix F**:).

Material, Geometry and Component Selection for Chassis Dyno Frame:
Material, geometry and component selection for the dynamometer was determined based on structural integrity, assembly time, and cost (**Table 8**).

The frame needed to be welded together and have flat surfaces to mount bearings and hydraulic components to. The A513 steel square tubing met those requirements and was also a low cost material. Even though a low weight was a requirement and a thinner wall tube, 0.035", could have been used, we felt that due to time limitations, we did not have time to TIG weld the thin walled tubes, so a thicker 0.065" wall thickness was chosen. The thicker wall tube allows us to MIG weld the frame together.

The bearing flange mount plates needed to be welded to the frame, so a similar steel was chosen.

The pump mount needs to be CNC machined, so we chose to make it out of 6061-T6 aluminum. This material is cost effective, strong enough for its application, and easy to machine.

The bearings were selected based on the shaft sizes and expected loads. The housed bearings, McMaster part 6494K330 was selected to support the roller shaft because it was the lowest cost housed bearing that met the load and shaft diameter requirements. We decided to use housed bearings because they are easy to install onto the frame. A custom bearing mount was not required.

The 2.5" inner diameter bearing part used to support the pump mount was selected because it was the cheapest bearing that met the dimensional requirements.

Geometry selection:
The roller diameter of 6 inches was decided because the rotation rate of at a surface speed of 40 mph worked well to drive the selected hydraulic pump. The 40 mph surface speed is the maximum vehicle speed our dyno is designed to simulate.

The roller length of 8.5 inches was specified because it gives clearance to the widest tire of 6 inches that the dyno is designed to work with.

Table 8: Material selection for frame.

Component	Material	Justification
Frame	ASTM A513 1" 0.065 WT square tube	Low price, good weldability, sufficient strength
Bearing Flange Mount	1018 Steel 0.125 plate	Low price, good weldability, sufficient strength
Pump Mount	6061-T6 1.25" aluminum plate	Low price, good machinability

Sensors and Data Acquisition:

On the dynamometer three temperature sensors, a speed sensor, and a load cell are used to gather data. The power is calculated by P=ωF. The rotational speed is measured by the speed sensor and the force is measured by a load cell. A Cherry geartooth speed sensor was chosen for simplicity and its rugged design. It is easily mounted with an adjustable housing. It is also immune to rotational misalignment, which allows for mounting inaccuracies. The housing is hard coated anodized aluminum. The sensor can operate at 4.5 to 24 volts DC as shown in the appendix, which works with both of the data acquisition systems the team was looking at. The data acquisition system was originally going to be selected according to the projects minimal budget, but the project has since been sponsored by National Instruments Corporation®. The hall-effect geartooth sensor senses the motion of ferrous geartooth targets. The threads on the aluminum housing of the sensor will allow for easy adjustment. It will be mounted very close to the rollers on the dynamometer. A ferrous material (steel) screw is drilled into a roller. Using a digital input/output on the DAQ, every time the ferrous material passes the sensor, a pulse will be displayed in LabView®. From these pulses and the roller diameter of the system LabView converts the signal into revolutions per minuets.

For the temperature sensors, Omega® RTD pipe plug probe sensors were chosen, the specification sheet is attached in **Appendix D**:. An RTD was chosen because it is much more accurate and linear than thermocouples. RTD probes are made for high pressure vessel applications and are rated for up to 2,500 psi. While the maximum pressure in the dynamometer will be 3,000psi near the pump, the temperature sensors will be in the reservoir and near the heat exchanger where the pressure will be minimal. The mounting threads on the probes allow for a simple attachment point at a T in the hose or to be screwed into the side of the reservoir. The RTD probes have a maximum of 450 degrees Fahrenheit which is well above the maximum temperature of the system of 150 degrees Fahrenheit. The force measurement is taken by an S-beam load cell. The load cell was chosen because it was donated by Dr. Joseph Mello and it met the specifications of 100lb from the max torque of 360 lbin in the appendix calculations.

The data acquisition system is a modular compactDAQ donated by the National Instruments Corporation®. The DAQ was selected for our specifications and the sensor specifications. Expansion of the data acquisition is much easier with the 2-24 bit analog input modules. The analog input comes with USB, Ethernet, and wireless connectivity. It also has built in quarter, half, and full-bridge support. A built in current and voltage excitation is perfect for strain gages and load cells. However the excitation for the speed sensor is three 9 volt batteries in series. This is because the maximum excitation voltage the analog module can provide is four volts. RTD measurements are also supported by the analog inputs. The load cell and the temperature sensors will use 1 channel each and each analog module has 4 channels. Therefore there will be 4-6 channels for additional analog sensors, depending on how many temperature sensors are used. The sinking digital input module has 8 channels and is 12 to 24 V logic. The speed sensor will use one digital channel on the digital module. All specification sheets are attached in **Appendix D**:.

LabView is used to manipulate the incoming signal from the DAQ **Figure 19**. The figure below shows the block diagram for the LabView setup. The right side and lower half is the digital input. The bottom half calculates the frequency of the roller, using a sample clock in the DAQ and the counter on the dynamometer. It is then algebraically manipulated to the speed of the wheel on the dynamometer using the fact that the wheel and the roller are at the same tangential velocity. The signal from the analog module 1 comes out of the block DAQ Analog and is separated into the four channels the module physically has. The temperature sensors go to read outs on the front panel, while the load cell uses the calibration best fit line to get the force output. The DAQ assistant for the analog and the digital modules stores the data in a file if needed for later manipulation. The grey border represents the while loop, as this is only a screen shoot.

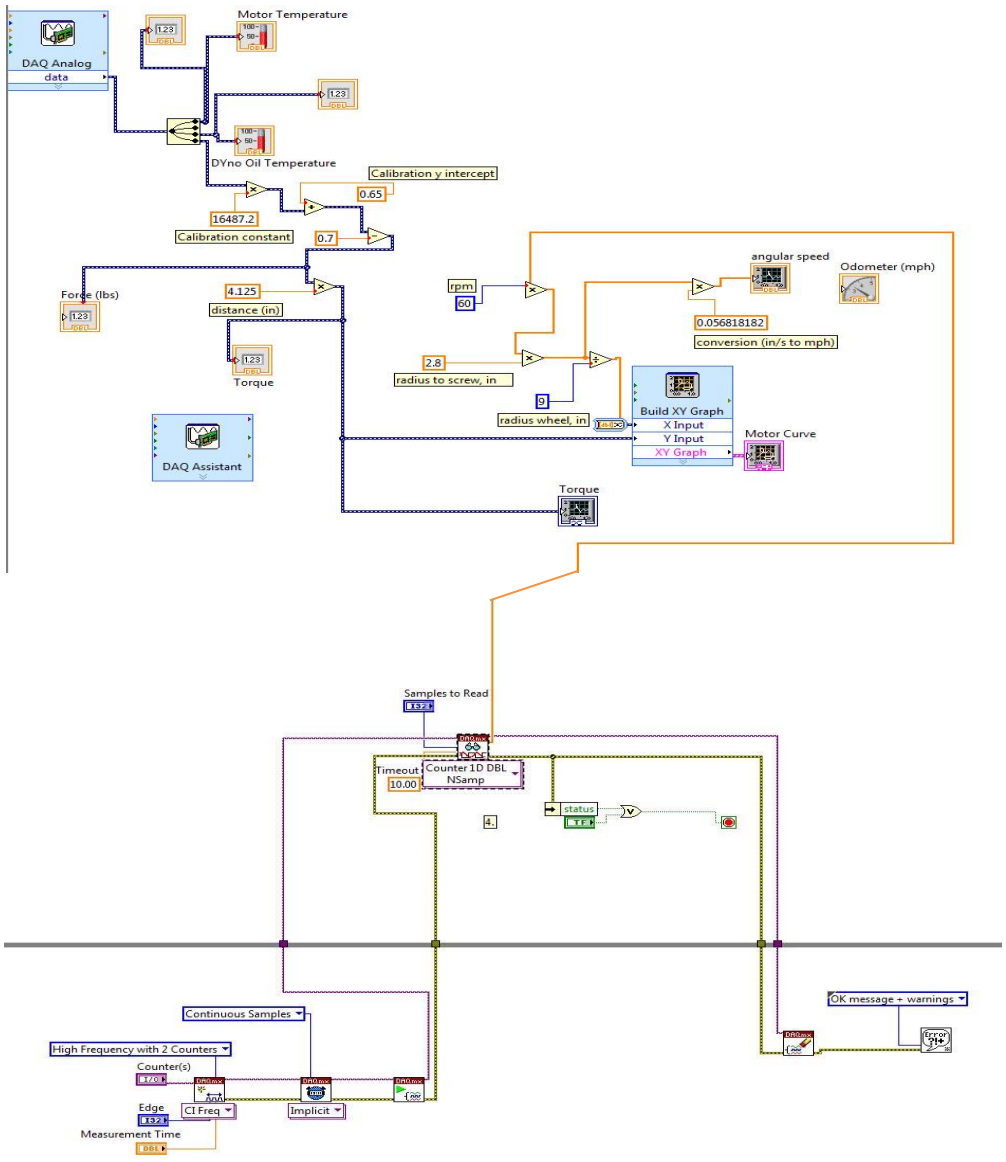


Figure 19: Block Diagram of LabView Torque and RPM Readings

Chassis Dynamometer Costs

One of the requirements for the project was that its total cost should not exceed $2500. Research for sponsor donations was conducted in order to minimize costs. The search was successful since we estimated a total cost of $925.35 for the project (**Table 9**). The final total cost is below the maximum allowable cost of $2500.

Table 9: Total projected costs for chassis dynamometer.

Materials	Total Cost
Frame Tubing	$73.60
Pump Mount plate	$49.39
Bearing Flanges	$11.49
Roller axles	$13.39
Roller Body	$74.80
Roller ends/bearing mount	$32.84
1 in. collar clamps	$14.60
Mounted bearings	$158.96
Ring Bearing	$69.95
7/16-14 nylon locknuts	$8.81
7/16-14 x 7/8 screws	$12.58
Cutting Fee	$9.00
Shipping	$50.03
Pump	$0.00
Needle Valve	$0.00
Reservoir	$100.00
Strainer	$0.00
Hoses	$0.00
Gauges	$0.00
RTD Probes	$208.00
Speed Sensor	$37.91
Load Cell	$0.00
Regulated Power	$0.00
DAQ	$0.00
Total	**$925.35**

Safety Considerations

Extreme precautions should be taken when operating the chassis dynamometer. The chassis dynamometer has rotating parts that can trap and pinch fingers, hands, and feet. Long hair must be tied back and anything loose must be put away. Before the dyno is used, make sure that any body parts are outside of the dyno frame.

Care must be taken to secure the vehicle before running the dyno. If the vehicle isn't secured, and the rollers suddenly stop, the vehicle will be thrown off of the dyno.

The hydraulic system can reach pressures up to 1000 psi. It is critical to the safety of nearby people that the safety panels are attached in case the hydraulic system leaks. Use the dynamometer only in a well-ventilated area. Car exhaust can build up and be harmful to people.

Maintenance Check-Ups

Minimal maintenance will be required for the chassis dynamometer. However, regular check-ups should be performed before each test. The maintenance check-up list includes:

- Check reservoir level on hydraulic system. Reservoir should be filled to about ¾ with standard SAE hydraulic oil.
- Check fasteners and connectors for tightness
- Check that all sensors are tightly secured to the frame and that they are properly connected to the DAQ.
- Check that all sensors are receiving the proper amount of electrical power.

Chapter 5: Design Verification Plan

Once the chassis dynamometer was built, the hydraulic system was run to test for leakage or loose parts. The Supermileage Team's prototype vehicle was placed on the rollers and run at full-open throttle. The needle valve was slowly closed to change the pressure across the needle valve and the change in temperature across the heat exchanger shall be monitored to make sure they don't exceed their limits. If at any time the temperature or pressure exceeded 175 degrees Fahrenheit or 3000 psi, the needle valve will be opened and the car stopped. A thorough inspection of the chassis dynamometer revealed that the system had leakage or loose parts.

The mechanical components of the dyno were tested for operational smoothness and strength. The frame was tested by applying 600 lbf on the top, which resulted in no perceptible deflection. The roller, bearing, and pump assembly was tested for consistant smoothness of rotation. This was simply done by rolling the rollers by hand and detecting any irregularities in the rotation. When the Dyno was assembled with a smooth-working pump, the rollers spun freely with no perceivable interruption in the rotation.

To test the sensors many different tests can be run and a few will be run over the summer. The speed sensor can be calibrated against a bicycle speedometer mounted on a bicycle. The bicycle will be run on the rollers at a constant rate at several speeds. By comparing the speed sensor readings to the bike speedometer readings, the sensor can be calibrated. A plot of speed against counts/min can be used to determine the appropriate correction factor for the speed sensor. The plot will consist of an upscale test, and a downscale test. For the upscale test, speed is increased in each increment. For the downscale test, the speed is decreased for each increment. The purpose of this is to find and correct for any system hysteresis.

The temperature probes can be tested against a thermometer or a thermocouple that is calibrated by using a cup of water or oil. A plot of temperature against sensor output voltage can be used to find the appropriate calibration gain. The test will include an upscale test and a downscale test to find and correct for hysteresis.

The load cell can be calibrated by applying several weights to the load cell and creating a plot of applied against output voltage of the load cell. The slope will give us the sensor gain. An upscale and downscale test will also be performed to find and correct for any hysteresis. To calibrate torque readings, a torque wrench will be used to apply torque to the drive shaft. A plot of torque applied vs voltage out can be used to fine-tune the load cell's calibration by taking that slope and dividing it with the slope of the load cell force vs voltage graph to get the lever arm distance.

All of these tests will be checked using an output to LabView from the DAQ and Measurement Automation. Further calibration and filters are needed as the torque measurement has a lot of noise, as shown in the testing results screen shot (**Figure 20**).

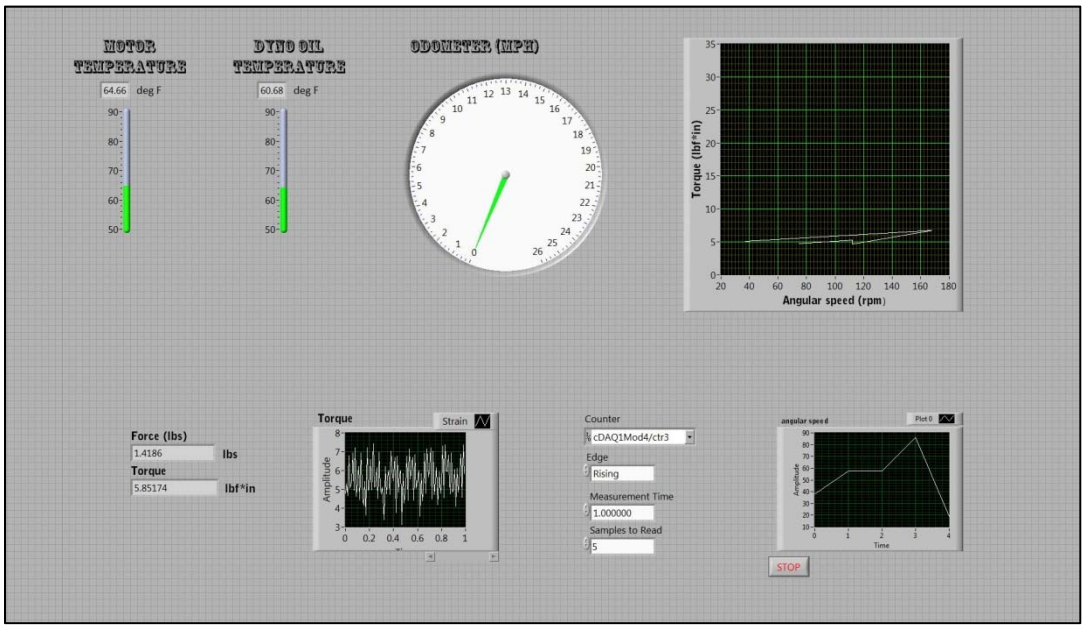


Figure 20: Screen Shot of LabView During Testing of Dyno

Chapter 6: Project Management Plan

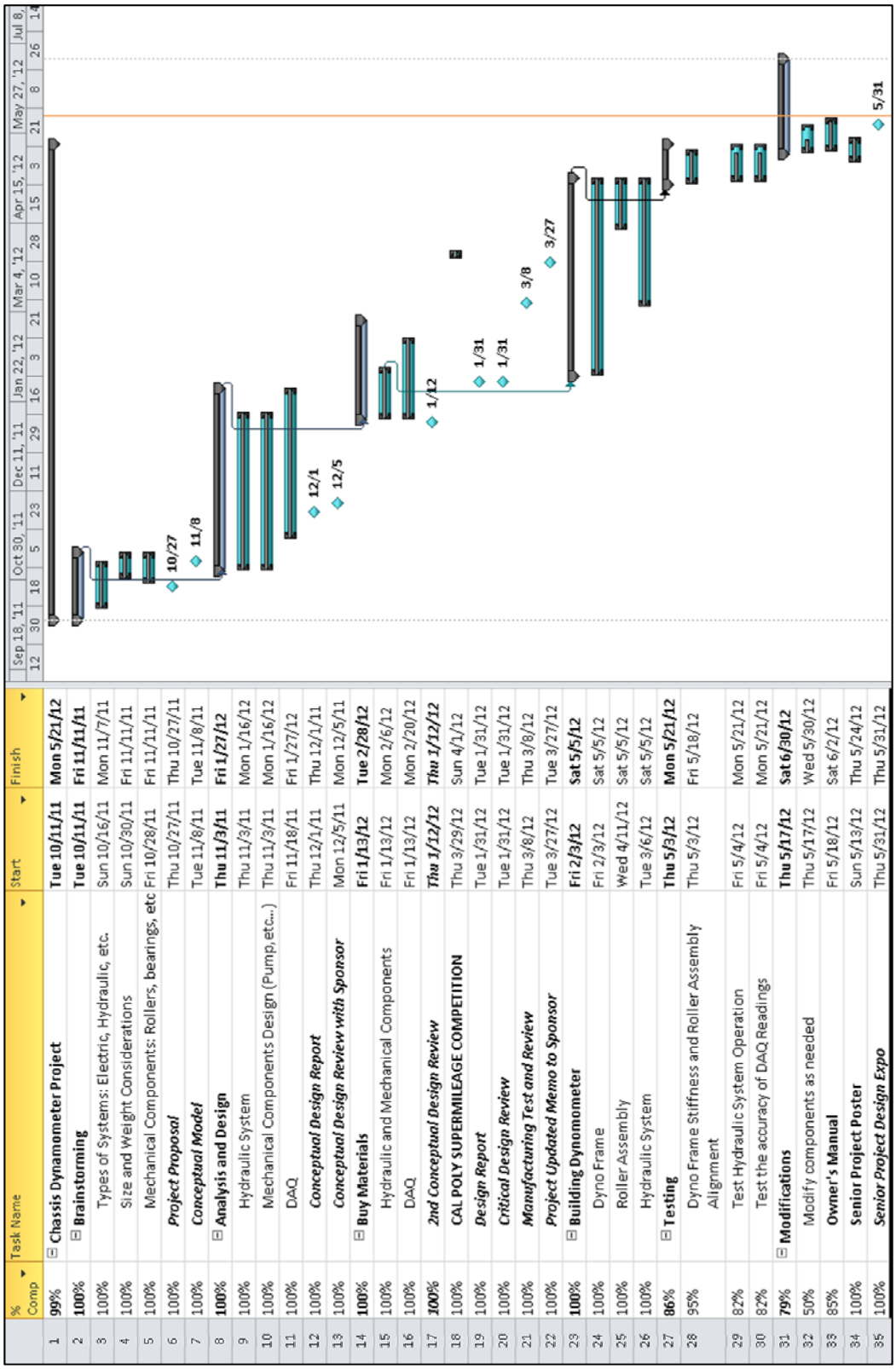
Responsibilities of conduct for team members of SMV Dynomics are outlined in the team contract. For each individual, project manager responsibilities were as follows below.

- Testing and Development Project Manager: Tim Lui
- Research and Design Project Manager: Jose Garcia
- Fabrication, installation, and quality assurance Project Manager: Kyla Purvis
- General Project Manager: Steve Janning

Each person was responsible for setting deadlines and requirements corresponding to their project responsibilities, based upon the best of their knowledge. The general project manager will organize the other project managers. Work groups included all group members for a collaborative system. However, project managers could delegate specific tasks to an individual. This will gave group members a sense of what needed to be done to motivate continual progress rather than slow beginning with a rushed and frantic end. This organization structure helped us keep up with our compact schedule and presents a tight system of checks and balances.

SMV Dynomics Project Timeline

The following Gantt Chart shows the overall scope of the project and the milestones and deadlines that had to be met in order to complete the project successfully.



	% Comp	Task Name	Start	Finish
1	99%	**Chassis Dynamometer Project**	**Tue 10/11/11**	**Mon 5/21/12**
2	100%	**Brainstorming**	**Tue 10/11/11**	**Fri 11/11/11**
3	100%	Types of Systems: Electric, Hydraulic, etc.	Sun 10/16/11	Mon 11/7/11
4	100%	Size and Weight Considerations	Sun 10/30/11	Fri 11/11/11
5	100%	Mechanical Components: Rollers, bearings, etc	Fri 10/28/11	Fri 11/11/11
6	100%	***Project Proposal***	Thu 10/27/11	Thu 10/27/11
7	100%	***Conceptual Model***	Tue 11/8/11	Tue 11/8/11
8	100%	**Analysis and Design**	**Thu 11/3/11**	**Fri 1/27/12**
9	100%	Hydraulic System	Thu 11/3/11	Mon 1/16/12
10	100%	Mechanical Components Design (Pump,etc...)	Thu 11/3/11	Mon 1/16/12
11	100%	DAQ	Fri 11/18/11	Fri 1/27/12
12	100%	***Conceptual Design Report***	Thu 12/1/11	Thu 12/1/11
13	100%	***Conceptual Design Review with Sponsor***	Mon 12/5/11	Mon 12/5/11
14	100%	**Buy Materials**	**Fri 1/13/12**	**Tue 2/28/12**
15	100%	Hydraulic and Mechanical Components	Fri 1/13/12	Mon 2/6/12
16	100%	DAQ	Fri 1/13/12	Mon 2/20/12
17	100%	***2nd Conceptual Design Review***	***Thu 1/12/12***	***Thu 1/12/12***
18	100%	**CAL POLY SUPERMILEAGE COMPETITION**	Thu 3/29/12	Sun 4/1/12
19	100%	***Design Report***	Tue 1/31/12	Tue 1/31/12
20	100%	***Critical Design Review***	Tue 1/31/12	Tue 1/31/12
21	100%	***Manufacturing Test and Review***	Thu 3/8/12	Thu 3/8/12
22	100%	***Project Updated Memo to Sponsor***	Tue 3/27/12	Tue 3/27/12
23	100%	**Building Dynomometer**	**Fri 2/3/12**	**Sat 5/5/12**
24	100%	Dyno Frame	Fri 2/3/12	Sat 5/5/12
25	100%	Roller Assembly	Wed 4/11/12	Sat 5/5/12
26	100%	Hydraulic System	Tue 3/6/12	Sat 5/5/12
27	86%	**Testing**	**Thu 5/3/12**	**Mon 5/21/12**
28	95%	Dyno Frame Stiffness and Roller Assembly Alignment	Thu 5/3/12	Fri 5/18/12
29	82%	Test Hydraulic System Operation	Fri 5/4/12	Mon 5/21/12
30	82%	Test the accuracy of DAQ Readings	Fri 5/4/12	Mon 5/21/12
31	79%	**Modifications**	**Thu 5/17/12**	**Sat 6/30/12**
32	50%	Modify components as needed	Thu 5/17/12	Wed 5/30/12
33	85%	**Owner's Manual**	Fri 5/18/12	Sat 6/2/12
34	100%	**Senior Project Poster**	Sun 5/13/12	Thu 5/24/12
35	100%	***Senior Project Design Expo***	Thu 5/31/12	Thu 5/31/12

Chapter 7: Conclusions and Recommendations

The main components needed for proper dyno operation were assembled and tested. The mechanical and hydraulic systems work as intended and passed their respective tests. The data acquisition system is capable of reading speed, torque, and power delivered to the rollers. The data acquisition system is also still capable of many more sensor inputs that may be added in the future.

Note that there are several small issues with the dyno. First, the rollers have a perceptible wobble, and at high speeds, this results in a lot of vibration. Also, the force transducer shows a lot of noise. The vibration due to the wobble may be the main source of the noise and the noise needs to be filtered out. The rollers should also be remade with less wobble.

Appendix A: Sponsors and Vendors

The following table lists all of the sponsors, as well as the vendors, that were contacted for project funding. Thanks to their generosity and/or product service SMV Dynomics was able to complete the chassis dynamometer.

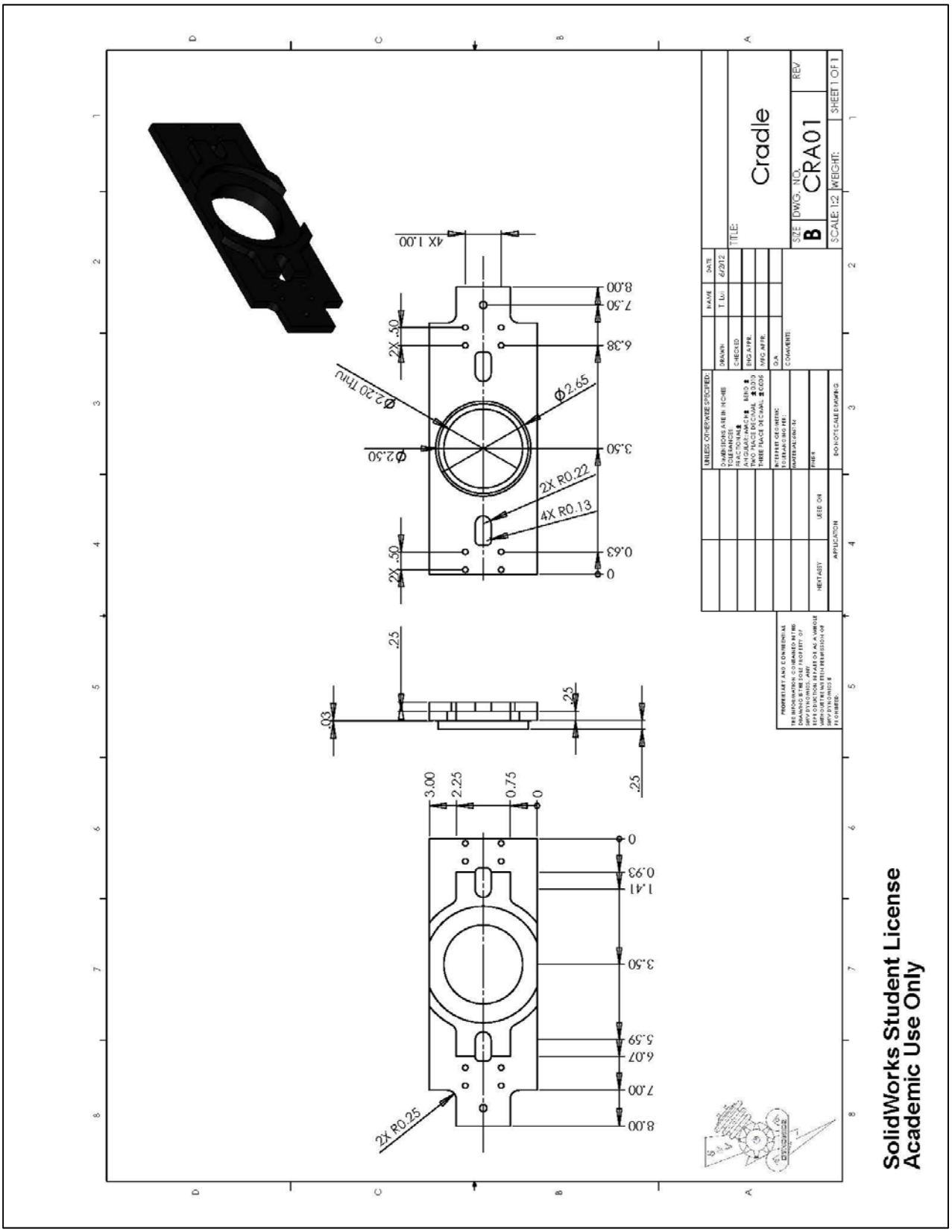
Sponsor/ Vendor	Name of Person	Location	Position	Contact Information
Supermileage Team	-	San Luis Obispo, CA	School Club	calpolysupermileage@googlegroups.com
Lovejoy	Carol Palmer		Customer Service Manager	cpalmer@lovejoy-inc.com
McMaster-Carr	-	Elmhurst, IL	-	chi.sales@mcmaster.com
National Instruments	Peter Flores	Los Angeles, CA	Field Sales Engineer	(213) 973-7356
-	Ingo Foldvari	San Diego, CA	Academic Program Manager	(760) 691-0877
Omega	-	-	temp@omega.com	(888) 826-6342
Otay Hydraulics	Jose Hinojosa	San Diego, CA	Owner	(619) 690-7577
VXB	-	Anaheim, CA	info@vxb.com	(800) 928-4430
Perco	-	Tijuana, Mexico	-	Tijuana, Mexico

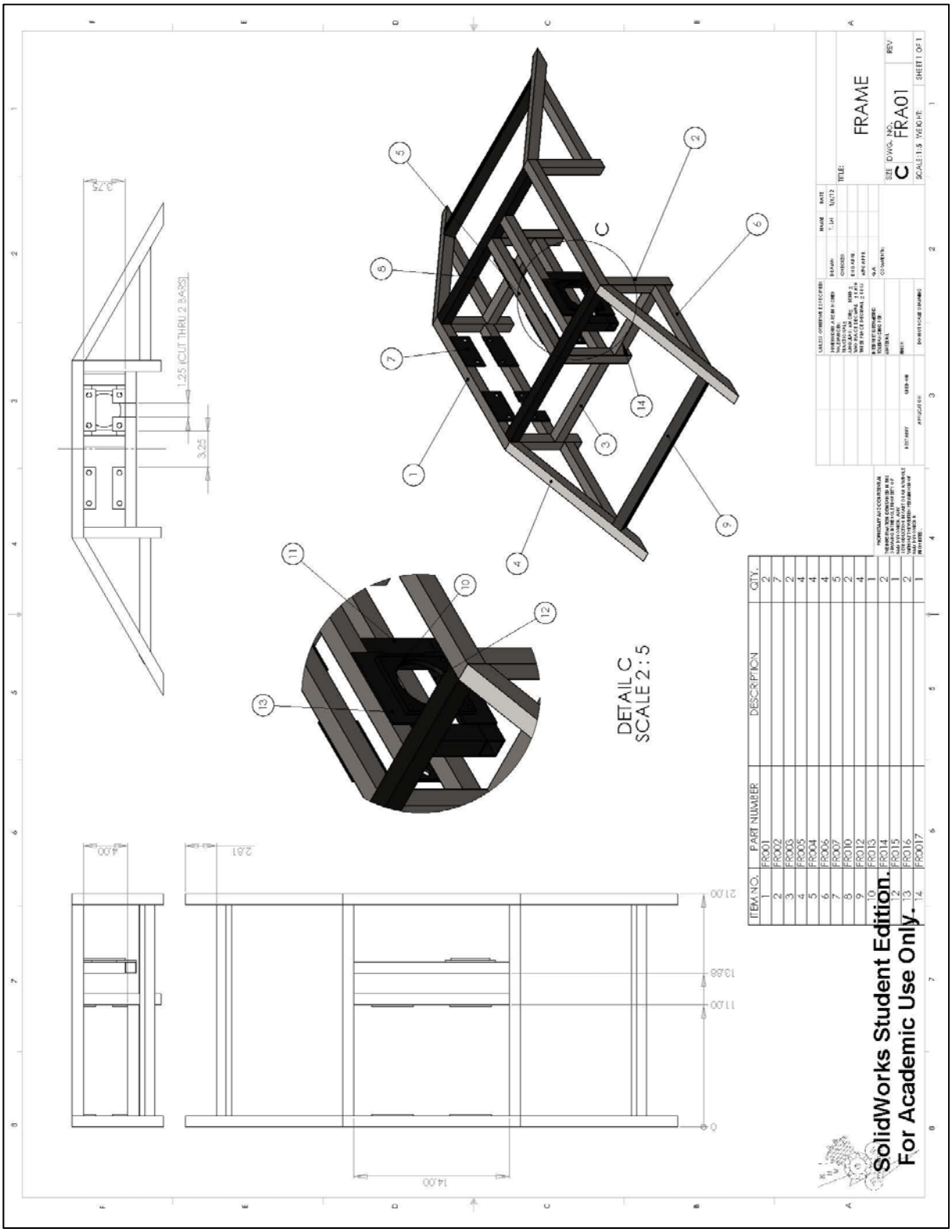
Appendix B: Quality Function Development

The purpose of the Quality Function Deployment (QFD) is to realize the most important requirements and compare existing requirements. The QFD shows that the most important is to make sure the dynamometer is easy to use. Using the list of requirement three dynamometers are compared with the specific needs and given a total score. The three dynamometers are the old SMV dyno, DYNOmite Kart, and TRIK-Dyno. The old SMV dyno is an engine dynamometer made for Supermileage as a senior project. One of the main problems with it is that no one knows how to use it and it gives a wide range of results. This is why it scored so low in the QFD. The DYNOmite scored low because its price of $5000 is over the $2500 budget. Also it isn't made for low power vehicles. The cars Supermileage builds are unique in the fact that they use a 5hp engine or lower. The TRIK-Dyno scored highest because it is built for karts, and those have low power engines. It is still out of the budget and it is not a chassis dynamometer. Overall the QFD shows that the few products that are close to what is required won't work for Supermileage and the chassis dynamometer will build will be unique.

SMV Dynomics Customer: SMV			Engineering Requirements (HOW'S)																				Benchmarks		
Customer Requirements	Reliable	15	■	■	■	■	■	•	Δ	Δ	Δ	○	Δ	Δ	Δ	■	■	■	■	■	■	■	■	1	4	4
	Easy to Transport	10	■	■	■	•	•	■	■	■	Δ	■	Δ	■	■	■	■	■	■	○	■	■	○	2	3	5
	Easy to use	20	■	■	■	•	•	•	•	■	•	■	•	\	\	■	■	○	○	○	•	\	•	1	3	4
	Accurate	15	•	•	•	■	■	■	■	Δ	Δ	•	■	•	■	•	•	○	○	•	■	•	■	3	5	5
	Cheap	10	Δ	Δ	Δ	Δ	■	•	■	•	○	■	■	■	■	Δ	Δ	○	Δ	○	■	Δ	■	2	1	1
	Safe	10	■	■	■	■	■	○	○	■	■	■	•	Δ	•	■	■	■	■	■	○	○	Δ	3	3	4
	Works with both cars	10	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	•	○	○	■	3	1	4
	O_2 sensor	5	■	■	■	■	■	Δ	Δ	Δ	■	■	■	■	■	○	○	○	•	■	■	■	Δ	1	1	1
	Sensor capabilities	5	•	•	•	■	■	■	Δ	○	■	Δ	■	■	■	•	•	•	•	■	■	Δ	Δ	5	5	5
	Units		mph	ft*lb	HP	lbs	ftxftxft	Hr/hr		2500	AC/DC	Hp	# bolts	inches		F	In^3/s		air/fuel	tires		Hp	seconds	210	305	385
	Targets		1mph	1 ft*lb	0.1	400	3x3x3	0.01				< 1hp	2	10		50-350			14.7	2		2 to 7	90			
	Old Dyno		4	4	4	1	1	1	1	3	2	5	1	5	4	1	1	5	1	5	1	3	1	54		
	TRIK-DYNO		5	5	5	4	5	2	1	1	3	5	1	1	1	1	4	5	1	5	4	4	1	64		
	DYNOmite Kart		5	5	5	2	1	2	4	1	3	3	3	4	3	1	4	5	1	1	4	4	1	62		
•	Strong Correlation																									
○	Medium Correlation																									
\	Small Correlation																									
■	No Correlation																									

Appendix C: Chassis Dyno Frame and Roller Assembly

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SHEET 1 OF 1
DETAIL C
SCALE 2 : 5
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3.25
0.75
4.00
2.61
21.00
13.88
11.00
14.00
0
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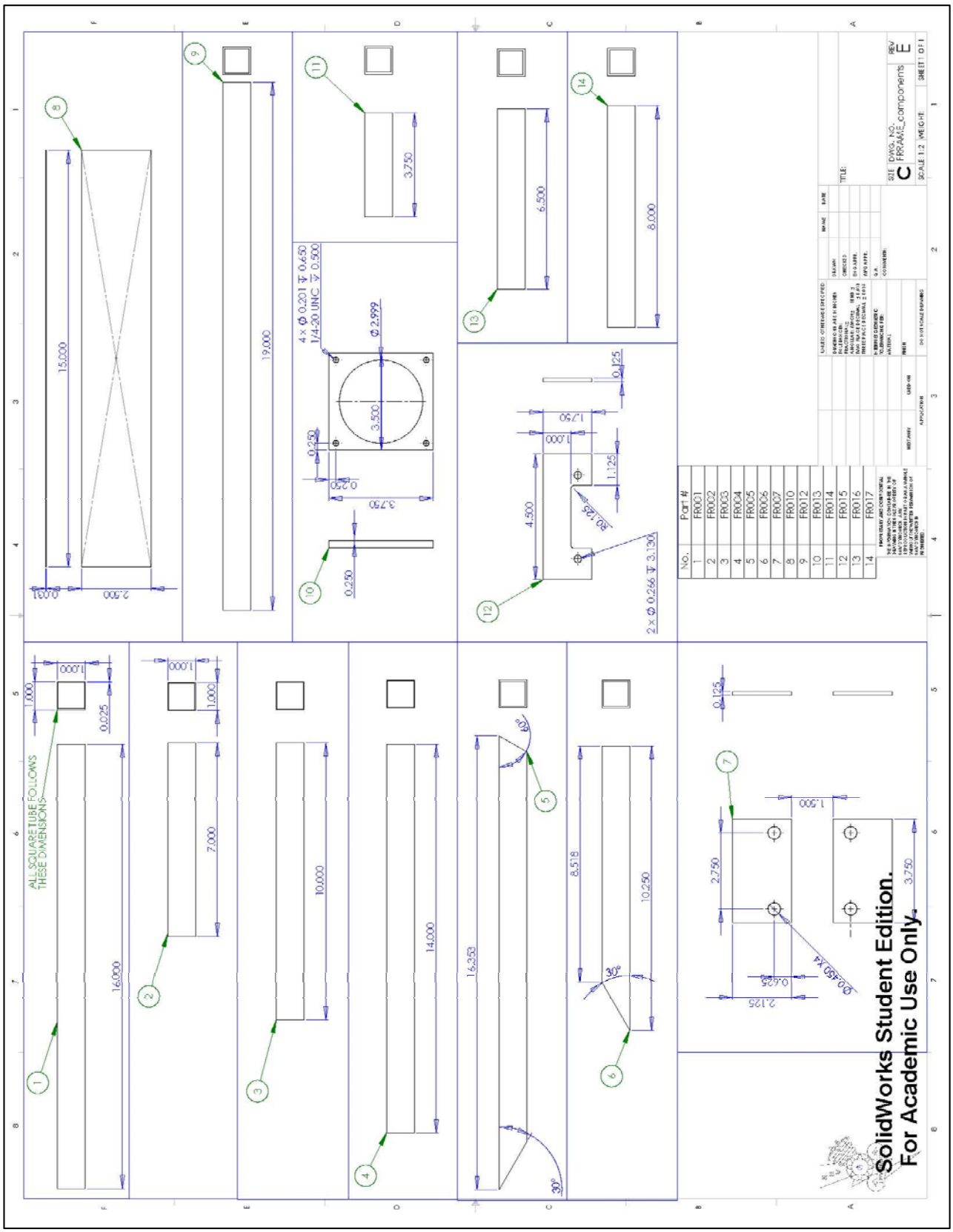
2 | FR002 | | 7
3 | FR003 | | 2
4 | FR004 | | 4
5 | FR005 | | 4
6 | FR006 | | 4
7 | FR007 | | 5
8 | FR010 | | 2
9 | FR012 | | 4
10 | FR013 | | 1
11 | FR014 | | 2
12 | FR015 | | 1
13 | FR016 | | 2
14 | FR017 | | 1
SolidWorks Student Edition.
For Academic Use Only.


ALL SQUARE TUBE FOLLOWS THESE DIMENSIONS
SolidWorks Student Edition.
For Academic Use Only.
Part #
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FR002
FR003
FR004
FR005
FR006
FR007
FR010
FR012
FR013
FR014
FR015
FR016
FR017
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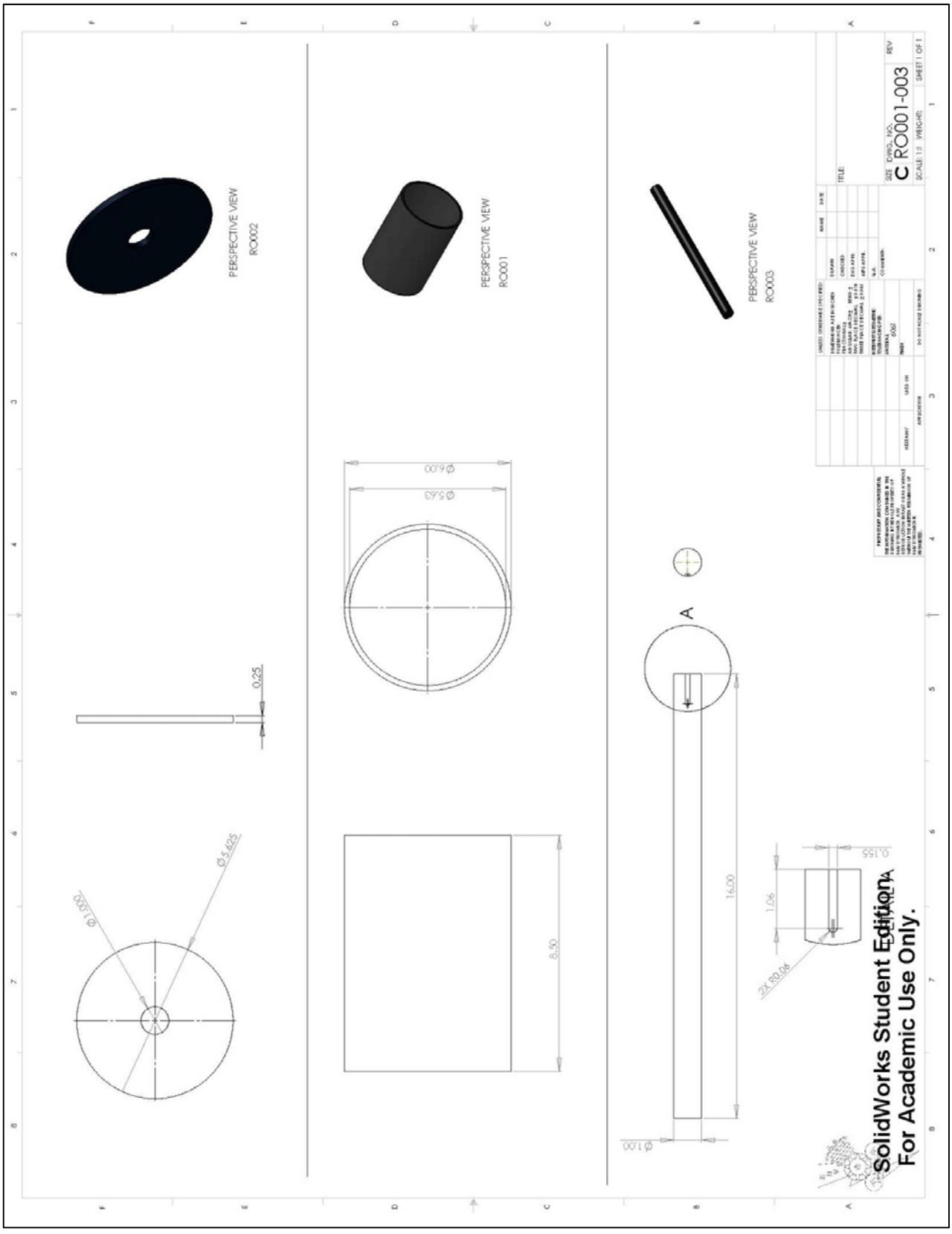
REV E
SCALE 1:2
WEIGHT
SHEET 1 OF 1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RO002
PERSPECTIVE VIEW
RO001
PERSPECTIVE VIEW
RO003
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Ø6.00
Ø5.63
Ø5.625
Ø1.000
8.50
16.00
1.06
0.155
2X R0.06
Ø1.00
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SIZE
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DWG. NO.
RO001-003
REV
SCALE: 1:3
WEIGHT:
SHEET 1 OF 1
TITLE:
SolidWorks Student Edition.
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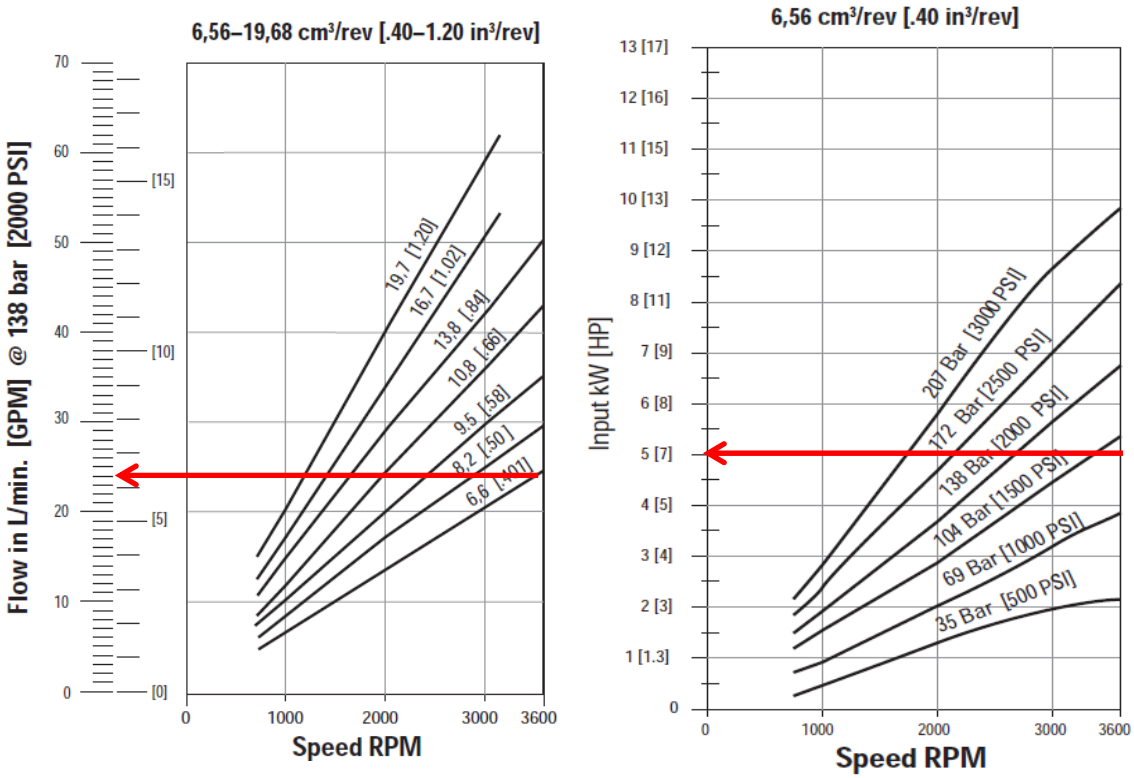
Appendix D: Hydraulic System

Displacement cm^3/r [in^3/r]	6,6 [.40]
Max. Intermittent Pressure bar [PSI]	241 [3500]
Rated Speed (RPM)	3600
Minimum Output Flow at 207 bar [3000 PSI] and Rated Speed LPM [GPM]	20,1 [5.3]
Input Power at 207 bar [3000 PSI] and Rated Speed and Cont. Pressure kW [HP]	9,7 [13.0]

Hydraulic Gear Pump



Hydraulic Gear Pump Performance Characteristics

Needle Valves – 3000 psig, 1/4 NPTF Connections

General Data

These valves may be used in hydraulic circuits as a shut-off valve in pressure gage lines or other small capacity lines. The body and handle of the valves are made of brass, and the stem of stainless steel. The packing is Teflon*, so the valves are suitable for use with all commonly used fluids.

** Registered trademark of DuPont Co.*

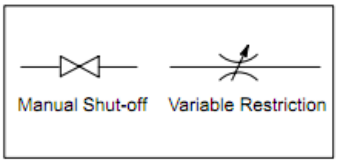
Ratings

Maximum operating pressure is 210 bar (3000 psig). Minimum burst pressure is 552 bar (8000 psig). The operating temperature range is –40 to 149° C (–40 to 300° F). Flow rates are shown in the following chart.

Approximate Flow at Maximum Open (Based on Light Oil)

Pressure Drop bar (psi)	Flow - L/min (USgpm)
0,34 (5)	4,16 (1.1)
0,69 (10)	5,68 (1.5)
1,38 (20)	8,33 (2.2)
2.76 (40)	11,73 (3.1)
4,14 (60)	14,01 (3.7)
5,52 (80)	16,28 (4.3)

Standard Graphical Symbol for Fluid Power Diagrams



Needle Valve

KEY SPECS	
Capacity (gal.)	7
Suction Port (in.)	2
Return Port (in.)	1
Mount Type	2 bolt
Material Type	Powder-coat steel
Dimensions L x W x H (in.)	16 x 10 x 10 1/2
Ship Weight	27.0 lbs

Hydraulic Oil Reservoir

KEY SPECS	
Accessory Type	Suction strainer
GPM	25 or less
Port Size (in.)	2 NPT
Suction Port (in.)	1 1/4
Length (in.)	8
Material Type	149 Micron mesh stainless steel screen
Ship Weight	1.0 lbs
Item#	778639

Hydraulic Strainer

Appendix E: Data Acquisition System

NATIONAL INSTRUMENTS

Technical Sales
United States
info@ni.com
(800) 531-5066

Dyno DAQ
Prepared by Kyla Purvis

Parts List

NI 9219 4 Ch-Ch Isolated, 24-bit, ±60V, 100S/s Univeral AI Module
779781-01

- Bundle includes measurement module and 1-slot NI CompactDAQ chassis
- USB, Ethernet, and 802.11 Wi-Fi connectivity
- 250 Vrms channel-to-channel isolation
- Built-in quarter-, half-, and full-bridge support
- Built-in voltage and current excitation
- Thermocouple, RTD, resistance, voltage, and current measurements

NI 9972 Backshell for 6-pos connector block (qty 4)
196720-01

- 250 Vrms channel-to-channel isolation
- Built-in quarter, half, and full-bridge support
- Built-in voltage and current excitation
- Thermocouple, RTD, resistance, voltage, and current measurements
- CJC per channel for accurate thermocouple measurement
- 100 S/s/ch simultaneous inputs (50S/s/ch for Thermocouple)

NI 9421 8-Ch 24 V, 100 us, Sinking DI Module
779002-01

- 8-channel, 100 us digital input
- 12 to 24 V logic, sinking digital inputs
- D-Sub or screw-terminal connector options
- Hot-swappable operation
- Extreme industrial certifications/ratings
- -40 to 70 °C operating range

NI 9932 Backshell with 10-pos connector block (qty 1)
779017-01

- Connect signal wires directly to the module

- Order as a spare or for multiple devices
- Direct connect terminal modules include connector(s)
- NI 9932 shown in image

---

cDAQ-9174, CompactDAQ chassis (4 slot USB)

781157-01

- Choose from more than 50 hot-swappable I/O modules with integrated signal conditioning
- Access the 4 general-purpose 32-bit counter/timers built into the chassis through the digital module
- Run 7 hardware-timed operations simultaneously from analog, digital, or counter/timer channels
- Stream continuous waveform measurements with patented NI Signal Streaming technology
- Take advantage of Windows 7 OS support
- Measure in minutes with NI-DAQmx software and automatic code generation using the DAQ Assistant

---

Power Cord, AC, U.S., 120 VAC, 2.3 meters

763000-01

Pricing Table

Part Number	Description	Est. Ship	Unit Price	Qty	Line Total
779781-01	NI 9219 4 Ch-Ch Isolated, 24-bit, ±60V, 100S/s Universal AI Module	1 - 2	$ 1,029	1	$ 1,029
196720-01	NI 9972 Backshell for 6-pos connector block (qty 4)	5 - 10	$ 30	1	$ 30
779002-01	NI 9421 8-Ch 24 V, 100 us, Sinking DI Module	5 - 10	$ 99	1	$ 99
779017-01	NI 9932 Backshell with 10-pos connector block (qty 1)	1 - 2	$ 30	1	$ 30
781157-01	cDAQ-9174, CompactDAQ chassis (4 slot USB)	1 - 3	$ 699	1	$ 699
763000-01	Power Cord, AC, U.S., 120 VAC, 2.3 meters	10 - 15	$ 9	1	$ 9
				Total:	$ 1,896

All sales are subject to the National Instruments Terms and Conditions of Sale. National Instruments shall not be bound by any conflicting or additional terms and conditions. Shipping dates are estimated and subject to change without notice. All prices are subject to verification by National Instruments.

Technical Sales
United States
(866) 531-6285
info@ni.com

NI 9219 Measurement System

4 Ch Universal Module for USB, Ethernet, or 802.11 Wi-Fi

- Bundle includes measurement module and 1-slot NI CompactDAQ chassis
- USB, Ethernet, and 802.11 Wi-Fi connectivity
- 250 Vrms channel-to-channel isolation
- Built-in quarter-, half-, and full-bridge support
- Built-in voltage and current excitation
- Thermocouple, RTD, resistance, voltage, and current measurements

Overview

The NI 9219 Measurement System measures 4 universal channels at 100 S/s with 24-bit resolution, sending data to a host PC over USB, Ethernet or 802.11 Wi-Fi.

Measurement Bundle Overview

The hardware for an NI CompactDAQ single measurement bundle consists of a USB, Ethernet, or 802.11 Wi-Fi chassis and one of the over 50 NI C Series measurement-specific modules. These small rugged bundles are ideal for portable or distributed measurements.

Chassis

The chassis controls the timing for the module and handles communication with the PC over the USB, Ethernet, or 802.11 Wi-Fi bus. Additionally, all NI CompactDAQ chassis include four counter/timers that you can access through a digital I/O module like the NI 9401.

Module

The NI 9219 is a 4-channel universal C Series module designed for multipurpose testing in any NI CompactDAQ or CompactRIO chassis. With the NI 9219, you can measure several signals from sensors such as strain gages, resistance temperature detectors (RTDs), thermocouples, load cells, and other powered sensors. The channels are individually selectable, so you can perform a different measurement type on each of the four channels. Measurement ranges differ for each type of measurement and include up to ±60 V for voltage and ±25 mA for current. See the manual for detailed specifications and ranges.

Because of the driver design, the NI 9219 does not limit the overall speed of an NI CompactDAQ system when used with faster sampling modules.

With 250 Vrms of channel-to-channel isolation, the NI 9219 protects not only the surrounding modules, chassis, and connected computer system but also the other channels within the same module. In addition to increased safety, channel-to-channel isolation eliminates problems associated with ground loops.

The NI 9219 uses 6-position spring terminal connectors in each channel for direct signal connectivity. You can purchase additional connectors to reduce signal connection time for multiple test units. In addition to extra connectors, a strain relief kit is available to secure the signal wires.

-Strain relief backshells for signal wire security and high-voltage protection (qty 4): NI 9972

-Extra connectors for 6-position connector modules (qty 10): NI 9973

Specifications

Specifications Documents

- Specifications (4)

Specifications Summary

General	
Product Name	NI 9219 Measurement Bundle
Product Family	Industrial I/O
Form Factor	CompactDAQ , Ethernet , USB , Wireless
Part Number	000000-00
Operating System/Target	Real-Time , Windows
Measurement Type	Temperature , Resistance , RTD , Bridge-based sensor , Thermocouple , Voltage , Current
RoHS Compliant	Yes
Signal Conditioning	Current excitation , Cold-junction compensation , Voltage excitation , Bridge completion , 0-20 mA current input
Analog Input	
Channels	4 , 0
Single-Ended Channels	0
Differential Channels	4
Resolution	24 bits
Sample Rate	100 S/s
Max Voltage	60 V
Maximum Voltage Range	-60 V , 60 V
Maximum Voltage Range Accuracy	243 mV
Minimum Voltage Range	-0.125 V , 0.125 V
Minimum Voltage Range Accuracy	271 µV
Maximum Current Range	-0.025 A , 0.025 A
Maximum Current Range Accuracy	152 µA
Simultaneous Sampling	Yes
Excitation Voltage	2.5 V

Bridge Configurations	Half Bridge , Full Bridge , Quarter Bridge
Analog Output	
Channels	0
Digital I/O	
Bidirectional Channels	0
Input-Only Channels	0
Output-Only Channels	0
Number of Channels	0
Counter/Timers	
Counters	0
Physical Specifications	
Length	9 cm
Width	2.3 cm
I/O Connector	MINI-COMBICON, 3.81 mm (6-Position)
Minimum Operating Temperature	-40 °C
Maximum Operating Temperature	70 °C
Minimum Storage Temperature	-40 °C
Maximum Storage Temperature	70 °C
Timing/Triggering/Synchronization	
Triggers cDAQ Chassis	No

Pricing

NI 9219

Bundle Contents

Estimated Shipping Days : 1 - 3 **Price : $ 1,288**

√ **Choose a communication method between your PC and module.**

NI cDAQ-9171, 1-Slot USB Chassis 781425-01 (Included in price)

NI cDAQ-9181, 1-Slot Ethernet Chassis 781496-01 Add $ 100

NI cDAQ-9191, 1-Slot WI-FI Chassis (U.S.) 781497-01 Add $ 200

NI cDAQ-9191, 1-Slot WI-FI Chassis (International) 781497-02 Add $ 200

√ **Analog Input Module**

NI 9219 4 Ch-Ch Isolated, 24-bit, ±60V, 100S/s Universal AI Module 779781-01 (included in price)

√ **Power**

Power Cord, AC, U.S., 120 VAC, 2.3 meters 763000-01 Add $ 9

Power Cord, 240V, 10A, North American 763068-01 Add $ 19

√ **Software**

LabVIEW Full Development System, Windows, English, Include 1 Year SSP 776670-35 Add $ 2,699

Estimated Shipping Days : 1 - 3 **Price : $ 1,288**

Qty: 1

You have selected United States as the country where you will use the product(s) (change).

* You have selected the United States as the country where you will use the product(s). Pricing may have changed since you printed this document on 02/02/2012. Please visit ni.com to see current pricing.

Place Order or Obtain Quote

Order Online or by Fax

1 . Navigate to *ni.com/products* and select "Order by Part Number" found under the "Business Center" section.
2 . Once you have added your items to your cart, see the "Your Cart Options" section to place your order, obtain a quote, or print a fax form.

Order by Phone

Call (866) 531-6285 to place your order or obtain a quote.

Resources

Additional Product Information

- Manuals (15)
- Dimensional Drawings (4)
- Product Certifications (4)

Related Information

- Videos: Learn How to Take Your First Measurement With NI CompactDAQ Out of the Box

Technical Sales
United States
(866) 531-6285
info@ni.com

Last Revised: 2010-06-18 17:00:20.0

NI 9421

8 Ch, 24 V Logic, 100 µs C Series Sinking Digital Input Module

- 8-channel, 100 µs digital input
- Hot-swappable operation
- -40 to 70 °C operating range
- 12 to 24 V logic, sinking digital inputs
- Extreme industrial certifications/ratings
- D-Sub or screw-terminal connector options

Overview

The NI 9421 is an eight-channel, 100 µs sinking digital input module for any NI CompactDAQ or CompactRIO chassis. Each channel is compatible with 12 to 24 V signals and features transient overvoltage protection of 2,300 Vrms between the input channels and earth ground. Each channel also has an LED that indicates the state of that channel. The NI cRIO-9421 works with industrial logic levels and signals for direct connection to a wide array of industrial switches, transducers, and devices. There are two connector options for the NI 9421 - a 10-position screw-terminal connector and a 25-position D-Sub connector. This industry-standard 25-position D-Sub connector provides for low-cost cabling to a wide variety of accessories from NI or other vendors. A number of vendors with custom D-Sub cable fabrication services can deliver cables with a pinout that matches your exact application needs. NI recommends the NI 9932 strain-relief connector accessory for the NI 9421 for screw-terminal connectivity and the NI 9934 accessory for 25-position D-Sub connectivity.

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Requirements and Compatibility

OS Information

- Real-Time OS
- Windows

Driver Information

- NI-DAQmx
- NI-RIO

Software Compatibility

- LabVIEW
- LabVIEW SignalExpress
- LabWindows/CVI
- Visual Studio
- Visual Studio .NET

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Comparison Tables

Product Name	Signal Levels	Number of Channels	Connectivity	Speed	Special Features
9411	±5 to 24 V	6	15-pin D-Sub	500 ns	Differential/single-ended digital input, differential quad encoder
9421	12 to 24 V	8	Screw-terminal, D-Sub	100 µs	Sinking digital input
9422	24 to 60 V	8	Screw-terminal	250 µs	Sinking/sourcing digital input
9423	11 to 30 V	8	Screw-terminal	1 µs	Sinking digital input
9425	12, 24 V	32	37-pin D-Sub	7 µs	Sinking digital input

9426	24 V	32	37-pin D-Sub	7 µs	Sourcing digital input

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Application and Technology

High-performance digital output and switching modules for NI CompactDAQ systems, CompactRIO embedded systems, and R Series expansion chassis provide extended voltage ranges and high-current-switching capacity for direct control of a wide array of industrial and automotive actuators. Each module features an integrated connector junction box with screw-terminal or cable options for flexible, low-cost signal wiring. All modules feature CompactRIO extreme industrial certifications and ratings including -40 to 70 °C operating temperatures and 50 g shock.

When used in CompactRIO, C Series digital output modules connect directly to reconfigurable I/O (RIO) field-programmable gate array (FPGA) hardware to create high-performance embedded systems. The reconfigurable FPGA hardware within CompactRIO provides a variety of options for timing, triggering, synchronization, digital waveform generation, or digital communication. For instance, with CompactRIO, you can implement a circuit to generate pulse-width modulation (PWM) outputs for controlling motors, heaters, or fans as well as to perform pulse code modulation encoding (PCME) for wireless telemetry applications.

C Series Compatibility

The C Series hardware family features more than 50 measurement modules and several chassis and carriers for deployment. With this variety of modules, you can mix and match measurements such as temperature, acceleration, flow, pressure, strain, acoustic, voltage, current, digital, and more to create a custom system. Install the modules in one of several carriers to create a single module USB, Ethernet, or Wi-Fi system, or combine them in chassis such as NI CompactDAQ and CompactRIO to create a mixed-measurement system with synchronized measurements. You can install up to eight modules in a simple, complete NI CompactDAQ USB data acquisition system to synchronize all of the analog output, analog input, and digital I/O from the modules. For a system without a PC, CompactRIO holds up to eight modules and features a built-in processor, RAM, and storage for an embedded data logger or control unit. For higher-speed control, CompactRIO chassis incorporate an FPGA that you can program with NI LabVIEW software to achieve silicone-speed processing on I/O data from C Series modules.

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Ordering Information

For a complete list of accessories, visit the product page on ni.com.

Products	Part Number	Recommended Accessories	Part Number
NI 8421 Counter Input with Screw Terminals			
NI 8421 with Screw Terminals	779002-01	No accessories required.	

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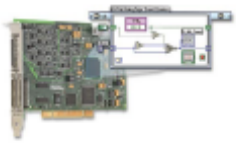
Software Recommendations

LabVIEW Professional Development System for Windows

- Advanced software tools for large project development
- Automatic code generation using DAQ Assistant and Instrument I/O Assistant
- Tight integration with a wide range of hardware
- Advanced measurement analysis and digital signal processing
- Open connectivity with DLLs, ActiveX, and .NET objects
- Capability to build DLLs, executables, and MSI installers

NI LabVIEW FPGA Module



- Create your own I/O hardware without VHDL coding or board design
- Graphically configure FPGAs on NI reconfigurable I/O (RIO) hardware targets
- Define your own control algorithms with loop rates up to 200 MHz
- Execute multiple tasks simultaneously and deterministically
- Implement custom timing and triggering logic, digital protocols, and DSP algorithms
- Incorporate existing HDL code and third-party IP including Xilinx CORE Generator functions

NI LabVIEW Real-Time Module

- Design deterministic real-time applications with LabVIEW graphical programming
- Download to dedicated NI or third-party hardware for reliable execution and a wide selection of I/O
- Take advantage of built-in PID control, signal processing, and analysis functions
- Automatically take advantage of multicore CPUs or set processor affinity manually
- Includes real-time operating system (RTOS), development and debugging support, and board support
- Purchase individually or as part of an NI Developer Suite bundle

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Support and Services

System Assurance Programs

NI system assurance programs are designed to make it even easier for you to own an NI system. These programs include configuration and deployment services for your NI PXI, CompactRIO, or Compact FieldPoint system. The NI Basic System Assurance Program provides a simple integration test and ensures that your system is delivered completely assembled in one box. When you configure your system with the NI Standard System Assurance Program, you can select from available NI system driver sets and application development environments to create customized, reorderable software configurations. Your system arrives fully assembled and tested in one box with your software preinstalled. When you order your system with the standard program, you also receive system-specific documentation including a bill of materials, an integration test report, a recommended maintenance plan, and frequently asked question documents. Finally, the standard program reduces the total cost of owning an NI system by providing three years of warranty coverage and calibration service. Use the online product advisors at ni.com/advisor to find a system assurance program to meet your needs.

Calibration

NI measurement hardware is calibrated to ensure measurement accuracy and verify that the device meets its published specifications. NI offers a number of calibration services to help maintain the ongoing accuracy of your measurement hardware. These services allow you to be completely confident in your measurements, and help you maintain compliance to standards like ISO 9001, ANSI/NCSL Z540-1 and ISO/IEC 17025. To learn more about NI calibration services or to locate a qualified service center near you, contact your local sales office or visit ni.com/calibration.

Technical Support

Get answers to your technical questions using the following National Instruments resources.

- **Support** - Visit ni.com/support to access the NI KnowledgeBase, example programs, and tutorials or to contact our applications engineers who are located in NI sales offices around the world and speak the local language.
- **Discussion Forums** - Visit forums.ni.com for a diverse set of discussion boards on topics you care about.
- **Online Community** - Visit community.ni.com to find, contribute, or collaborate on customer-contributed technical content with users like you.

Repair

While you may never need your hardware repaired, NI understands that unexpected events may lead to necessary repairs. NI offers repair services performed by highly trained technicians who quickly return your device with the guarantee that it will perform to factory specifications. For more information, visit ni.com/repair.

Training and Certifications

The NI training and certification program delivers the fastest, most certain route to increased proficiency and productivity using NI software and hardware. Training builds the skills to more efficiently develop robust, maintainable applications, while certification validates your knowledge and ability.

- **Classroom training in cities worldwide** - the most comprehensive hands-on training taught by engineers.
- **On-site training at your facility** - an excellent option to train multiple employees at the same time.
- **Online instructor-led training** - lower-cost, remote training if classroom or on-site courses are not possible.
- **Course kits** - lowest-cost, self-paced training that you can use as reference guides.
- **Training memberships** and training credits - to buy now and schedule training later.

Visit ni.com/training for more information.

Extended Warranty

NI offers options for extending the standard product warranty to meet the life-cycle requirements of your project. In addition, because NI understands that your requirements may change, the extended warranty is flexible in length and easily renewed. For more information, visit ni.com/warranty.

OEM

NI offers design-in consulting and product integration assistance if you need NI products for OEM applications. For information about special pricing and services for OEM customers, visit ni.com/oem.

Alliance

Our Professional Services Team is comprised of NI applications engineers, NI Consulting Services, and a worldwide National Instruments Alliance Partner program of more than 600 independent consultants and integrators. Services range from start-up assistance to turnkey system integration. Visit ni.com/alliance.

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Detailed Specifications

The following specifications are typical for the range −40 to 70 °C unless otherwise noted. The specifications are the same for the NI 9421 and the NI 9423 unless otherwise noted. All voltages are relative to COM unless otherwise noted.

Input Characteristics	
Number of channels	8 digital input channels
Input type	Sinking
Digital logic levels	
OFF state	
Input voltage	≤5 V

Input current (NI 9421)	≤300 µA
Input current (NI 9423)	≤150 µA
ON state	
Input voltage	11–30 V
Input current	≥3 mA
I/O protection	
Input voltage	
NI 9421	40 V max
NI 9423	35 V max
Reverse biased voltage	–30 V max
Input current	
NI 9421	7 mA max, internally limited
NI 9423	8.5 mA max, internally limited
Input delay time	
NI 9421	100 µs max
NI 9423	1 µs max
MTBF	
NI 9421	2,086,204 hours at 25 °C; Bellcore Issue 2, Method 1, Case 3, Limited Part Stress Method
NI 9423	979,623 hours at 25 °C; Bellcore Issue 2, Method 1, Case 3, Limited Part Stress Method

Note Contact NI for Bellcore MTBF specifications at other temperatures or for MIL-HDBK-217F specifications. Go to *ni.com/certification* and search by module number or product line for more information about MTBF and other product certifications.

NI 9421 Power Requirements

Power consumption from chassis	
Active mode	240 mW max
Sleep mode	7 mW max
Thermal dissipation (at 70 °C)	
Active mode	1.3 W max
Sleep mode	1.1 W max

NI 9423 Power Requirements

Power consumption from chassis	
Active mode	290 mW max
Sleep mode	7 mW max
Thermal dissipation (at 70 °C)	
Active mode	1.5 W max
Sleep mode	1.3 W max

Physical Characteristics

If you need to clean the module, wipe it with a dry towel.

Note For two-dimensional drawings and three-dimensional models of the C Series module and connectors, visit ni.com/dimensions and search by module number.

Screw-terminal wiring	12 to 24 AWG copper conductor wire with 10 mm (0.39 in.) of insulation stripped from the end
Torque for screw terminals	0.5 to 0.6 N · m (4.4 to 5.3 lb · in.)
Ferrules	0.25 mm^2 to 2.5 mm^2
Weight	
NI 9421/9423 with screw terminal	150 g (5.3 oz)
NI 9421 with DSUB	145 g (5.1 oz)

Safety

NI 9421/9423 with Screw Terminal Safety Voltages	
Connect only voltages that are within the following limits.	
Channel-to-COM	30 V max
Isolation	
Channel-to-channel	None
Channel-to-earth ground	
Continuous	250 V_{rms}, Measurement Category II
Withstand	2,300 V_{rms}, verified by a 5 s dielectric withstand test

Measurement Category II is for measurements performed on circuits directly connected to the electrical distribution system (MAINS [1]). This category refers to local-level electrical distribution, such as that provided by a standard wall outlet (for example, 115 AC voltage for U.S. or 230 AC voltage for Europe). Examples of Measurement Category II are measurements performed on household appliances, portable tools, and similar hardware.

Caution Do not connect the NI 9421/9423 with screw terminal to signals or use for measurements within Measurement Categories III or IV.

NI 9421 with DSUB Safety Voltages	
Connect only voltages that are within the following limits.	
Channel-to-COM	30 V max
Isolation	
Channel-to-channel	None
Channel-to-earth ground	
Continuous	60 VDC, Measurement Category I
Withstand	1,000 V_{rms}, verified by a 5 s dielectric withstand test

Measurement Category I is for measurements performed on circuits not directly connected to the electrical distribution system referred to as MAINS [2] voltage. This category is for measurements of voltages from specially protected secondary circuits. Such voltage measurements include signal levels, special hardware, limited-energy parts of hardware, circuits powered by regulated low-voltage sources, and electronics.

Caution Do not connect the NI 9421 with DSUB to signals or use for measurements within Measurement Categories II, III, or IV.

Hazardous Locations	
U.S. (UL)	Class I, Division 2, Groups A, B, C, D, T4; Class I, Zone 2, AEx nC IIC T4
Canada (C-UL)	Class I, Division 2, Groups A, B, C, D, T4; Class I, Zone 2, Ex nC IIC T4
Europe (DEMKO)	EEx nC IIC T4

Safety Standards

This product is designed to meet the requirements of the following standards of safety for electrical equipment for measurement, control, and laboratory use:

- IEC 61010-1, EN 61010-1
- UL 61010-1, CSA 61010-1

Note For UL and other safety certifications, refer to the product label or the *Online Product Certification* section.

Electromagnetic Compatibility

This product is designed to meet the requirements of the following standards of EMC for electrical equipment for measurement, control, and laboratory use:

- EN 61326 (IEC 61326): Class A emissions; Industrial Immunity
- EN 55011 (CISPR 11): Group 1, Class A emissions
- AS/NZS CISPR 11: Group 1, Class A emissions
- FCC 47 CFR Part 15B: Class A emissions
- ICES-001: Class A emissions

Note For the standards applied to assess the EMC of this product, refer to the *Online Product Certification* section.

Note For EMC compliance, operate this device with double-shielded cables.

CE Compliance

This product meets the essential requirements of applicable European Directives, as amended for CE marking, as follows:

- 2006/95/EC; Low-Voltage Directive (safety)
- 2004/108/EC; Electromagnetic Compatibility Directive (EMC)

Note For the standards applied to assess the EMC of this product, refer to the *Online Product Certification* section.

Online Product Certification

Refer to the product Declaration of Conformity (DoC) for additional regulatory compliance information. To obtain product certifications and the DoC for this product, visit ni.com/certification, search by module number or product line, and click the appropriate link in the Certification column.

Shock and Vibration

To meet these specifications, you must panel mount your system. If you are using the NI 9421/9423 with screw terminal, you also must either affix ferrules to the ends of the terminal wires or use the NI 9932 backshell kit to protect the connections.

Operating vibration	
Random (IEC 60068-2-64)	5 g_{rms}, 10 to 500 Hz
Sinusoidal (IEC 60068-2-6)	5 g, 10 to 500 Hz
Operating shock (IEC 60068-2-27)	30 g, 11 ms half sine, 50 g, 3 ms half sine, 18 shocks at 6 orientations

Environmental

National Instruments C Series modules are intended for indoor use only but may be used outdoors if installed in a suitable enclosure. Refer to the manual for the chassis you are using for more information about meeting these specifications.

Operating temperature (IEC 60068-2-1, IEC 60068-2-2)	–40 to 70 °C
Storage temperature (IEC 60068-2-1, IEC 60068-2-2)	–40 to 85 °C
Ingress protection	IP 40
Operating humidity (IEC 60068-2-56)	10 to 90% RH, noncondensing
Storage humidity (IEC 60068-2-56)	5 to 95% RH, noncondensing
Maximum altitude	2,000 m
Pollution Degree (IEC 60664)	2

Environmental Management

National Instruments is committed to designing and manufacturing products in an environmentally responsible manner. NI recognizes that eliminating certain hazardous substances from our products is beneficial not only to the environment but also to NI customers.

For additional environmental information, refer to the *NI and the Environment* Web page at ni.com/environment. This page contains the environmental regulations and directives with which NI complies, as well as other environmental information not included in this document.

Waste Electrical and Electronic Equipment (WEEE)

EU Customers At the end of their life cycle, all products *must* be sent to a WEEE recycling center. For more information about WEEE recycling centers and National Instruments WEEE initiatives, visit ni.com/environment/weee.htm.

电子信息产品污染控制管理办法 （中国 RoHS）

中国客户 National Instruments 符合中国电子信息产品中限制使用某些有害物质指令 (RoHS)。
关于 National Instruments 中国 RoHS 合规性信息，请登录 ni.com/environment/rohs_china。
(For information about China RoHS compliance, go to ni.com/environment/rohs_china.)

[1] MAINS is defined as a hazardous live electrical supply system that powers hardware. Suitably rated measuring circuits may be connected to the MAINS for measuring purposes.

[2] MAINS is defined as a hazardous live electrical supply system that powers hardware. Suitably rated measuring circuits may be connected to the MAINS for measuring purposes.

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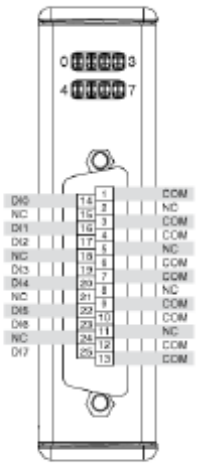
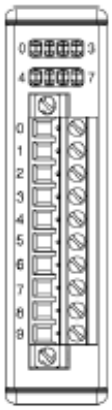
Pinouts/Front Panel Connections



Pin assignments (25-pin)



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Ordering Information | Detailed Specifications

For user manuals and dimensional drawings, visit the product page resources tab on ni.com.

Last Revised: 2011-12-28 13:54:39.0

NI CompactDAQ

USB Data Acquisition Systems

- Mix sensor measurements with analog and digital I/O in the same instrument
- Acquire from analog input modules at different rates with multiple timing engines
- Run up to seven I/O tasks simultaneously
- Windows 7/XP support
- Hi-Speed USB communication with NI Signal Streaming technology
- LabVIEW SignalExpress LE data-logging software included
- Four 32-bit general-purpose counters built into chassis (access through digital module or BNC triggers)
- BNC trigger connections on the cDAQ-9178 for up to 1 MHz clocks and triggers

Overview

The NI cDAQ-9178 is an eight-slot NI CompactDAQ chassis designed for small, portable, mixed-measurement test systems. Combine the cDAQ-9178 with up to eight NI C Series I/O modules for a custom analog input, analog output, digital I/O, and counter/timer measurement system.

Modules are available for a variety of sensor measurements including thermocouples, RTDs, strain gages, load and pressure transducers, torque cells, accelerometers, flow meters, and microphones. NI CompactDAQ systems combine sensor measurements with voltage, current, and digital signals to create custom, mixed-measurement systems with a single, simple USB cable back to the PC, laptop, or netbook.

The cDAQ-9178 has four 32-bit general-purpose counter/timers built in. You can access these counters through an installed, hardware-timed digital module such as the NI 9401 or NI 9402 for applications that involve quadrature encoders, PWM, event counting, pulse train generation, and period or frequency measurement.

Use the two built-in BNC connections to share clocks or triggers up to 1 MHz.

The cDAQ-9178 chassis is shipped with the following:
- AC/DC converter that plugs directly into the chassis
- USB cable with a thumbscrew lock for strain relief

Power cord sold separately.

The NI-DAQmx driver shipped with every chassis includes the following:
- LabVIEW SignalExpress LE for simple data-logging applications
- API for NI LabVIEW, ANSI C/C++, C#, Visual Basic .NET
- DAQ Assistant code generation for NI LabVIEW, LabWindows™/CVI, and Measurement Studio
- Example programs for all supported languages
- NI Measurement & Automation Explorer (MAX) for system configuration and test

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Comparison Tables

Model	Slots	Counters	Number of Simultaneous Tasks	Number of AI Timing Engines

cDAQ-9178	8	4	7	3
cDAQ-9174	4	4	7	3

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Application and Technology

Mix Analog, Digital, and Sensor Measurements in the Same System

Many devices can measure temperature, voltage, or bridge-based sensors, but NI CompactDAQ can integrate all of these measurements and more into a single device that outputs all of the data via the same bus interface, such as USB. An NI CompactDAQ system can mix multiplexed voltage input signals, simultaneously sampled accelerometers, low-speed thermocouples, and TTL digital I/O all in the same 4- or 8-slot chassis using the same driver, NI-DAQmx. NI CompactDAQ makes programming easier because the same driver is used for all measurements. This solution saves space and simplifies service and support. With NI CompactDAQ, there is only one box on your lab bench, and, if there are problems with any of the measurements or equipment, award-winning National Instruments support is your contact for all your instrumentation needs.

Figure 1. NI cDAQ-9174 with Three Analog and One Digital Module Connected to a Laptop

C Series Modules

You have more than 50 C Series modules, most of which work with NI CompactDAQ, to choose from for different measurements including thermocouple, voltage, resistance temperature detector (RTD), current, resistance, strain, digital (TTL and other), accelerometers, and microphones. Channel counts on the individual modules range from three to 32 channels to accommodate a wide range of system requirements. C Series modules combine signal conditioning, connectivity, and data acquisition into a small module for each specific measurement type. You can insert these modules into any of the C Series chassis to create a variety of systems. You can create a mix of channel counts and measurement types within one system by selecting the desired modules and installing them into one of several C Series systems. For this reason, systems built on the C Series platform are highly customizable. See ni.com/crio/cseries for the C Series compatibility table.

Figure 2. Three High-Speed Analog Input Modules

Rugged Design

NI CompactDAQ and all C Series modules are constructed from A380 cast aluminum for a rugged system that can withstand operating temperatures from -20 to 55 °C, and up to 30 g of shock. NI CompactDAQ was built to be used in the lab but not to necessarily stay there. With a rugged, flexible system such as NI CompactDAQ, you can reconfigure and move a single test system from place to place without having to purchase different equipment for every lab or test stand. C Series modules are equally rugged and designed with spring loaded latches to lock into place when installed in the chassis. The shock and vibration specifications are all tested on an NI CompactDAQ system with modules installed, so modules do not fall out or come undocked under the specified conditions. For cable strain relief, a locking USB cable with thumbscrew is included to prevent accidental

disconnection during use. The rugged features of NI CompactDAQ help you quickly begin testing because you need less time to prepare the instrumentation for the rigors of field testing. For added system portability, or to help track multiple systems around the lab, purchase the CASE-0750 rugged carrying case that has room for chassis, modules, power supplies, and signal wire.

Figure 3. The carrying case has removable foam blocks for further customization.

Multiple Timing Engines to Acquire from Different Modules at Different Rates

With the cDAQ-9174/78 chassis, you can install a thermocouple module next to an accelerometer measurement module and acquire from both simultaneously at different rates. The cDAQ-9174/78 chassis have multiple analog input timing engines, which means you can group all of your analog input modules in up to three sets of modules. These sets, known as tasks, can all run at different rates because each one has its own timing engine in the chassis backplane. This alleviates the need to decimate or parse lower-speed data from the higher-speed data as you need to do in the original cDAQ-9172 chassis.

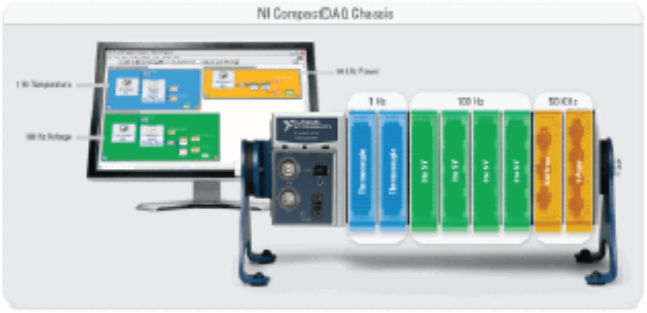

Figure 4. Run analog input modules at different rates with multiple AI timing engines.

Four 32-Bit General-Purpose Counters Built In

The cDAQ-9174/78 chassis both have four 32-bit counters built in. These counters are accessed through an installed hardware-timed digital I/O module (sold separately) such as the NI 9401 or NI 9402. Once you have installed the digital module, you can create a counter task in software for operations such as quadrature encoder, period and frequency measurement, or finite pulse train and PWM generation. For some operations, you can access the counters in the cDAQ-9178 chassis through the built-in BNC connectors on the chassis.

Flexible Power Options

The upgraded chassis features a new physical connection for power supplies. Each chassis is shipped with an AC/DC converter that plugs directly into the chassis. (Note that the power cord to go from the AC/DC converter to the wall is sold separately.) For other power options, such as a power supply with leads for VIC, an automotive electrical system, or an off-the-shelf battery pack, purchase the screw-terminal accessory for the chassis to enable easy connection of a V and C lead to the chassis. NI CompactDAQ requires a 9 to 30 VDC power supply and uses a maximum load 15 W of power.

Figure 5. NI cDAQ-9178 Connections Showing BNC Triggers, Flexible Power Connector, and USB Port with Threaded Hole for Cable Strain Relief

Included Data-Logging Software

NI ships NI CompactDAQ, and every other NI data acquisition (DAQ) device, with a driver kit that includes the following:

- Measurement & Automation Explorer (MAX) – This configuration utility is for quick measurement debugging or system diagnostic test via the device self-test.
- NI-DAQmx – Driver and API for all NI data acquisition devices. This installer includes interfaces to LabVIEW, ANSI C/C++, C#, Visual Basic .NET, and hundreds of example programs for LabVIEW and text-based languages.
- LabVIEW SignalExpress LE – With configuration-based data logging, you can get up and running out of the box without programming. Using LabVIEW SignalExpress LE, you can acquire data from the hardware, build a custom user interface, and log data to Technical Data Management Streaming (TDMS) files or to Microsoft Excel for graphing and postprocessing. LabVIEW SignalExpress is available for purchase and includes analysis and processing blocks for use within the data-logging environment.

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Ordering Information

For a complete list of accessories, visit the product page on ni.com.

Products	Part Number	Recommended Accessories	Part Number
NI CompactDAQ Chassis			
cDAQ-9174 4 slot chassis	781157-01	No accessories required.	
cDAQ-9178 8 slot chassis	781156-01	No accessories required.	
Accessories			
Rugged Carying Case (CASE-0760)	780315-01	No accessories required.	
Filler Module for Empty Slots	196917-01	No accessories required.	
Replacement/Spare Power Supply	780703-01	No accessories required.	
Desktop Mounting Kit (as seen in images)	779473-01	No accessories required.	
Screw Terminals for Alternate Power Supply	780702-01	No accessories required.	
Power Cords			
Japan, 100VAC	763634-01	No accessories required.	
Switzerland, 220 VAC	763065-01	No accessories required.	
Europe, 240 VAC	763067-01	No accessories required.	
Australia, 240 VAC	763066-01	No accessories required.	
North America, 240 VAC	763068-01	No accessories required.	
US 120VAC	763000-01	No accessories required.	
UK, 240 VAC	763064-01	No accessories required.	

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Support and Services

System Assurance Programs

NI system assurance programs are designed to make it even easier for you to own an NI system. These programs include configuration and deployment services for your NI PXI, CompactRIO, or Compact FieldPoint system. The NI Basic System Assurance Program provides a simple integration test and ensures that your system is delivered completely assembled in one box. When you configure your system with the NI Standard System Assurance Program, you can select from available NI system driver sets and application development environments to create customized, reorderable software configurations. Your system arrives fully assembled and tested in one box with your software preinstalled. When you order your system with the standard program, you also receive system-specific documentation including a bill of materials, an integration test report, a recommended maintenance plan, and frequently asked question documents. Finally, the standard program reduces the total cost of owning an NI system by providing three years of warranty coverage and calibration service. Use the online product advisors at ni.com/advisor to find a system assurance program to meet your needs.

Calibration

NI measurement hardware is calibrated to ensure measurement accuracy and verify that the device meets its published specifications. NI offers a number of calibration services to help maintain the ongoing accuracy of your measurement hardware. These services allow you to be completely confident in your measurements, and help you maintain compliance to standards like ISO 9001, ANSI/NCSL Z540-1 and ISO/IEC 17025. To learn more about NI calibration services or to locate a qualified service center near you, contact your local sales office or visit ni.com/calibration.

Technical Support

Get answers to your technical questions using the following National Instruments resources.

- **Support** - Visit ni.com/support to access the NI KnowledgeBase, example programs, and tutorials or to contact our applications engineers who are located in NI sales offices around the world and speak the local language.
- **Discussion Forums** - Visit forums.ni.com for a diverse set of discussion boards on topics you care about.
- **Online Community** - Visit community.ni.com to find, contribute, or collaborate on customer-contributed technical content with users like you.

Repair

While you may never need your hardware repaired, NI understands that unexpected events may lead to necessary repairs. NI offers repair services performed by highly trained

technicians who quickly return your device with the guarantee that it will perform to factory specifications. For more information, visit ni.com/repair.

Training and Certifications

The NI training and certification program delivers the fastest, most certain route to increased proficiency and productivity using NI software and hardware. Training builds the skills to more efficiently develop robust, maintainable applications, while certification validates your knowledge and ability.

- **Classroom training in cities worldwide** - the most comprehensive hands-on training taught by engineers.
- **On-site training at your facility** - an excellent option to train multiple employees at the same time.
- **Online instructor-led training** - lower-cost, remote training if classroom or on-site courses are not possible.
- **Course kits** - lowest-cost, self-paced training that you can use as reference guides.
- **Training memberships** and training credits - to buy now and schedule training later.

Visit ni.com/training for more information.

Extended Warranty

NI offers options for extending the standard product warranty to meet the life-cycle requirements of your project. In addition, because NI understands that your requirements may change, the extended warranty is flexible in length and easily renewed. For more information, visit ni.com/warranty.

OEM

NI offers design-in consulting and product integration assistance if you need NI products for OEM applications. For information about special pricing and services for OEM customers, visit ni.com/oem.

Alliance

Our Professional Services Team is comprised of NI applications engineers, NI Consulting Services, and a worldwide National Instruments Alliance Partner program of more than 600 independent consultants and integrators. Services range from start-up assistance to turnkey system integration. Visit ni.com/alliance.

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Detailed Specifications

These specifications are for the NI cDAQ-9171/9174/9178 chassis only.
These specifications are typical at 25 °C unless otherwise noted. For the C Series I/O module specifications, refer to the documentation for the C Series I/O module you are using.

Analog Input	
Input FIFO size	127 samples per slot
Maximum sample rate [1]	Determined by the C Series I/O module(s)
Timing accuracy [2]	50 ppm of sample rate
Timing resolution [2]	12.5 ns
Number of channels supported	Determined by the C Series I/O module(s)
Analog Output	
Numbers of channels supported	
Hardware-timed task	
Onboard regeneration	16
Non-regeneration	Determined by the C Series I/O module(s)
Non-hardware-timed task	Determined by the C Series I/O module(s)
Maximum update rate	
Onboard regeneration	1.6 MS/s (multi-channel, aggregate)
Non-regeneration	Determined by the C Series I/O module(s)
Timing accuracy	50 ppm of sample rate
Timing resolution	12.5 ns
Output FIFO size	
Regeneration	8,191 samples shared among channels used
Non-regeneration	127 samples per slot
AO waveform modes	Non-periodic waveform, periodic waveform regeneration mode from onboard memory, periodic waveform regeneration from host buffer including dynamic update
Digital Waveform Characteristics	

Waveform acquisition (DI) FIFO	127 samples per slot
Waveform generation (DO) FIFO	
NI cDAQ-9171	2,047 samples
NI cDAQ-9174	
Slots 1-4	2,047 samples
NI cDAQ-9178	
Slots 1-4	2,047 samples
Slots 5-8	1,023 samples
Note (NI cDAQ-9178) When modules are installed in slots 1 through 4, FIFO is 2,047 samples per slot for all slots. When any module is installed in slots 5 through 8, FIFO is 1,023 samples per slot for all eight slots.	
Digital input sample clock frequency	
Streaming to application memory	System-dependent
Finite	0 to 10 MHz
Digital output sample clock frequency	
Streaming from application memory	System-dependent
Regenerate from FIFO	0 to 10 MHz
Finite	0 to 10 MHz
Digital output or digital input sample clock source	Any PFI, analog sample or convert clock, analog output sample clock, Ctr *n* Internal Output, and many other sources
General-Purpose Counter/Timers	
Number of counter/timers	4
Resolution	32 bits
Counter measurements	Edge counting, pulse, semi-period, period, two-edge separation, pulse width
Position measurements	X1, X2, X4 quadrature encoding with Channel Z reloading; two-pulse encoding
Output applications	Pulse, pulse train with dynamic updates, frequency division, equivalent time sampling
Internal base clocks	80 MHz, 20 MHz, 100 kHz
External base clock frequency	0 to 20 MHz
Base clock accuracy	50 ppm
Output frequency	0 to 20 MHz
Inputs	Gate, Source, HW_Arm, Aux, A, B, Z, Up_Down
Routing options for inputs	Any module PFI, chassis PFI BNC, analog trigger, many internal signals
FIFO	Dedicated 127-samples FIFO
Frequency Generator	
Number of channels	1
Base clocks	10 MHz, 20 MHz, 100 kHz
Divisors	1 to 16 (integers)
Base clock accuracy	50 ppm
Output	
NI cDAQ-9171/9174	Available on module PFI terminals
NI cDAQ-9178	Available on any chassis PFI BNC terminal or module PFI terminals
Module PFI Characteristics	
Functionality	Static digital input, static digital output, timing input, and timing output
Timing output sources	Many analog input, analog output, counter, digital input, and digital output timing signals
Debounce filter settings	Selectable per input: 125 ns, 6.425 µs, 2.56 ms, disable, high and low transitions
Timing input frequency	0 - 20 MHz
Timing output frequency	0 - 20 MHz

Chassis PFI Characteristics (NI cDAQ-9178 Only)

Max input or output frequency	1 MHz
Cable length	3 m (10 ft)
Cable impedance	50 Ω
TRIG 0 (PFI 0), TRIG 1 (PFI 1) connectors	BNC
Power-on state	High impedance

Input/output voltage protection

Voltage	Minimum	Maximum
Input	−20 V	25 V
Output	−15 V	20 V

Maximum operating conditions

Level	Minimum	Maximum
I_{OL} output low current	–	8 mA
I_{OH} output high current	–	−8 mA

DC input characteristics

Level	Minimum	Maximum
Positive going threshold	1.43 V	2.28 V
Negative going threshold	0.86 V	1.53 V
Hysteresis	0.48 V	0.87 V

DC output characteristics - Level High

Conditions	Minimum	Maximum
–	–	5.25 V
Sourcing 100 µA	4.65 V	–
Sourcing 2 mA	3.60 V	–
Sourcing 3.5 mA	3.44 V	–

DC output characteristics - Level Low

Conditions	Minimum	Maximum
Sinking 100 µA	–	0.10 V
Sinking 2 mA	–	0.64 V
Sinking 3.5 mA	–	0.8 V

Digital Triggers

Source

NI cDAQ-9171/9174	Any module PFI terminal
NI cDAQ-9178	Any chassis PFI BNC terminal or module PFI terminal
Polarity	Software-selectable for most signals
Analog input function	Start Trigger, Reference Trigger, Pause Trigger, Sample Clock, Sample Clock Timebase
Analog output function	Start Trigger, Pause Trigger, Sample Clock, Sample Clock Timebase
Counter/timer functions	Gate, Source, HW_Arm, Aux, A, B, Z, Up_Down

Module I/O States

At power-on	Module-dependent. Refer to the documentation included with the C Series I/O module(s).

Note The chassis may revert the input/output of the modules to its power-on state when the USB cable is removed.

Power Requirements

Caution You must use a National Electric Code (NEC) Class 2 power source with the NI cDAQ-9178/9174 chassis.

Note Some I/O modules have additional power requirements. For more information about C Series I/O module(s) power requirements, refer to documentation included with the C Series I/O module(s).

Note Sleep mode for C Series I/O modules is not supported in the NI cDAQ-917x.

NI cDAQ-9171

Power consumption from USB, 4.75 to 5.25 V	500 mA maximum
Suspend mode	2.5 mA maximum

NI cDAQ-9174/9178	
Input voltage range	9–30 V
Maximum required input power	15 W
Power input connector	2 positions 3.5 mm pitch pluggable screw terminal with screw locks similar to Sauro CTMH020F8-0N001
Power input mating connector	Sauro CTF020V8, Phoenix Contact 1714977, or equivalent
Power consumption from USB, 4.10 to 5.25 V	500 µA maximum

Bus Interface

USB specification	USB 2.0 Hi-Speed
High-performance data streams	
NI cDAQ-9171	6
NI cDAQ-9174/9178	7
Data stream types available	Analog input, analog output, digital input, digital output, counter/timer input, counter/timer output

Note If you are connecting the NI cDAQ-917x to a USB hub, the hub must be externally powered.

Physical Characteristics

NI cDAQ-9171 chassis	
Weight (unloaded)	Approx. 353 g (12.5 oz)
Dimensions (unloaded)	131.4 mm x 88.6 mm x 33.3 mm (5.17 in. x 3.49 in. x 1.31 in.)
NI cDAQ-9174 chassis	
Weight (unloaded)	Approx. 574 g (20.2 oz)
Dimensions (unloaded)	15.9 cm x 8.81 cm x 5.89 cm (6.28 in. x 3.5 in. x 2.3 in.)
NI cDAQ-9178 chassis	
Weight (unloaded)	Approx. 878 g (31.0 oz)
Dimensions (unloaded)	25.4 cm x 8.81 cm x 5.89 cm (10.0 in. x 3.5 in. x 2.3 in.)

If you need to clean the chassis, wipe it with a dry towel.

Safety

Safety Standards

If you need to clean the chassis, wipe it with a dry towel.

This product is designed to meet the requirements of the following standards of safety for electrical equipment for measurement, control, and laboratory use:

- IEC 61010-1, EN 61010-1
- UL 61010-1, CSA 61010-1

Note For UL and other safety certifications, refer to the product label or visit ni.com/certificaton, search by model number or product line, and click the appropriate link in the Certification column.

Environmental

Temperature	
Operating	–20 °C to 55 °C (IEC-60068-2-1 and IEC-60068-2-2)
Storage	–40 °C to 85 °C (IEC-60068-2-1 and IEC-60068-2-2)
NI cDAQ-9174/9178 ingress protection	IP 30
Humidity	
Operating	10 to 90% RH, noncondensing (IEC-60068-2-56)
Storage	5 to 95% RH, noncondensing (IEC-60068-2-56)
Maximum altitude	2,000 m
Pollution Degree (IEC 60664)	2

Indoor use only.

Shock and Vibration

To meet these specifications, you must panel mount the NI cDAQ-917x system, use an NI locking USB cable, and affix ferrules to the ends of the terminal lines.

Operating shock	30 g peak, half-sine, 11 ms pulse (Tested in accordance with IEC-60068-2-27. Test profile developed in accordance with MIL-PRF-28800F.)
Random vibration	
Operating	5 to 500 Hz, 0.3 grms
Non-operating	5 to 500 Hz, 2.4 grms (Tested in accordance with IEC-60068-2-64. Nonoperating test profile exceeds the requirements of MIL-PRF-28800F, Class 3.)

Safety

This product meets the requirements of the following standards of safety for electrical equipment for measurement, control, and laboratory use:

- IEC 61010-1, EN 61010-1
- UL 61010-1, CSA 61010-1

Note For UL and other safety certifications, refer to the product label or the Online Product Certification section.

Electromagnetic Compatibility

This product is designed to meet the requirements of the following standards of EMC for electrical equipment for measurement, control, and laboratory use:

- EN 61326 EMC requirements; Minimum Immunity
- EN 55011 Emissions; Group 1, Class A
- AS/NZS CISPR 11: Group 1, Class A emissions
- FCC 47 CFR Part 15B: Class A emissions
- ICES-001: Class A emissions

Note In the United States (per FCC 47 CFR), Class A equipment is intended for use in commercial, light-industrial, and heavy-industrial locations. In Europe, Canada, Australia and New Zealand (per CISPR 11) Class A equipment is intended for use only in heavy-industrial locations.

Note Group 1 equipment (per CISPR 11) is any industrial, scientific, or medical equipment that does not intentionally generates radio frequency energy for the treatment of material or inspection/analysis purposes.

Note For EMC declarations and certifications, and additional information, refer to the Online Product Certification section..

CE Compliance

This product meets the essential requirements of applicable European Directives, as amended for CE marking, as follows:

- 2006/95/EC; Low-Voltage Directive (safety)
- 2004/108/EC; Electromagnetic Compatibility Directive (EMC)

Online Product Certification

Refer to the product Declaration of Conformity (DoC) for additional regulatory compliance information. To obtain product certifications and the DoC for this product, visit ni.com/certification, search by module number or product line, and click the appropriate link in the Certification column.

Environmental Management

National Instruments is committed to designing and manufacturing products in an environmentally responsible manner. NI recognizes that eliminating certain hazardous substances from our products is beneficial not only to the environment but also to NI customers.

For additional environmental information, refer to the *NI and the Environment* Web page at ni.com/environment. This page contains the environmental regulations and directives with which NI complies, as well as other environmental information not included in this document.

Waste Electrical and Electronic Equipment (WEEE)

EU Customers At the end of their life cycle, all products *must* be sent to a WEEE recycling center. For more information about WEEE recycling centers and National Instruments WEEE initiatives, visit ni.com/environment/weee.htm.

电子信息产品污染控制管理办法 （中国 RoHS）

中国客户 National Instruments 符合中国电子信息产品中氯制使用某些有害物质指令 (RoHS)。
关于 National Instruments 中国 RoHS 合规性信息，请登录 ni.com/environment/rohs_china。
(For information about China RoHS compliance, go to ni.com/environment/rohs_china.)

[1] Performance dependent on type of installed C Series I/O modules and number of channels in the task.
[2] Does not include group delay. Refer to C Series I/O module documentation for more information

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Technical Sales
United States
(866) 531-6285
info@ni.com

Last Revised: 2010-03-03 15:06:31.0

24-Bit Universal Analog Input

NI 9219

- 250 Vrms channel-to-channel isolation
- Built-in quarter-, half-, and full-bridge support
- Built-in voltage and current excitation
- Thermocouple, RTD, resistance, voltage, and current measurements
- CJC per channel for accurate thermocouple measurement
- 100 S/s/ch simultaneous inputs (50 S/s/ch for thermocouple)

Overview

The NI 9219 is a four-channel universal C Series module designed for multipurpose testing in any NI CompactDAQ or CompactRIO chassis. With the NI 9219, you can measure several signals from sensors such as strain gages, RTDs, thermocouples, load cells, and other powered sensors. The channels are individually selectable, so you can perform a different measurement type on each of the four channels. Measurement ranges differ for each type of measurement and include up to ±60 V for voltage and ±25 mA for current. Please see the manual for detailed specifications and ranges.

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Requirements and Compatibility

OS Information

- Real-Time OS
- Windows

Driver Information

- NI-DAQmx
- NI-RIO

Software Compatibility

- LabVIEW
- LabVIEW SignalExpress
- LabWindows/CVI
- Measurement Studio
- Visual C++
- Visual Studio
- Visual Studio .NET

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Comparison Tables

Thermocouple Module	Channels	Sample Rate	Resolution	Feature
NI 9213	16	1,200 S/s	24-bit	Lowest cost/channel
NI 9219	4	50 S/s/ch	24-bit	Channel-to-channel isolation
NI 9211	4	14 S/s	24-bit	Low-channel count

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Application and Technology

Because of the driver design, the NI 9219 does not limit the overall speed of an NI CompactDAQ system when used with faster sampling modules. With 250 Vrms of channel-to-channel isolation, the NI 9219 protects not only the surrounding modules, chassis, and connected computer system but also the other channels within the same module. In addition to increased safety, channel-to-channel isolation eliminates problems associated with ground loops.

Connectivity Accessories

The NI 9219 uses six-position spring terminal connectors in each channel for direct signal connectivity. You can purchase additional connectors to reduce signal connection time for multiple test units. In addition to extra connectors, a strain relief kit is available to secure the signal wires. NI recommends:

- NI 9972 - strain relief backshells for signal wire security and high-voltage protection (qty 4)
- NI 9973 - extra connectors for six-position connector modules (qty 10)

NI C Series Compatibility

The NI C Series hardware family features more than 50 measurement modules and several chassis and carriers for deployment. With this variety of modules, you can mix and match measurements such as temperature, acceleration, flow, pressure, strain, acoustic, voltage, current, digital, and more to create a custom system. Install the modules in one of several carriers to create a single module USB, Ethernet, or Wi-Fi system, or combine them in chassis such as NI CompactDAQ and CompactRIO to create a mixed-measurement system with synchronized measurements. You can install up to eight modules in a simple, complete NI CompactDAQ USB data acquisition system to synchronize all of the analog output, analog input, and digital I/O from the modules. For a system without a PC, CompactRIO holds up to eight modules and features a built-in processor, RAM, and storage for an embedded data logger or control unit. For higher-speed control, CompactRIO chassis incorporate a field-programmable gate array (FPGA) that you can program with NI LabVIEW software to achieve silicon-speed processing on I/O data from C Series modules.

Advanced Features

When used with CompactRIO, NI C Series analog input modules connect directly to reconfigurable I/O (RIO) FPGA hardware to create high-performance embedded systems. The reconfigurable FPGA hardware within CompactRIO provides a variety of options for custom timing, triggering, synchronization, filtering, signal processing, and high-speed decision making for all C Series analog modules. For instance, with CompactRIO, you can implement custom triggering for any analog sensor type on a per-channel basis using the flexibility and performance of the FPGA and the numerous arithmetic and comparison function blocks built into the LabVIEW FPGA Module.

Key Features

- High-accuracy, high-performance analog measurements for any CompactRIO embedded system, R Series expansion chassis, or NI CompactDAQ chassis
- Screw terminals, BNC, D-Sub, spring terminals, strain relief, high voltage, cable, solder cup backshell, and other connectivity options
- Available channel-to-earth ground double-isolation barrier for safety, noise immunity, and high common-mode voltage range
- CompactRIO Extreme Industrial Certifications and Ratings
- Built-in signal conditioning for direct connection to sensors and industrial devices

Visit ni.com/compactrio or ni.com/compactdaq for up-to-date information on module availability, example programs, application notes, and other developer tools.

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Ordering Information

For a complete list of accessories, visit the product page on ni.com.

Products	Part Number	Recommended Accessories	Part Number
NI 9219			
NI 9219	779781-01	No accessories required.	

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Software Recommendations

LabVIEW Professional Development System for Windows

- Advanced software tools for large project development
- Automatic code generation using DAQ Assistant and Instrument I/O Assistant
- Tight integration with a wide range of hardware
- Advanced measurement analysis and digital signal processing
- Open connectivity with DLLs, ActiveX, and .NET objects
- Capability to build DLLs, executables, and MSI installers

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Support and Services

System Assurance Programs

NI system assurance programs are designed to make it even easier for you to own an NI system. These programs include configuration and deployment services for your NI PXI, CompactRIO, or Compact FieldPoint system. The NI Basic System Assurance Program provides a simple integration test and ensures that your system is delivered completely assembled in one box. When you configure your system with the NI Standard System Assurance Program, you can select from available NI system driver sets and application development environments to create customized, reorderable software configurations. Your system arrives fully assembled and tested in one box with your software preinstalled. When you order your system with the standard program, you also receive system-specific documentation including a bill of materials, an integration test report, a recommended maintenance plan, and frequently asked question documents. Finally, the standard program reduces the total cost of owning an NI system by providing three years of warranty coverage and calibration service. Use the online product advisors at ni.com/advisor to find a system assurance program to meet your needs.

Calibration

NI measurement hardware is calibrated to ensure measurement accuracy and verify that the device meets its published specifications. NI offers a number of calibration services to help maintain the ongoing accuracy of your measurement hardware. These services allow you to be completely confident in your measurements, and help you maintain compliance to standards like ISO 9001, ANSI/NCSL Z540-1 and ISO/IEC 17025. To learn more about NI calibration services or to locate a qualified service center near you, contact your local sales office or visit ni.com/calibration.

Technical Support

Get answers to your technical questions using the following National Instruments resources.

- **Support** - Visit ni.com/support to access the NI KnowledgeBase, example programs, and tutorials or to contact our applications engineers who are located in NI sales offices around the world and speak the local language.
- **Discussion Forums** - Visit forums.ni.com for a diverse set of discussion boards on topics you care about.
- **Online Community** - Visit community.ni.com to find, contribute, or collaborate on customer-contributed technical content with users like you.

Repair

While you may never need your hardware repaired, NI understands that unexpected events may lead to necessary repairs. NI offers repair services performed by highly trained technicians who quickly return your device with the guarantee that it will perform to factory specifications. For more information, visit ni.com/repair.

Training and Certifications

The NI training and certification program delivers the fastest, most certain route to increased proficiency and productivity using NI software and hardware. Training builds the skills to more efficiently develop robust, maintainable applications, while certification validates your knowledge and ability.

- **Classroom training in cities worldwide** - the most comprehensive hands-on training taught by engineers.
- **On-site training at your facility** - an excellent option to train multiple employees at the same time.
- **Online instructor-led training** - lower-cost, remote training if classroom or on-site courses are not possible.
- **Course kits** - lowest-cost, self-paced training that you can use as reference guides.
- **Training memberships** and training credits - to buy now and schedule training later.

Visit ni.com/training for more information.

Extended Warranty

NI offers options for extending the standard product warranty to meet the life-cycle requirements of your project. In addition, because NI understands that your requirements may change, the extended warranty is flexible in length and easily renewed. For more information, visit ni.com/warranty.

OEM

NI offers design-in consulting and product integration assistance if you need NI products for OEM applications. For information about special pricing and services for OEM customers, visit ni.com/oem.

Alliance

Our Professional Services Team is comprised of NI applications engineers, NI Consulting Services, and a worldwide National Instruments Alliance Partner program of more than 600 independent consultants and integrators. Services range from start-up assistance to turnkey system integration. Visit ni.com/alliance.

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Detailed Specifications

The following specifications are typical for the range –40 to 70 °C unless otherwise noted.

Input Characteristics	
Number of channels	4 analog input channels
ADC resolution	24 bits
Type of ADC	Delta-sigma (with analog prefiltering)
Sampling mode	Simultaneous
Type of TEDS supported	IEEE 1451.4 TEDS Class II (Interface)

Mode Input ranges		
Mode	**Nominal Range(s)**	**Actual Range(s)**
Voltage	±60 V, ±15 V, ±4 V, ±1 V, ±125 mV	±60 V, ±15 V, ±4 V, ±1 V, ±125 mV
Current	±25 mA	±25 mA
4-Wire and 2-Wire Resistance	10 kΩ, 1 kΩ	10.5 kΩ, 1.05 kΩ
Thermocouple	±125 mV	±125 mV
4-Wire and 3-Wire RTD	Pt 1000, Pt 100	5.05 kΩ, 505 Ω
Quarter-Bridge	350 Ω, 120 Ω	390 Ω, 150 Ω
Half-Bridge	±500 mV/V	±500 mV/V
Full-Bridge	±62.5 mV/V, ±7.8 mV/V	±62.5 mV/V, ±7.8125 mV/V
Digital In	—	0–60 V
Open Contact	—	1.05 kΩ

Conversion time, no channels in TC mode	
High speed	10 ms for all channels
Best 60 Hz rejection	110 ms for all channels
Best 50 Hz rejection	130 ms for all channels
High resolution	500 ms for all channels
Conversion time, one or more channels in TC mode	
High speed	20 ms for all channels
Best 60 Hz rejection	120 ms for all channels
Best 50 Hz rejection	140 ms for all channels
High resolution	510 ms for all channels
Overvoltage protection	
Terminals 1 and 2	±30 V
Terminals 3 through 6, across any combination	±60 V
Input impedance	
Voltage and Digital In modes (±60 V, ±15 V, ±4 V)	1 MΩ
Current mode	<40 Ω
All other modes	>1 GΩ

Accuracy		
Mode, Range	**Gain Error (Percent of Reading)**	**Offset Error (ppm of Range)**
	Typ (25 °C, ±5 °C), Max (–40 to 70 °C)	
Voltage, ±60 V	±0.3, ±0.4	±20, ±50
Voltage, ±15 V	±0.3, ±0.4	±60, ±180
Voltage, ±4 V	±0.3, ±0.4	±240, ±720
Voltage, ±1 V	±0.1, ±0.18	±15, ±45
Voltage/Thermocouple, ±125 mV	±0.1, ±0.18	±120, ±360
Current, ±25 mA	±0.1, ±0.6	±30, ±100
4-Wire and 2-Wire [1] Resistance, 10 kΩ	±0.1, ±0.5	±120, ±320
4-Wire and 2-Wire [1] Resistance, 1 kΩ	±0.1, ±0.5	±1200, ±3200
4-Wire and 3-Wire RTD, Pt 1000	±0.1, ±0.5	±240, ±640
4-Wire and 3-Wire RTD, Pt 100	±0.1, ±0.5	±2400, ±6400
Quarter-Bridge, 350 Ω	±0.1, ±0.5	±2400, ±6400
Quarter-Bridge, 120 Ω	±0.1, ±0.5	±2400, ±6400
Half-Bridge, ±500 mV/V	±0.03, ±0.07	±300, ±450
Full-Bridge, ±62.5 mV/V	±0.03, ±0.08	±300, ±1000
Full-Bridge, ±7.8 mV/V	±0.03, ±0.08	±2200, ±8000

Cold-junction compensation sensor accuracy	±1°C typ

Stability		
Mode, Range	Gain Drift (ppm of Read-ing/°C)	Offset Drift (ppm of Range/°C)
Voltage, ±60 V	±20	±0.2
Voltage, ±15 V	±20	±0.8
Voltage, ±4 V	±20	±3.2
Voltage, ±1 V	±10	±0.2
Voltage/Thermocouple, ±125 mV	±10	±1.6
Current, ±25 mA	±15	±0.4
4-Wire and 2-Wire Resistance, 10 kΩ	±15	±3
4-Wire and 2-Wire Resistance, 1 kΩ	±15	±30
4-Wire and 3-Wire RTD, Pt 1000	±15	±6
4-Wire and 3-Wire RTD, Pt 100	±15	±60
Quarter-Bridge, 350 Ω	±15	±120
Quarter-Bridge, 120 Ω	±15	±240
Half-Bridge, ±500 mV/V	±3	±20
Full-Bridge, ±62.5 mV/V	±3	±20
Full-Bridge, ±7.8 mV/V	±3	±20

Input noise in ppm of $Range_{rms}$				
Mode, Range	Conversion Time			
	High speed	Best 60 Hz re-jection	Best 50 Hz re-jection	High resolution
Voltage, ±60 V	7.6	1.3	1.3	0.5
Voltage, ±15 V	10.8	1.9	1.9	0.7
Voltage, ±4 V	10.8	2.7	2.7	1.3
Voltage, ±1 V	7.6	1.3	1.3	0.5
Voltage/Thermocouple, ±125 mV	10.8	1.9	1.9	1.0
Current, ±25 mA	10.8	1.9	1.9	1.0
4-Wire and 2-Wire Resistance, 10 kΩ	4.1	1.3	0.8	0.3
4-Wire and 2-Wire Resistance, 1 kΩ	7.1	1.8	1.2	0.7
4-Wire and 3-Wire RTD, Pt 1000	7.6	1.7	1.1	0.4
4-Wire and 3-Wire RTD, Pt 100	10.8	1.9	1.9	0.9
Quarter-Bridge, 350 Ω	5.4	1.0	1.0	0.7
Quarter-Bridge, 120 Ω	5.4	1.0	1.0	0.7
Half-Bridge, ±500 mV/V	3.8	0.5	0.5	0.2
Full-Bridge, ±62.5 mV/V	5.4	1.0	1.0	0.8
Full-Bridge, ±7.8 mV/V	30	4.7	4.7	2.3

Input bias current	<1 nA
INL	±15 ppm
CMRR (f_{in} = 60 Hz)	>100 dB
NMRR	
Best 60 Hz rejection	90 dB at 60 Hz
Best 50 Hz rejection	80 dB at 50 Hz
High resolution	65 dB at 50 Hz and 60 Hz

Excitation level for Half-Bridge and Full-Bridge modes		
Mode	Load Resistance (Ω)	Excitation (V)
Half-Bridge	700	2.5

	240	2.0
Full-Bridge	350	2.7
	120	2.2

Excitation level for Resistance, RTD, and Quarter-Bridge modes	
Load Resistance (Ω)	**Excitation (mV)**
120	50
350	150
1 k	430
10 k	2200

MTBF	384,716 hours at 25 °C; Bellcore Issue 2, Method 1, Case 3, Limited Part Stress Method

Note Contact NI for Bellcore MTBF specifications at other temperatures or for MIL-HDBK-217F specifications.

Power Requirements

Power consumption from chassis	
Active mode	750 mW max
Sleep mode	25 µW max
Thermal dissipation (at 70 °C)	
Active mode	625 mW max
Sleep mode	25 µW max

Physical Characteristics

Note For two-dimensional drawings and three-dimensional models of the C Series module and connectors, visit ni.com/dimensions and search by module number.

Spring-terminal wiring	18 to 28 AWG copper conductor wire with 7 mm (0.28 in.) of insulation stripped from the end
Weight	156 g (5.5 oz)

Safety

If you need to clean the module, wipe it with a dry towel.

Safety Voltages

Connect only voltages that are within the following limits.

Channel-to-channel	
Continuous	250 VAC, Measurement Category II
Withstand	1,390 VAC, verified by a 5 s dielectric withstand test
Channel-to-earth ground	
Continuous	250 VAC, Measurement Category II
Withstand	2,300 VAC, verified by a 5 s dielectric withstand test
Zone 2 hazardous locations applications in Europe channel-to-channel and channel-to-earth ground	60 VDC, Measurement Category I

Measurement Category I is for measurements performed on circuits not directly connected to the electrical distribution system referred to as MAINS [2] voltage. This category is for measurements of voltages from specially protected secondary circuits. Such voltage measurements include signal levels, special equipment, limited-energy parts of equipment, circuits powered by regulated low-voltage sources, and electronics.

Caution Do *not* connect to signals or use for measurements within Measurement Categories II, III, or IV.

Measurement Category II is for measurements performed on circuits directly connected to the electrical distribution system. This category refers to local-level electrical distribution, such as that provided by a standard wall outlet (e.g., 115 V for U.S. or 230 V for Europe). Examples of Measurement Category II are measurements performed on household appliances, portable tools, and similar products.

Caution Do *not* connect to signals or use for measurements within Measurement Categories III or IV.

Hazardous Locations

U.S. (UL)	Class I, Division 2, Groups A, B, C, D, T4; Class I, Zone 2, AEx nA IIC T4
Canada (C-UL)	Class I, Division 2, Groups A, B, C, D, T4; Class I, Zone 2, Ex nA IIC T4
Europe (DEMKO)	Ex nA IIC T4

Safety Standards

This product is designed to meet the requirements of the following standards of safety for electrical equipment for measurement, control, and laboratory use:

- IEC 61010-1, EN 61010-1
- UL 61010-1, CSA 61010-1

Note For UL and other safety certifications, refer to the product label or the *Online Product Certification* section.

Electromagnetic Compatibility

This product meets the requirements of the following EMC standards for electrical equipment for measurement, control, and laboratory use:

- EN 61326 (IEC 61326): Class A emissions; Industrial Immunity
- EN 55011 (CISPR 11): Group 1, Class A emissions
- AS/NZS CISPR 11: Group 1, Class A emissions
- FCC 47 CFR Part 15B: Class A emissions
- ICES-001: Class A emissions

Note For the standards applied to assess the EMC of this product, refer to the *Online Product Certification* section.

Note For EMC compliance, operate this device with shielded cables.

CE Compliance

This product meets the essential requirements of applicable European Directives, as amended for CE marking, as follows:

- 2006/95/EC; Low-Voltage Directive (safety)
- 2004/108/EC; Electromagnetic Compatibility Directive (EMC)

Note For the standards applied to assess the EMC of this product, refer to the *Online Product Certification* section.

Online Product Certification

Refer to the product Declaration of Conformity (DoC) for additional regulatory compliance information. To obtain product certifications and the DoC for this product, visit ni.com/certification, search by module number or product line, and click the appropriate link in the Certification column.

Shock and Vibration

To meet these specifications, you must panel mount the system.

Operating vibration	
Random (IEC 60068-2-64)	5 g_{rms}, 10 to 500 Hz
Sinusoidal (IEC 60068-2-6)	5 g, 10 to 500 Hz
Operating shock (IEC 60068-2-27)	30 g, 11 ms half sine, 50 g, 3 ms half sine, 18 shocks at 6 orientations

Environmental

National Instruments C Series modules are intended for indoor use only but may be used outdoors if installed in a suitable enclosure. Refer to the manual for the chassis you are using for more information about meeting these specifications.

Operating temperature (IEC 60068-2-1, IEC 60068-2-2)	–40 to 70 °C
Storage temperature (IEC 60068-2-1, IEC 60068-2-2)	–40 to 85 °C
Ingress protection	IP 40
Operating humidity (IEC 60068-2-56)	10 to 90% RH, noncondensing
Storage humidity (IEC 60068-2-56)	5 to 95% RH, noncondensing
Maximum altitude	2,000 m
Pollution Degree (IEC 60664)	2

Environmental Management

National Instruments is committed to designing and manufacturing products in an environmentally responsible manner. NI recognizes that eliminating certain hazardous substances from our products is beneficial not only to the environment but also to NI customers.

For additional environmental information, refer to the *NI and the Environment* Web page at ni.com/environment. This page contains the environmental regulations and directives with which NI complies, as well as other environmental information not included in this document.

Waste Electrical and Electronic Equipment (WEEE)

EU Customers At the end of their life cycle, all products *must* be sent to a WEEE recycling center. For more information about WEEE recycling centers and National Instruments WEEE initiatives, visit ni.com/environment/weee.htm.

电子信息产品污染控制管理办法 （中国 RoHS）

中国客户 National Instruments 符合中国电子信息产品中限制使用某些有害物质指令 (RoHS)。
关于 National Instruments 中国 RoHS 合规性信息，请登录 ni.com/environment/rohs_china。
(For information about China RoHS compliance, go to ni.com/environment/rohs_china.)

Calibration

You can obtain the calibration certificate for this device at ni.com/calibration.

Calibration Interval	1 year

[1] 2-Wire Resistance mode accuracy depends on the lead wire resistance. This table assumes 0 Ω of lead wire resistance.

[2] MAINS is defined as the (hazardous live) electrical supply system to which equipment is designed to be connected for the purpose of powering the equipment. Suitably rated measuring circuits may be connected to the MAINS for measuring purposes.

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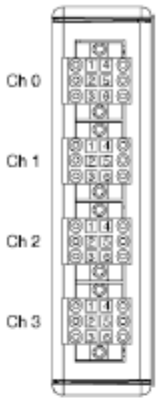
Pinouts/Front Panel Connections



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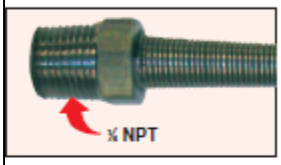
6.

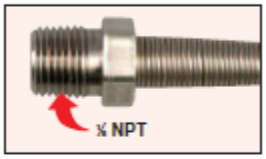
Dual Element RTD Pipe Plug Sensors

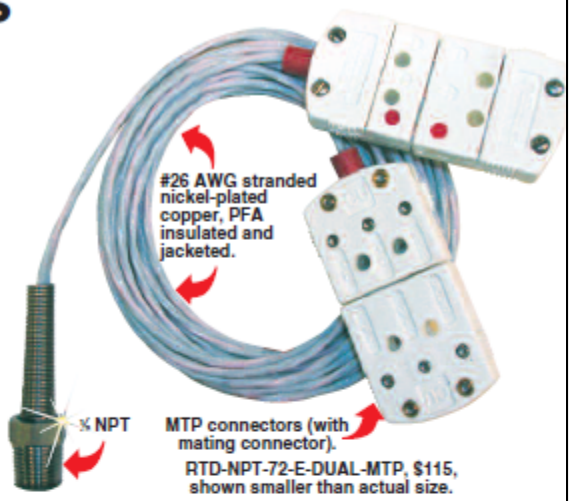
Starts at
$115

MADE IN USA

- Ideal for Use in Pressure Vessel Applications, 172 bar (2500 psi) Max
- PFA Insulated Lead Wires
- High-Accuracy, 100 Ω, Thin-Film Class "A" DIN Platinum Elements
- 3-Wire Construction for Connecting to Most Handheld Instruments







RTD-NPT-72-E-DUAL-MTP, $115, shown smaller than actual size.

MOST POPULAR MODELS HIGHLIGHTED!

To Order *(Specify Model Number)*

Model Number	Sensing Element	Cable	Thread Size	Max Temp	Price
RTD-NPT-72-E-DUAL-MTP	100 Ω Class "A" DIN	72" L PFA insulated with MTP connectors	⅛ NPT	230°C (450°F)	$115
RTD-NPT-72-E-DUAL-1/4-MTP	100 Ω Class "A" DIN	72" L PFA insulated with MTP connectors	¼ NPT	230°C (450°F)	115
RTD-NPT-72-E-DUAL-1/4-MTP-HT	100 Ω Class "A" DIN	72" L fiberglass insulated with MTP connectors	¼ NPT	480°C (896°F)	134
RTD-NPT-72-E-DUAL-MTP-HT-S	100 Ω Class "A" DIN	72" L SST braided fiberglass insulated with MTP connectors	⅛ NPT	480°C (896°F)	134

*Ordering Examples: **RTD-NPT-72-E-DUAL-MTP**, dual 100 Ω Class "A" DIN Platinum thin-film elements, 3-wire connections, ¼ NPT mounting thread, 72" long PFA insulated cables with MTP connectors, **$115**. **RTD-NPT-72-E-DUAL-1/4-MPT-HT**, dual 100 Ω Class "A" DIN Platinum thin-film elements, 3-wire connections, ¼ NPT mounting thread, 72" long fiberglass insulated cables with MTP connectors, **$134**.*

*Options: Sensors supplied with MTP connectors standard. For OTP connectors add "**-OTP**" to model number and **$14** to price. For NO connectors remove "**-MTP**" from model number and subtract **$14** from price (leads will be stripped). For a 3-pin audio connector, add "**-TA3F**" to the model number and **$34** to the price. Specify ⅛ or ¼ NPT mounting thread at no additional charge.*

Popular Options Include:

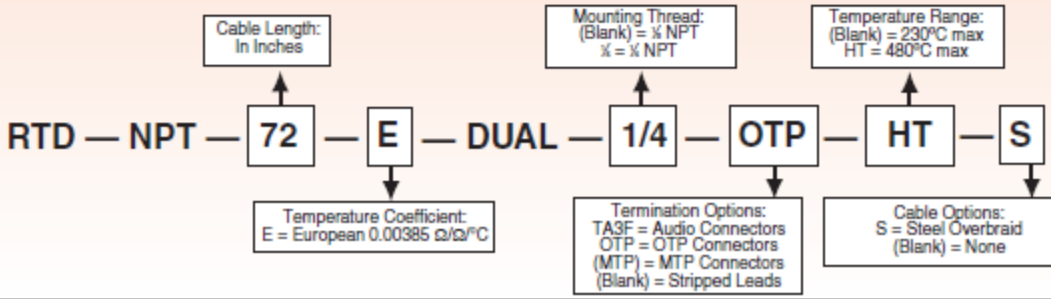
CN1A, $181, see page P-27.

DP461-RTD meter, $365, see page M-63.

iDRX/iDRN signal conditioner, $250, visit omega.com/idrn-idrx

DRF-RTD signal conditioner, $180, visit omega.com/drf-rtd

How are OMEGA's Model Numbers Constructed?



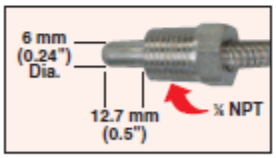
*Ordering Example: **RTD-NPT-72-E-1/4-DUAL-1/4-OTP-HT-S**, two 100 Ω class "A" DIN, 72" fiberglass insulated, ¼ NPT, 480°C (896°F), and OTP connector, $134 + 7 = **$141**.*

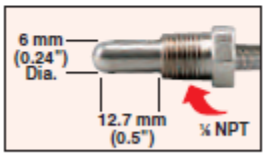
Pipe Plug RTD Sensor

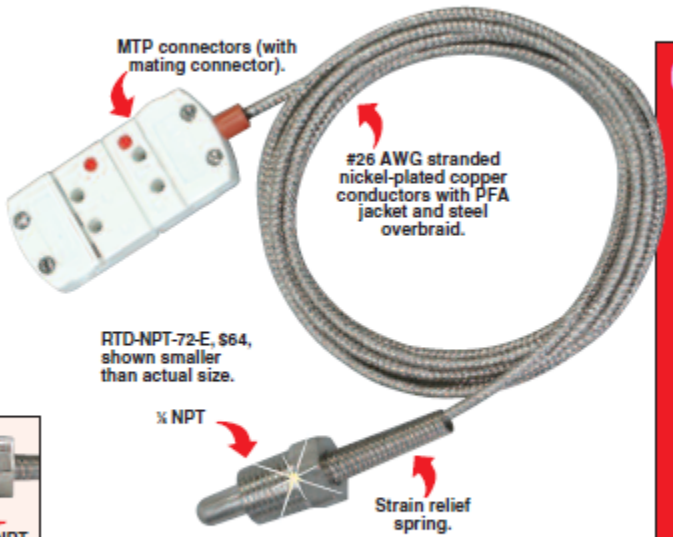
RTD-NPT Series
Starts at
$64

MADE IN USA

- Ideal for Use in Pressure Vessel Applications, 172 bar (2500 psi) Max
- 6 mm (0.24") Diameter, SST Probe
- Steel Braided, PFA Insulated Lead Wires
- High-Accuracy, 100 Ω, Class "A" DIN Thin-Film Platinum Element (European Curve)
- 3-Wire Construction for Connecting to Most Handheld Instruments with Red/Red/White Per ASTM-E-1137







MOST POPULAR MODELS HIGHLIGHTED!

To Order *(Specify Model Number)*

Model Number	Sensing Element	Cable	Thread Size	Max Temp	Price
RTD-NPT-72-E	100Ω Class "A" DIN	72" L PFA insulated (stripped leads)	¼ NPT	230°C (450°F)	$64
RTD-NPT-72-E-MTP	100Ω Class "A" DIN	72" L PFA insulated	¼ NPT	230°C (450°F)	71
RTD-NPT-72-E-1/8-MTP	100Ω Class "A" DIN	72" L PFA insulated	⅛ NPT	230°C (450°F)	71
RTD-NPT-72-E-MTP-HT	100Ω Class "A" DIN	72" L fiberglass insulated	¼ NPT	480°C (896°F)	84
RTD-NPT-72-E-1/8-MTP-HT	100Ω Class "A" DIN	72" L fiberglass insulated	⅛ NPT	480°C (896°F)	84

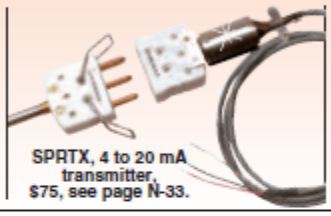
Ordering Examples: *RTD-NPT-72-E-TA3F, 100 Ω Class "A" European curve, single element, with ¼ NPT mounting thread, 72" long PFA insulated cable with audio connector, $64 + 17 = **$81**. RTD-NPT-72-E-MTP-HT, 100 Ω Class "A" European curve, single element, with ¼ NPT mounting thread, 72" long fiberglass insulated cable with steel overbraid, **$84**. RTD-NPT-72-E-1/8-MTP-HT, Class "A" element, European curve, with ⅛ NPT mounting thread, 72" long fiberglass insulated cable with SST braid, **$84**.*

Options Available: *Sensors supplied with MTP connectors, add **"-OTP"** to model number and **$7** to price for each heavy-duty connector, add **"-TA3F"** to model number and **$17** to price for each audio connector. For stripped leads (no connector) remove **"-MTP"** from model number, and subtract **$7**.*

Popular Options Include:

CN3271-R1 high/low limit controller, $220, see page P-101.

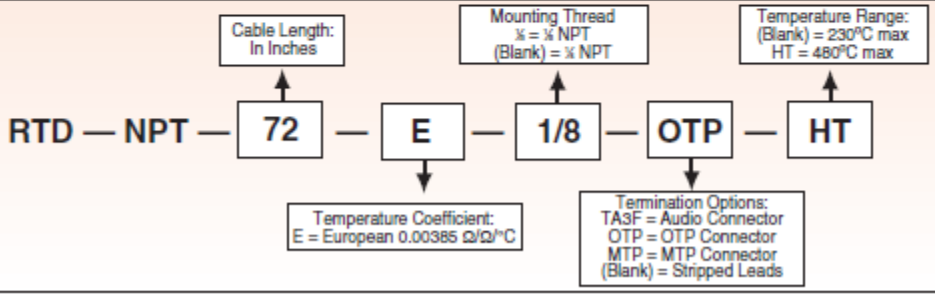
DP25B-RTD ¼ DIN panel meter, $245, see page M-24.



SPRTX, 4 to 20 mA transmitter, $75, see page N-33.

TX92 transmitter, $188, see page N-39.

How are OMEGA's Model Numbers Constructed?

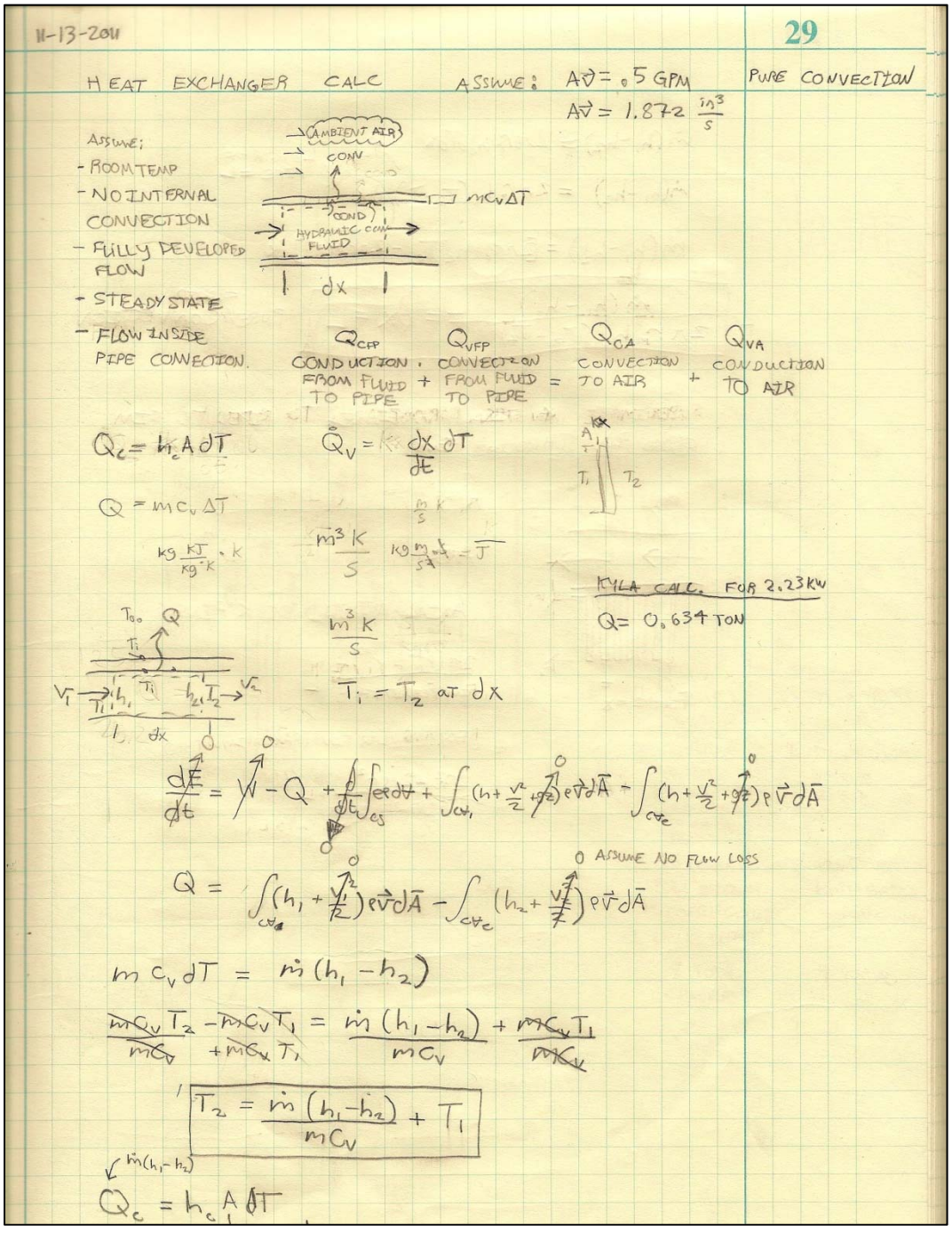


Ordering Example: *RTD-NPT-72-E-OTP-HT, 100 Ω Class "A" European curve, with ¼ NPT, 72" L fiberglass insulated cable, heavy-duty connector, $84 + 7 = **$91**.*

C-72

C

Appendix F: Hand Calculations



Heat Exchanger Disspation Requirement

$\dot{m}(h_1 - h_2) = 2\pi r_p h_c dT dx$

T_2 — LENGTH OF PIPE = L

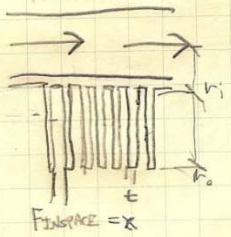
$\dot{m}(h_1 - h_2) = 2\pi r_p h_c (T_0 - T_i)\, dx$

$\dot{m}(h_1 - h_2) = [2\pi r_p h_c T_0 - 2\pi r_p h_c T_i]\, dx$

$$\frac{\dot{m}(h_1 - h_2)}{2\pi r_p h_c (T_0 - T_2)} = dx = L$$

FORCED PURE CONVECTION

SUPER IMPOSE A FIN SURFACE AREA TO PIPES TO SIM CROSS FLOW THROUGH FINS



AREA

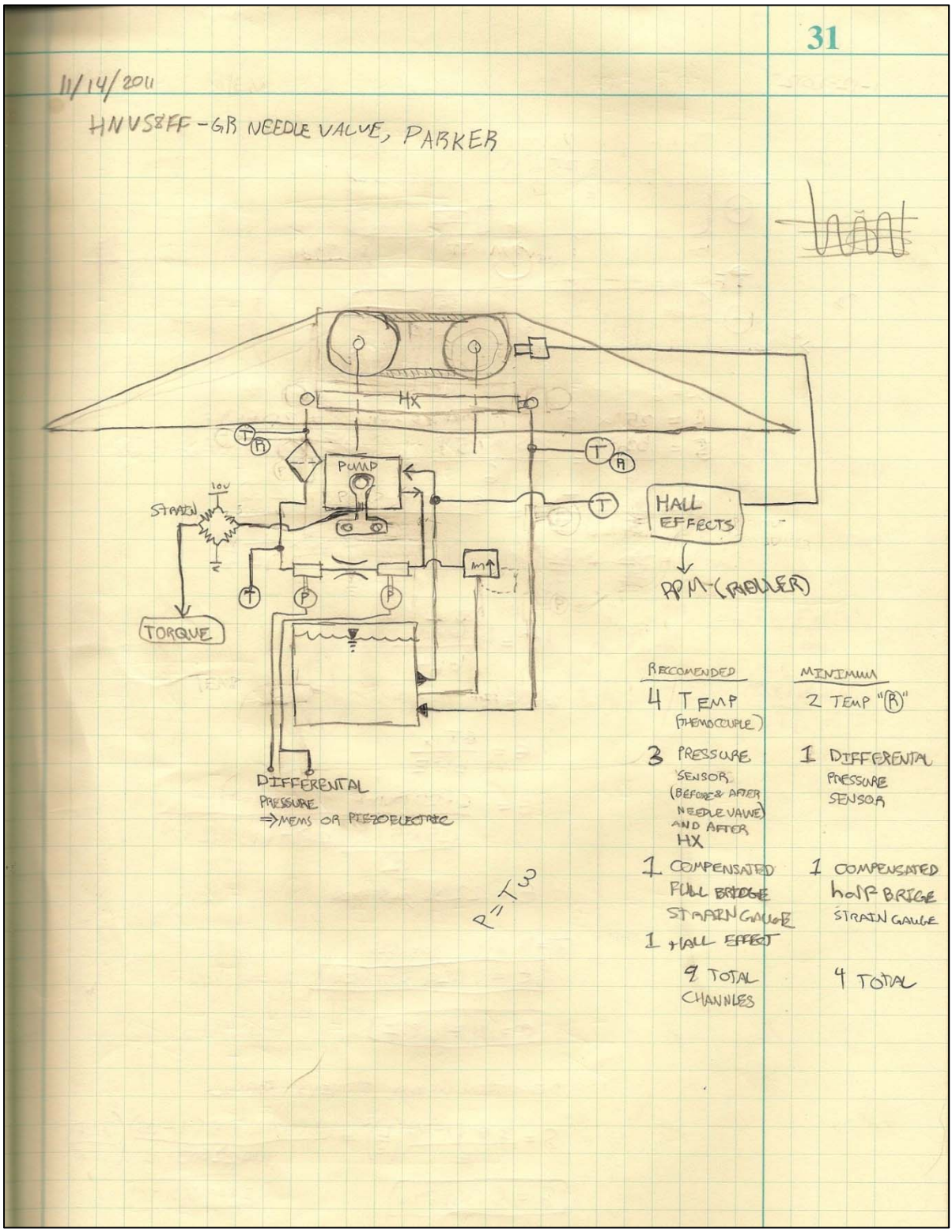
AXIALY MOUNTED DISK FINS

$$\frac{2\pi(r_o^2 - r_i^2)}{\text{FINS PER INCH}}$$

RECTANGULAR FINS (CAR RADIATOR TYPE)

$$\frac{2r_o^2 - 2\pi r_i^2}{\text{FINS PER INCH}}$$

Heat Exchanger Dissipation Requirement

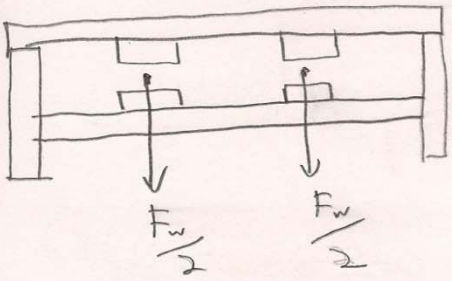


Preliminary Schematic of Hydraulic and Heat System

12/28/12 29

Frame Analysis

Given:

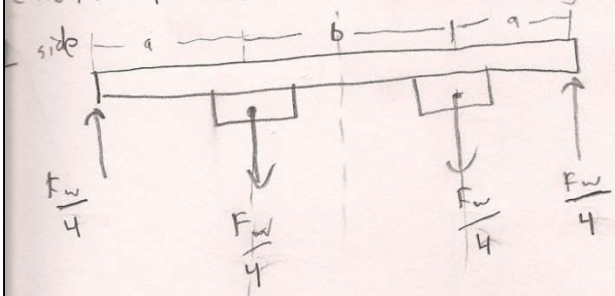


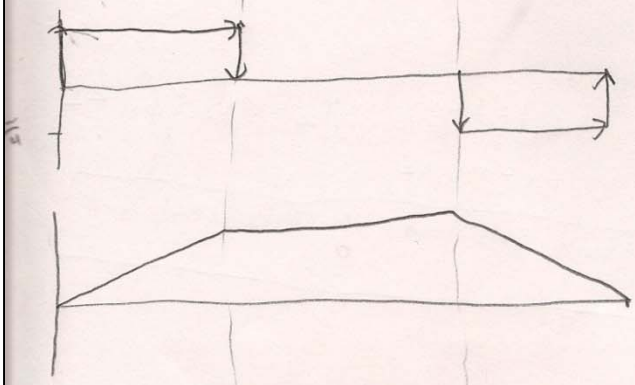
2x 1"x1" tubing
.065 wall thickness
$S_y = 30{,}000$ psi

$F_w = 400$ lbf

well, this is statically indeterminate,
so let's simplify it and see if it works.

Case 1: Top supports all of the loading:





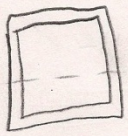
Max moment: $\frac{F_w}{4} \cdot a$

Frame Yield and Deflection Analysis

12/28/12 Frame strength continued 30

$\sigma = \frac{My}{I}$ $I = \frac{1}{12}BH^3$

$= \frac{1}{12}(1)(1)^3 - \frac{1}{12}(1-2\cdot.065)(1-2\cdot.065)^3$



$y = .5$ in $I = .0356$ in^4

tot $A = 4.5$

Bending $\sigma_{max} = \frac{(F_w/4)(a)(y)}{I}$

$\sigma_{max} = \frac{100 \cdot 4.5 \cdot .5}{.0356}$

$\sigma_{max} = 6320$ $S_y = 30{,}000$

$n_y = 4.75$

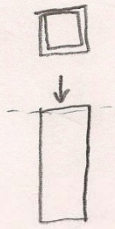
axial compression

$A = -(1-2\cdot.065)^2 + 1$ bust

$F = 200$ lbf

$\sigma = \frac{F}{A} = \frac{200 \text{ lbf}}{.243 \text{ in}^2 \cdot 2}$

$= 411$ psi



Max shear for bottom member

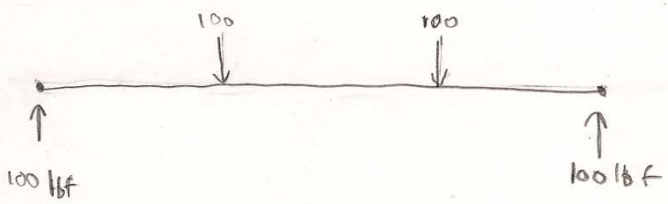
$\tau = \frac{3}{4}\frac{V}{t}\left[\frac{b^3 - (b-2t)^3}{b^4 - (b-2t)^4}\right]$ where $b = 1$ in, $t = .065$ in, $V = 100$ lbf

$\tau_{max} = 922.6$ psi << 30000 psi

conclusion: we can build this out of 1018 steel and it won't break

Frame Yield and Deflection Analysis

Deflection:



ok... before proceeding, let's check single point load max deflection.

$$\delta = \frac{F L^3}{EI48} \qquad L = 13.5 \text{ in}$$

$$\delta = \frac{400 \cdot 13.5^3}{30\times10^6 \cdot .0356 \cdot 48}$$

$$= .019 \text{ in} \leftarrow \text{which is fine.}$$

Frame Yield and Deflection Analysis

1/5/12

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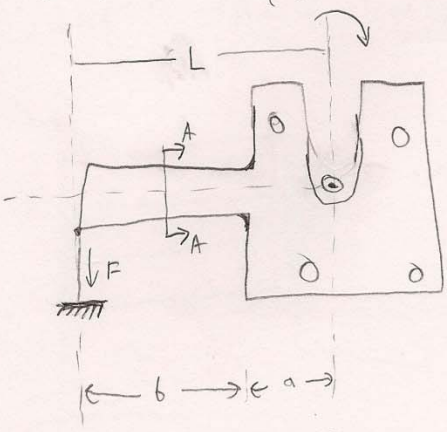
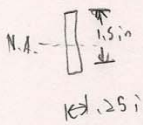
Max expected torque: 30 ft-lb

6061 T6





Material

Yield for max expected torque

$F = \frac{30}{L} \cdot \frac{12 in}{ft}$ $\quad L = 4.5 in$

$\sigma = \frac{F \cdot 6 \cdot .75}{I}$ $\quad I = \frac{1}{12} \cdot .25 \cdot 1.5^3$

$= .0703 in^4$

$= \frac{360 \cdot 4.5 \cdot .75}{.0703}$

$= 17283 psi < 40,000 psi$

$n_y = 2.314$

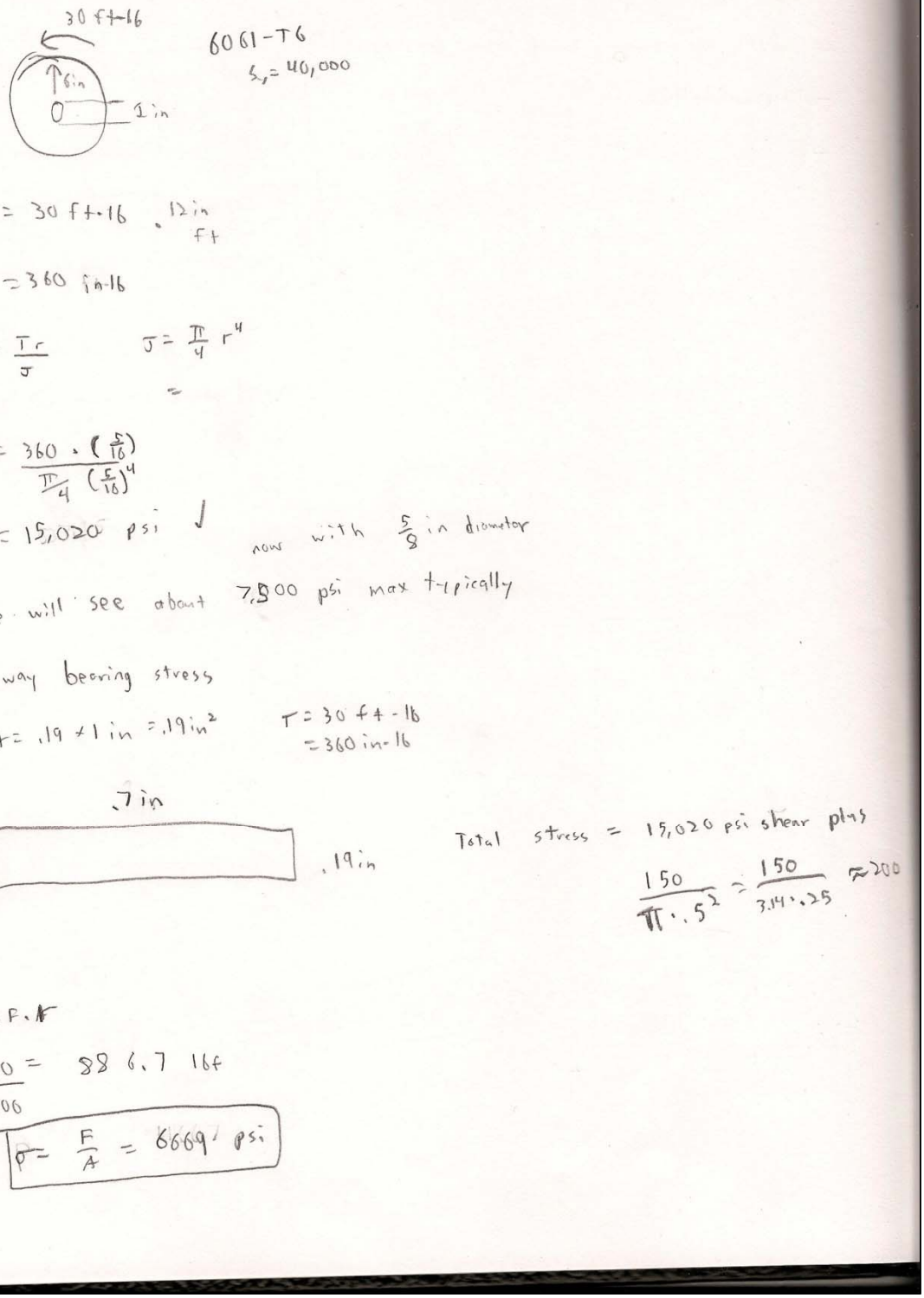
Deflection

$\delta_{max} = \frac{Pl^3}{3EI}$

$= \frac{360 \cdot 4.5^3}{3 \cdot .0703 \cdot 10.4 \times 10^6}$ $= .0150 in$ deflection

Pump Mount Yield and Deflection Analysis

1/9/12 Torque Analysis on Roller parts 36



Roller Yield analysis

11/10/11 FLOW RATE CALC.

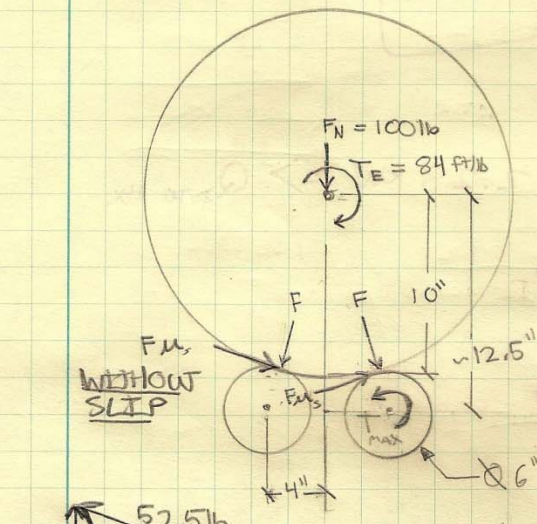
$$Q = PVA$$

$$\frac{lb}{s} = \frac{lb}{in^3} \cdot \frac{IN}{s} \cdot IN^2$$

$$\frac{\frac{lb}{s}}{\frac{lb}{in} \cdot IN^2} = \frac{IN}{s}$$

MTE HYDRAULICS
B307

FRICTIONAL ROLLER LIMIT 11/10/2011



STATIC FRICTION BETWEEN TIRE AND GRIP TAPE

$\mu_s = 1.0$

$F_N = 100lb = (400/4)lb$

$T_E = 84 ft/lb$

$F_{\mu_s} = 52.5lb(1.0)$

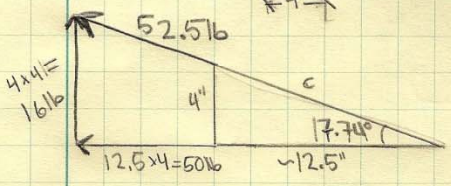
UNCOUPLED ROLLERS

$F_{\mu_s} = F_{FRICTION\ UNCOUPLED\ ROLLERS} = 52.5lb$ (i.e. NO BELT CONNECTION)

COUPLED ROLLERS

$F_F = F_{\mu_s} \times 2 = 105lbf$

ASSUMING NO BELT SLIP AT THIS LOAD



$T_{max} = F_F \cdot \frac{\varnothing}{2} = 105lbf \cdot 3"$

$T_{MAX} = 315\ IN\ lbf = 26.25\ ft\ lbf$

IF $F_N = \frac{350}{4} = 87.5lb$ AND $\mu = .7$

$F_N = \frac{87.5}{2} = 45.9lb$

$F_F = 2 \cdot (45.9 \times 0.7) = 64.31bf$

Rubber & DRY CONCRETE = $\mu_s = .5$

$T_{MAX} = F_F \cdot \frac{\varnothing}{2} = 64.31bf \cdot 3"$

$T_{max} < 16 ft/lb$

$T_{MAX} = 192.92\ IN\ lbf$

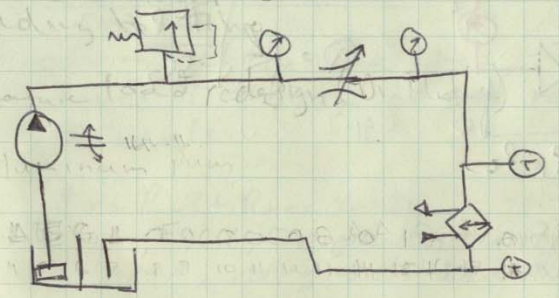
$T_{max} = 16\ ft\ lb$

$\mu_s = .5 \Rightarrow T_{MAX} = 11.47 ft/lb$

Roller torque limit

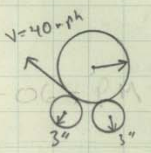
25

12/27/11



Assumptions:

Max Vehicle speed is 40 mph



$$\frac{40 \text{ miles}}{\text{hr}} \left| \frac{5280 \text{ ft}}{1 \text{ mile}} \right| \frac{1 \text{ hr}}{3600 \text{ sec}} = 58.67 \text{ ft/sec}$$

$$V = r\omega$$

$$\omega = \frac{V}{r} = \frac{58.67 \text{ ft/sec}}{\frac{3}{12} \text{ ft}} = 235 \frac{\text{rad}}{\text{sec}} \left(\frac{1 \text{ rev}}{2\pi \text{ rad}}\right)\left(\frac{60 \text{ sec}}{1 \text{ min}}\right)$$

$$= 2244 \text{ rpm}$$

Output Flow

$$Q = d\omega$$

$$= (0.40 \text{ in}^3/\text{rev})(2244 \text{ rpm})\left(\frac{1 \text{ gallon}}{231 \text{ in}^3}\right)$$

$$= 3.89 \text{ gpm}$$

Shaft Torque

$$T = \frac{pd}{2\pi}$$

$$p = \frac{T(2\pi)}{d} = \frac{(16 \text{ ft-lbs})(2\pi)}{(0.40 \text{ in}^3/\text{rev})}\left(\frac{12 \text{ in}}{1 \text{ ft}}\right) = 3016 \text{ psi}$$

Hydraulic Horsepower:

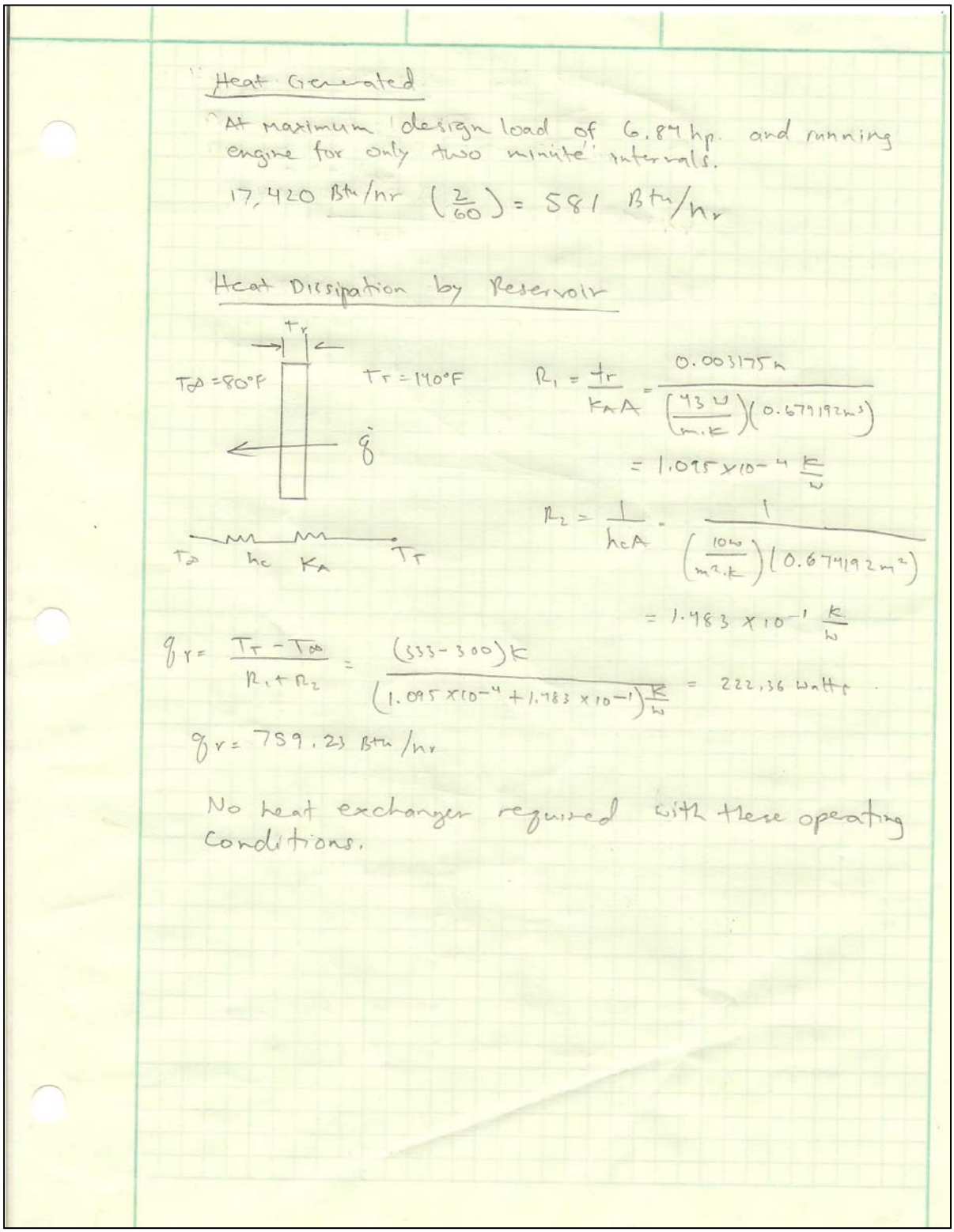
$$HP = (\text{psi} \times \text{gpm})/1714$$

$$= \frac{3016 \text{ psi} \times 3.89 \text{ gpm}}{1714} = 6.84 \text{ hp}$$

Heat Generated

$$\frac{6.84 \text{ hp}}{1 \text{ hp}} \left| \frac{2545 \text{ Btu/hr}}{} \right. = 17{,}420 \text{ Btu/hr}$$

Hydraulic calculations to determine system components



Heat transfer calculations for reservoir heat dissipation

Appendix G: References

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