Portable Dirt Late Model Pull Down Machine

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in partial fulfillment of the
requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

by

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Thesis Advisor:

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This project was a group project between Josh Dietz, Dylan Rivers, and Tamas Bonyhati. It was sponsored by Josh Dietz and all the components were donated to him.

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ABSTRACT

A dirt late model is a racing car which operates on a dirt oval track. These cars are different from traditional race cars due to their suspension which includes a fifth lateral spring to control the rear wheel positions. Effectively, the rear ends of these vehicles are not mounted to the frame and instead float on the fifth lateral spring. The effect of this is a mechanical force based steering system which improves grip on the right rear tire and rotates the rear axle of the vehicle to enhance left hand cornering; this position is referred to as "dynamic position". Due to the complexity of the suspension, a calculated solution to simulate the vehicle on the track is not viable. Therefore, a system was created to pull the suspension elements into their respective positions to simulate a vehicle in different conditions, i.e.: acceleration and deceleration. Many existing systems require manual positioning, which leads to human error. This is the problem that is addressed: the precision and accuracy of positioning using automated PLC control.

PROBLEM DEFINITION AND RESEARCH

PROBLEM STATEMENT

Our problem is to create a machine capable of dynamically loading a car to accurately simulate real world forces. These forces are present when the car is entering and exiting a corner at speed. Full measurements take a highly expensive fixturing system and are not available for use when most needed, at the track. Currently the only way to simulate this in a timely manner is by using shock travel data to predict the suspension geometry. This is not an accurate prediction due to chassis and suspension deflection under load as well as tire deformation.

BACKGROUND

Pull down devices are used to simulate the suspension movements of a race car when it is moving around the racetrack. There are a number of devices currently available, but their high cost and complicated operation makes them impractical to be used in the field. We are interested in this problem because we have been racing for 15 years combined and have been using trial-and-error to set up on our car. This machine will greatly reduce the amount of guess-and-check required. A pull-down machine works by moving the race car into states that mimic the position of the vehicle in various real-life scenarios, (i.e.: acceleration, deceleration and turning). It achieves this through actuators that pull down on the chassis to simulate on track dynamic loading of the race car. These loading conditions can include acceleration, braking, and cornering forces. Through the dynamic change of the race car one can then measure various aspects of the race car. These measurements include:

- Wheel Loads through suspension travel
- Suspension Travel
- Dynamic Camber of front wheels
- Wheelbase movement through dynamic change of the car (Rear Axle Lead)
- Spoiler Height
- Ground Clearance

To test a setup change on the car now one has to use a so-called “spring smasher” to get the load change at a certain ride height, but this doesn’t provide the whole picture of what this will do to the car in the corner like dynamic camber, roll steer and the travel of each corner of the race car. A “spring smasher” is a device used to determine wheel loads at certain distances. One end of the shock absorber is fixed, while the other end travels up and down using an electric actuator. The shock absorber is then moved up or down to known travel or load positions, while a load cell measures the load applied to the shock at the desired distance.

RESEARCH

SCOPE OF THE PROBLEM

The problem with today's pulldown machines is that they are too expensive for the average racer to purchase to use on an individual basis. Today, racers must take their race cars to a shop where they rent the pull-down machine for the day. Current pull down machines are cumbersome to use for the end user. The challenge for us is to design and manufacture a pull-down machine that costs significantly less than the current machines available on the market today.

CURRENT STATE OF THE ART

There are many pull down systems on the market today but most of them are either expensive or they are time consuming to setup and use. The DRP pull down system is sold in many different configurations and their cost range from $35,000 to $46,000. These systems are sold with more and more features as the price increases. (1) The advantage of the DRP system is that it comes with multiple different features and can measure a wide range of variables. The $6,000 option of DRP pull down setup comes with 14 different features but does not include the scale pads that will allow one to get wheel loads when the car is in a dynamic position. The $46,000 option for DRP comes with 35 different features but not all of its features are useful for all users. Not many local racers can afford this expensive option. Other than cost, the other major disadvantage of the DRP pull down systems is that none of the different options are portable.

Another pull down setup that is on the market is the Mittler Brothers pull down system. This system is mainly used for asphalt cars but it has a price tag of $95,000. (2) The Mittler Brothers pull down system is meant for high-budget NASCAR teams that can afford this level of investment. This machine is capable of measuring anything one may need to on the race car. It can also simulate the car as it is moving around the racetrack.

CONTROLS SYSTEM:

The current state of the art systems use manual controls to drive the actuators to their desired positions. Extremely high-end systems, such as the Mitler Brothers pulldown machine use automated actuators to achieve optimal distances for spring compression. This system, however, is highly expensive at 95,000 USD, effectively putting it out of the price range of entry level racers. Downsides to current state of the art systems include high cost, complex setup procedures and the reliance on non-industrial electronics that may lack the reliability and safety features of industrial controls systems.

END USER

The end user of this product would be low budget and entry-level racers to provide a quick and efficient, portable calibration machine. The average racer is not able to afford currently available systems or have the time and space required to set up and use existing systems. With this system there would be little time required to set up and it will be easy to move. This would allow you to quickly setup and teardown this system at any shop or even at the track.

CONCLUSIONS AND SUMMARY OF RESEARCH

In summary, today's pull-down systems perform necessary functions for the customer, but they are expensive and are not practical to the average local racer. Furthermore, the current systems are not portable and cannot be taken to the track or to someone else's race shop to analyze how their car acts when it is in a dynamic position. Our pull-down system will be significantly less expensive for the end user and will be easier to use and set up. The system will be easy to disassemble and move to a new location as needed.

CUSTOMER FEATURES

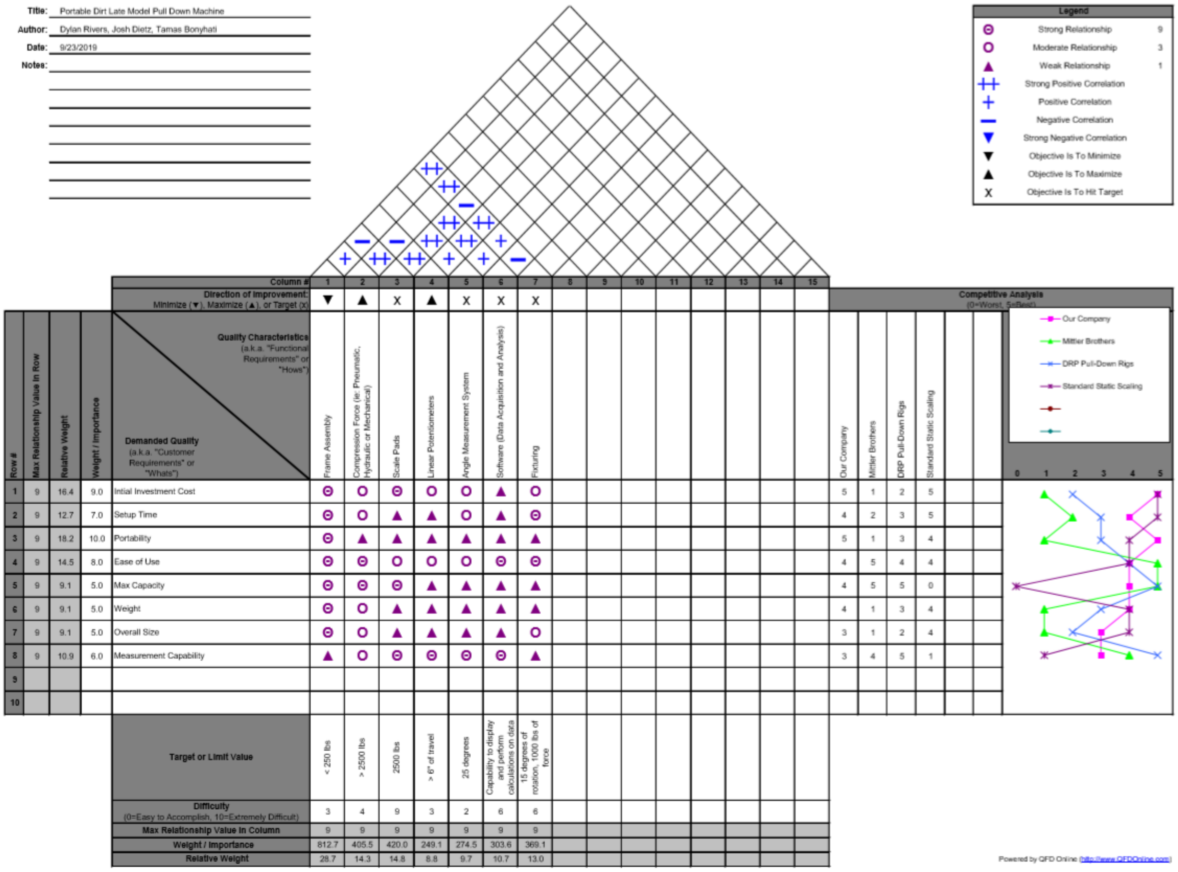
The customer features for our project are:

- Ease of Use
- Setup time
- Portability
- Initial Investment Cost

PRODUCT OBJECTIVES

- To create a portable system on frame and wheels so that it can be moved from track to track. (Relative Weight: 18.2)
- To create a pull-down machine with a low initial investment. (Relative Weight: 16.4)
- To design and create a pull-down machine that is easy to use and setup as well as measure all the necessary and important characteristics of a dirt late model. (Relative Weight: 14.5)

QUALITY FUNCTION DEPLOYMENT



Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality (a.k.a. "Customer Requirements" or "Whats") / Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	1 Frame Assembly	2 Compression Force (ie: Pneumatic, Hydraulic or Mechanical)	3 Scale Pads	4 Linear Potentiometers	5 Angle Measurement System	6 Software (Data Acquisition and Analysis)	7 Fixturing	Our Company	Mittler Brothers	DRP Pull-Down Rigs	Standard Static Scaling
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	▼	▲	x	▲	x	x	x				
1	9	16.4	9.0	Intial Investment Cost	Θ	O	Θ	O	O	▲	O	5	1	2	5
2	9	12.7	7.0	Setup Time	Θ	O	▲	▲	O	▲	Θ	4	2	3	5
3	9	18.2	10.0	Portability	Θ	▲	▲	▲	▲	▲	▲	5	1	3	4
4	9	14.5	8.0	Ease of Use	Θ	Θ	O	O	O	Θ	Θ	4	5	4	4
5	9	9.1	5.0	Max Capacity	Θ	Θ	Θ	▲	▲	▲	▲	4	5	5	0
6	9	9.1	5.0	Weight	Θ	O	▲	▲	▲	▲	▲	4	1	3	4
7	9	9.1	5.0	Overall Size	Θ	O	▲	▲	▲	▲	O	3	1	2	4
8	9	10.9	6.0	Measurement Capability	▲	O	Θ	Θ	Θ	Θ	▲	3	4	5	1
9															
10															
				Target or Limit Value	< 250 lbs	> 2500 lbs	2500 lbs	> 6" of travel	25 degrees	Capability to display and perform calculations on data	15 degrees of rotation, 1000 lbs of force				
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	3	4	9	3	2	6	6				
				Max Relationship Value in Column	9	9	9	9	9	9	9				
				Weight / Importance	812.7	405.5	420.0	249.1	274.5	303.6	369.1				
				Relative Weight	28.7	14.3	14.8	8.8	9.7	10.7	13.0				

Fig. 1: House of Quality

Customer Features

The customer features for our project are:

- Ease of Use
- Setup time
- Portability
- Initial Investment Cost

Engineering Characteristics

The engineering characteristics to achieve the customer needs are:

- Material and Component Choice for the system (Investment cost)
- Frame Assembly (Designing a frame that can be folded up and portable)
- Software – make all measurements and loads organized and easy to understand
- Actuation system – choose actuators that are simple to setup, inexpensive and achieve moving the car into a dynamic position

DESIGN

The controls system of the pulldown rig must be safe, easy to use and perform within the specified boundaries set by the end user. In summary, the automated system must operate in a closed loop and include a manual mode for mounting and some aspects of testing. The controls system actuates all the cylinders and reads the values of the potentiometers to convert them to distance. It analyses the distance data and determines if the position of the shocks per wheel and torque arm are within the acceptable bounds, readjusting as necessary to accommodate for changes from moving different actuators around the car.

PLC:

Fig 2: Micro 820 PLC

An Allen Bradley Micro 820 was employed to control the actuation system and to read data. This model is relatively inexpensive and is capable of all the needs of the project. It includes:

- 4 analog inputs
- 6 digital outputs
- 1 RS232 HMI port

Using an industrial PLC as a controller greatly increases the safety of the system by allowing for non-physical fail-safes to be incorporated into the logic. It also has a much lower chance, (practically zero) for locking up in a state which would cause injury to the operator or damage to the car unlike other methods such as text based programmable controllers (i.e.: Arduino).

HMI:

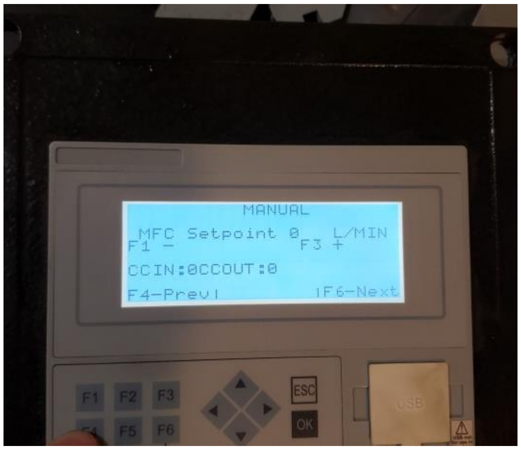


Fig 3: HMI

A 6-line RS232 HMI was used for controls. This system is the singular interface between the user and the solenoid valve pack as well as the potentiometers. It displays the mode the system is in, the values of all the potentiometers and various other data

POTENTIOMETERS:

Fig 4: String Potentiometers

Three 4-20mA string potentiometers were employed to measure shock compression distance:

Fig 4.1 The Right Front:

Fig 4.2 The Right Rear:

Fig 4.3 The Torque Arm:

RELAYS:

Fig 5: Relay

Allen Bradley's DIN rail relays were used to interface between the PLC and the solenoids controlling the valves. This is due to two factors:

a) Electronic noise: As these relays provide isolation between the circuits controlling large inductive loads such as solenoids and the pump motor from the noise-sensitive analog measurement circuits

b) Digital IO is 24VDC and the hydraulic control valve solenoids are 12VDC.

PUMP CONTROL:

While the pump can be controlled by digital IO from the PLC, we opted to use the supplied button control from the pump. This was mainly due to safety concerns as the button acts essentially as an enable switch: motions can only occur while the operator physically energizes the pump and as soon as the pump start button is released, all motions stop. While the PLC is more than capable of accurately controlling the pump to limit battery drain, we determined it would not be as safe as a manual control.

POWER DISTRIBUTION:

The PLC and associated components were powered off a 24V DC output AC adapter to mitigate electrical noise. While the PLC is capable of running off a battery bank for extended periods, we decided it would be far more convenient to connect the power supply of the 24V circuit to a generator or outlet. This decision also enabled us to virtually eliminate any electrical noise from the solenoids and pump.

PROCESS LAYOUT:

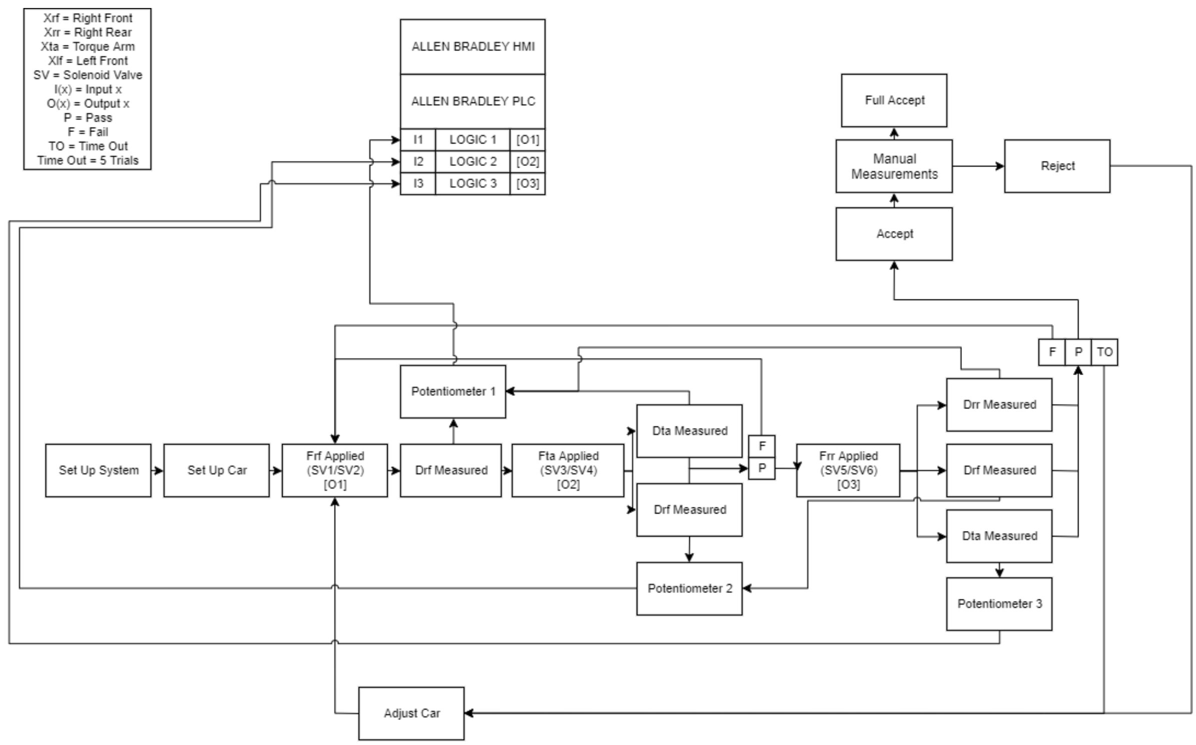


Fig 6: Process Layout

A closed loop system was defined to control the system:

After each potentiometer reaches the desired distance, a check is performed against the previous potentiometers. If the distance on any of the previous potentiometers has travelled out of range due to the movement of a different actuator, it will be readjusted to the correct distance by controlling the associated actuator. This process continues until a certain timeout number of cycles is reached or all the potentiometers are within the required distance.

Once this process is complete, the wheel weights are measured and recorded along with various manual measurements, (car angle, tire angle, etc.) and the process is either accepted or rejected. On reject, the car is adjusted, (shimming shocks, different springs, etc.) and the test is run again until the desired wheel weights and distances are attained.

PROGRAM:

This section covers the various screens and functions in the PLC Code. The F4 and F6 keys are used to navigate screens.

Screen 1: Automatic mode Setup

Allows the user to edit the desired distances using the F1-F3 keys to select each cylinder (right front, right rear and torque arm) and adjust their value to the desired distance. The F5 key allows the user to adjust the acceptable tolerance of the system from ±0.0625” to ±0.2500”.

Screen 2: Manual Control

Allows the user, when in manual mode to use the F1-F3 keys to select a cylinder to move. Then the up and down arrow keys control the extend or retract solenoid respectively. Therefore, when the pump is on, the user can manually jog the cylinders to any position. This screen also acts as a display for all potentiometer distances in inches.

Screen 3: Automatic Control

The OK button starts the automatic cycle if the system is in automatic mode, the ESC button acts as a cycle stop for the system, (somewhat redundant as the pump is not tied to the PLC). The system then notifies the user when the car is in position, or if the car cannot reach the position with the current settings as well as an cycle stop warning which must be cleared with a 5 second hold of the OK button.

Screen 4: Manual/Automatic Select

Allows the user to select between manual and automatic operation.

Screen 5: Potentiometer Calibration

Allows the user to set and span the potentiometers to convert them from count values to inches. The user can use the up and down arrow keys to select a potentiometer, then the F1 key sets the 0 value and the F2 key sets the span value. The F3 and F5 key allow the user to set, in inches, the 0 value and the span value (in our case 14 inches and 22 inches respectively). These values are then stored in the PLC until the next calibration.

ELECTRONICS DESIGN:

Power: PLC

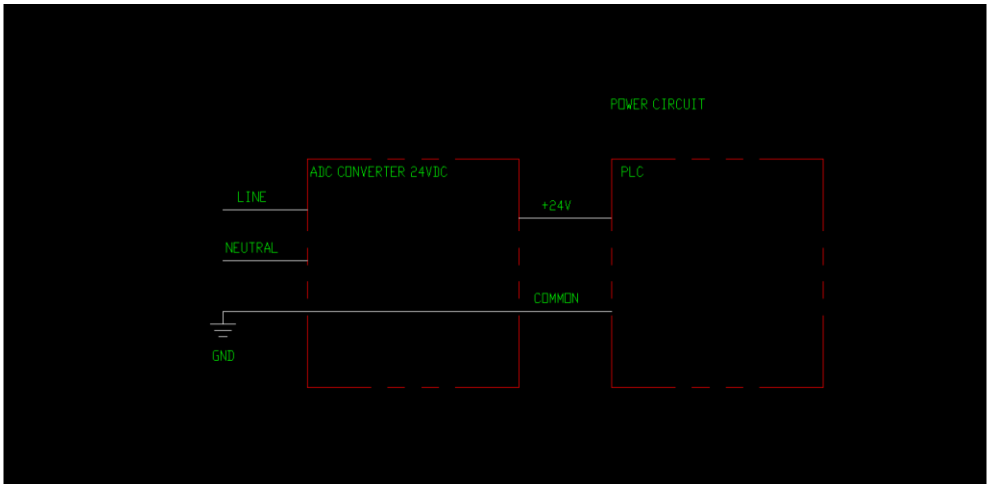


Fig 7.1: Power Circuit PLC

Power: Solenoids and Pump

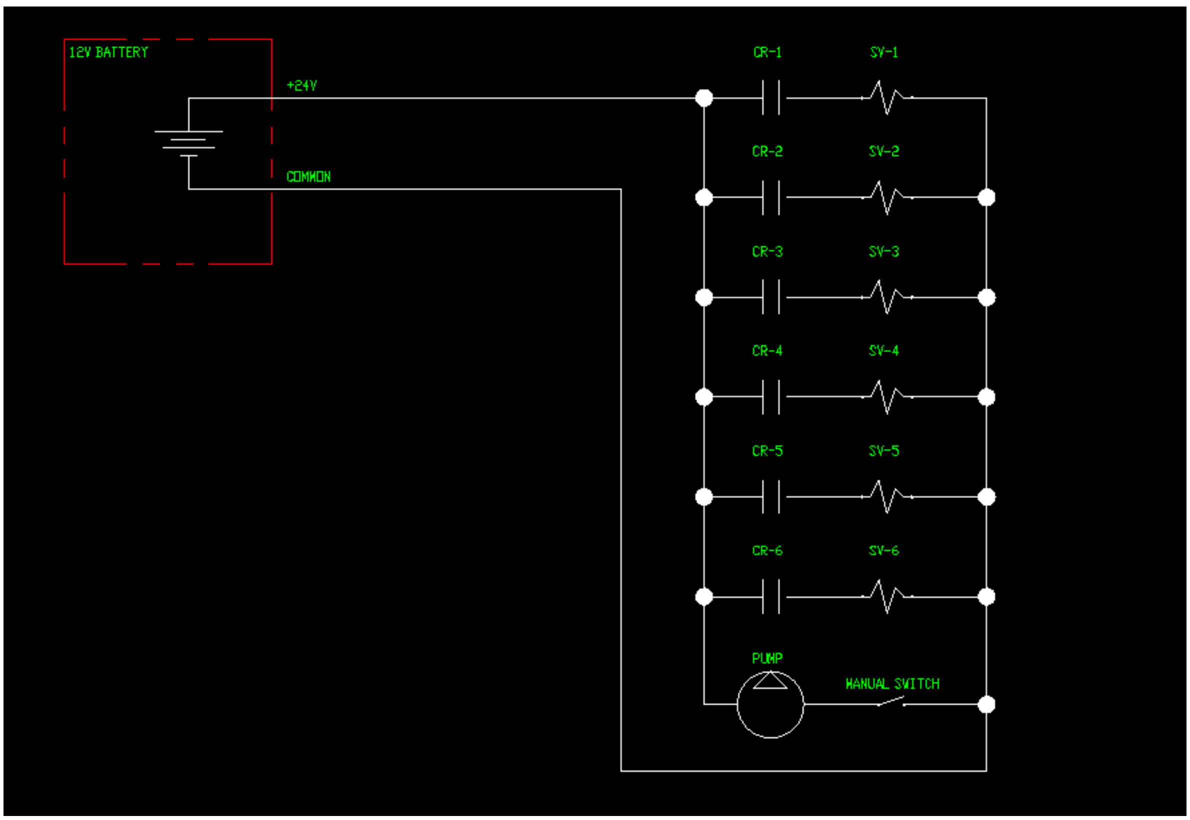


Fig:7.2: Power Circuit Solenoids and Pump

Control: Inputs and Outputs

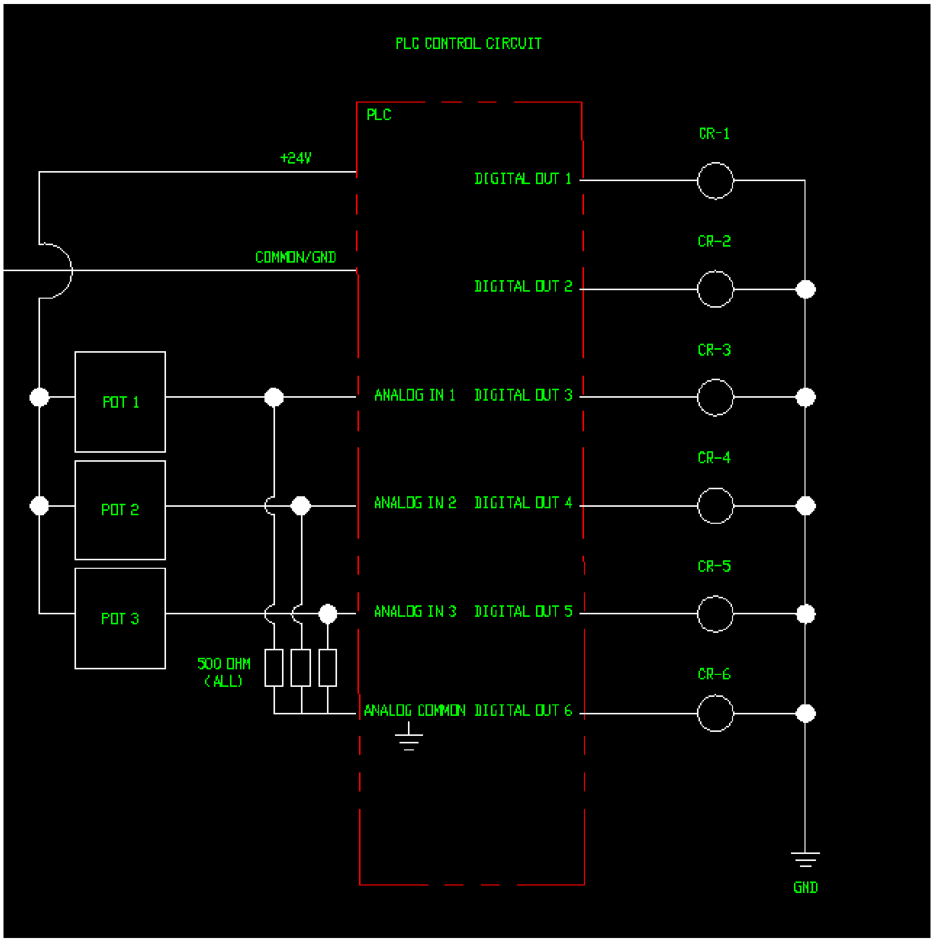


Fig 7.3: Control Circuit

The relays CR-1 through 6 are directly controlled by the digital outputs on the plc. The 3 string potentiometers run through individual 500-ohm resistors in order to convert the 4-20 mA current to a 10V equivalent as the PLC can only read voltage from its analog to digital converter.

Maximum input voltage for A/D converters: U_{AD}=10V
Highest current output from distance transducers:I_{string_pot}= 20mA

Necessary resistor to covert the current output to voltage: $R=U_{AD}/I_{string\_pot}$=10V/0.020A = 500ohm.

Minimum current from string potentiometers $I_{string\_pot\_min}$=4mA

Minimum voltage: $U_{AD\_min}= I_{string\_pot\_min}*R=0.004*500=2V$

Design Alternatives

Arduino: Not reliable enough for use with high pressure hydraulic controls

Raspberry PI: Not reliable enough for use with high pressure hydraulic controls

Final Assembly

Below is the completed pull down machine with the hydraulic cylinders, pump, and valve pack. The valve pack and hydraulic pump are fixtured to the frame of the pull-down machine. The hydraulic cylinders are then attached to the frame and then to the chassis of the car. The pump and valve pack are then controlled by the PLC through relays.

Fig. 8: Final Assembly of Pull-Down Machine

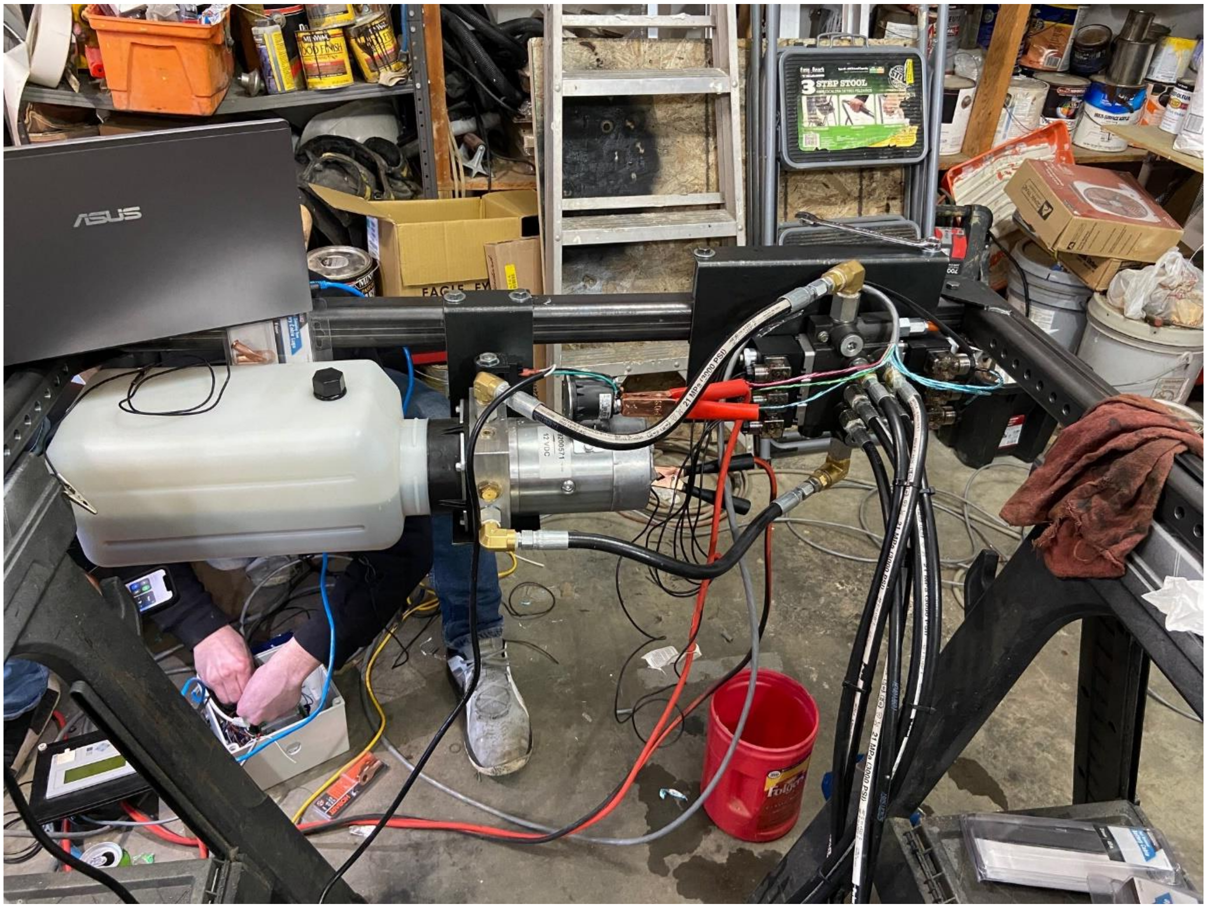


Fig. 9: Hydraulic Pump and Valve Pack, With PLC and HMI (On Floor)

PROJECT MANAGEMENT

BUDGET, PROPOSED/ACTUAL

Table 1: Preliminary Budget

Preliminary Budget	
Component	**Cost**
Frame/Fixturing	$400
Actuation System	$800
Measuring System	$500
Total:	$1,700

Table 2: Proposed Budget

Proposed Budget	
Component	Cost
Frame/Fixturing	$500
Actuation System	$1,300
Measuring System	$700
Total:	$2,500

Table 3: Final Budget

Actual/Final Budget	
Component	Cost
Frame/Fixturing	$800
Actuation System	$1,600
Measuring System	$700
Total:	$3,100

SCHEDULE, PROPOSED /ACTUAL

Table 4: Proposed Schedule

Proposed Schedule	
Milestone	**Date**
Choose Design Concept	10/18/2019
Complete Calculations	11/15/2019
Finalize Design	12/6/2019
Order Materials	1/17/2020
Complete Manufacturing	3/20/2020
Test	3/27/2020
Revisions	4/3/2020
Tech Expo	4/9/2020

Table 5: Actual/Final Schedule

Actual Schedule	
Milestone	**Date**
Choose Design Concept	10/18/2019
Complete Calculations	11/15/2019
Finalize Design	12/6/2019
Order Materials	1/17/2020
Complete Manufacturing	4/11/2020
Test	4/18/2020
Tech Expo	Cancelled

TESTING

The purpose of our testing was to determine repeatability. As this is intended to be a product to be sold, we determined that a process capability analysis (CPK) was appropriate to determine if we achieved our goals. A CPK value of 1.33 was to be attained to be considered good. The right rear distance value is not included in this requirement as we were testing for acceleration, during which the right rear cylinder is disconnected and free to move to any position.

1. Car will be set with the standard chassis manufacturer recommended settings.
2. The machine will pull each corner down until a desired shock distance is reached. (±1/16”)
3. Test will be run 30 times with the wheel loads recorded
4. Wheel Load Error = ± 2% of Expected Wheel Load (± 15 lbf)
5. RF spring is shimmed by ⅛” and test is run 3 times to see if wheel weight is affected on the right front.

Table 6: Test 1 - Recorded Values

Wheel Weights (lb.)					Measured Distances (in.)		
Test	Right Front	Left Front	Left Rear	Right Rear	Right Front	Torque Arm	Right Rear
1	1103	704	633	562	14.45	16.24	22.86
2	1109	702	630	559	14.45	16.25	22.76
3	1095	704	632	564	14.45	16.19	22.8
4	1090	710	625	557	14.45	16.21	22.8
5	1108	690	631	559	14.45	16.25	22.8
6	1116	698	644	553	14.43	16.3	22.89
7	1098	698	647	553	14.47	16.25	22.82
8	1100	692	646	551	14.45	16.24	22.83
9	1086	695	643	550	14.51	16.22	22.8
10	1096	681	645	551	14.48	16.21	22.81
11	1095	687	652	545	14.45	16.24	22.85
12	1106	701	642	546	14.45	16.25	22.86
13	1101	697	639	548	14.45	16.19	22.76
14	1097	696	649	550	14.45	16.21	22.8
15	1093	700	650	552	14.45	16.25	22.8
16	1104	703	642	559	14.43	16.3	22.8
17	1106	697	644	555	14.47	16.25	22.89
18	1108	695	651	547	14.51	16.24	22.82
19	1099	705	640	542	14.48	16.22	22.83
20	1091	699	645	555	14.45	16.21	22.8
21	1105	703	642	556	14.45	16.25	22.81
22	1103	697	651	543	14.45	16.24	22.85
23	1095	695	641	549	14.47	16.25	22.8
24	1089	685	642	554	14.45	16.19	22.8
25	1100	687	646	558	14.45	16.21	22.89
26	1105	704	649	557	14.43	16.25	22.82
27	1108	693	652	552	14.47	16.3	22.83
28	1098	700	655	545	14.45	16.25	22.89
29	1100	701	643	548	14.51	16.24	22.82
30	1101	698	651	551	14.48	16.22	22.83
AVG	1100	697	643	552	14.46	16.237	22.824
STDEV	6.803	6.526	7.308	5.586	0.021	0.029	0.035
LSL	1070	667	613	522	14.335	16.112	22.699
USL	1130	727	673	582	14.585	16.362	22.949
CPK	1.469	1.532	1.368	1.790	1.931	1.425	1.183

Table 7: Test 2 – Recorded Values

Setup Change: Adding 1/8" Packer Shim to RF shock							
Prediction of change: should increase wheel weight on the RF							
Wheel Weights (lb.)					Measured Distances (in.)		
Test	Right Front	Left Front	Left Rear	Right Rear	Right Front	Torque Arm	Right Rear
1	1170	677	660	531	14.51	16.2	22.7
2	1160	680	658	540	14.52	16.3	22.76
3	1165	686	654	542	14.52	16.25	22.81

Above it can be seen that shimming the right front shock increased the weight seen on the right front scale pad. A change of 60-75 lbf was expected, which is shown within our data, proving the system can detect modifications to the suspension of the car.

SUSTAINABILITY AND MATERIAL USAGE

Future Recommendations:

- Manufacture and construct frame out of aluminum so that it is lighter in weight
- Use a different actuation system
- Redesign locating system of pads to fit a car lift under the car to make adjustments easier

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- **Machintek (Donated machining time)**
- **Jim Couch,CTEK (Donated machining time)**
- **Brian Gray (Donated scale pads)**
- **Peter Bonyhati (Controls Knowledge, Donated PLC and Electronics)**

APPENDIX A (RESEARCH)

DRP Pull Down Machine:

Mittler Brother's Pull-Down Machine

APPENDIX B

Below is a picture of the survey that we used to collect information on which features are important to the end user. The customer features that had the highest average ranking of importance where investment cost, setup time, portability, and ease of use.

Portable Dirt Late Model Pull-Down Machine Survey

This survey will be used to prioritize various features to maximize customer satisfaction. The system in question will address issues for setting up dirt late models. This system will measure various aspects of a car through dynamic on track travel to aid in setup ability.

How important is each feature to you?

Please circle the appropriate answer. 1=low importance 5=high importance

Initial Investment Cost	1	2	3	4	5	N/A
Setup Time	1	2	3	4	5	N/A
Portability	1	2	3	4	5	N/A
Ease of Use	1	2	3	4	5	N/A
Max Capacity	1	2	3	4	5	N/A
Weight	1	2	3	4	5	N/A
Overall Size	1	2	3	4	5	N/A
Measurement Capability	1	2	3	4	5	N/A

How satisfied are you with current setup technology?

Please circle the appropriate answer. 1=very unsatisfied 5=very satisfied

Initial Investment Cost	1	2	3	4	5	N/A
Setup Time	1	2	3	4	5	N/A
Portability	1	2	3	4	5	N/A
Ease of Use	1	2	3	4	5	N/A
Max Capacity	1	2	3	4	5	N/A
Weight	1	2	3	4	5	N/A
Overall Size	1	2	3	4	5	N/A
Measurement Capability	1	2	3	4	5	N/A

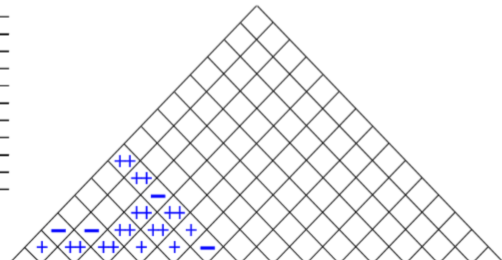
How much would you be willing to invest in this setup tool?

$500 - $1000, $1000 - $3000, $3000 - $10000, $10000+

APPENDIX C

Title: Portable Dirt Late Model Pull Down Machine
Author: Dylan Rivers, Josh Dietz, Tamas Bonyhati
Date: 9/23/2019
Notes:

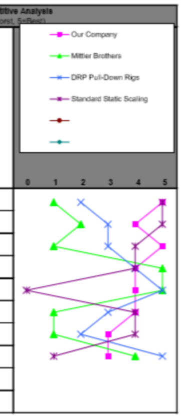
Legend		
Θ	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
−	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
X	Objective Is To Hit Target	



Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	▼	▲	x	▲	x	x	x								
				Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Frame Assembly	Compression Force (ie: Pneumatic, Hydraulic or Mechanical)	Scale Pads	Linear Potentiometers	Angle Measurement System	Software (Data Acquisition and Analysis)	Fixturing								
1	9	16.4	9.0	Intial Investment Cost	Θ	O	Θ	O	O	▲	O								
2	9	12.7	7.0	Setup Time	Θ	O	▲	▲	O	▲	Θ								
3	9	18.2	10.0	Portability	Θ	▲	▲	▲	▲	▲	▲								
4	9	14.5	8.0	Ease of Use	Θ	Θ	O	O	O	Θ	Θ								
5	9	9.1	5.0	Max Capacity	Θ	Θ	Θ	▲	▲	▲	▲								
6	9	9.1	5.0	Weight	Θ	O	▲	▲	▲	▲	▲								
7	9	9.1	5.0	Overall Size	Θ	O	▲	▲	▲	▲	O								
8	9	10.9	6.0	Measurement Capability	▲	O	Θ	Θ	Θ	Θ	▲								
9																			
10																			
				Target or Limit Value	< 250 lbs	> 2500 lbs	2500 lbs	> 6" of travel	25 degrees	Capability to display and perform calculations on data	15 degrees of rotation, 1000 lbs of force								
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	3	4	9	3	2	6	6								
				Max Relationship Value in Column	9	9	9	9	9	9	9								
				Weight / Importance	812.7	405.5	420.0	249.1	274.5	303.6	369.1								
				Relative Weight	28.7	14.3	14.8	8.8	9.7	10.7	13.0								

Competitive Analysis (0=Worst, 5=Best)

Row #	Our Company	Mittler Brothers	DRP Pull-Down Rigs	Standard Static Scaling
1	5	1	2	5
2	4	2	3	5
3	5	1	3	4
4	4	5	4	4
5	4	5	5	0
6	4	1	3	4
7	3	1	2	4
8	3	4	5	1



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APPENDIX D

Product Objectives

- To create a portable system on frame and wheels so that it can be moved from track to track. (Relative Weight: 18.2)
- To create a pull-down machine with a low initial investment. (Relative Weight: 16.4)
- To design and create a pull-down machine that is easy to use and setup as well as measure all the necessary and important characteristics of a dirt late model. (Relative Weight: 14.5)