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Automobile's hydraulic system controlled by a programmable logic controller

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Abstract

The purpose of our design is to control the fluctuation of an automobile's hydraulic system using a Programmable Logic Controller (PLC). An Automation Direct PLC is programmed with DirectSoft 32 Relay Ladder Logic Stage Programming software. In addition, an Autoloc remote is used to activate the PLC; magnetic positioning sensors, the PLCs ladder logic program and the hydraulic system—consisting of solenoids/pumps and dumps—are the main components for our design.

We intend to use the same ideas and design methods as in industry applications to control the hydraulics of a *Lowrider* vehicle. The overall process will be the same; PLC will control, execute program; and therefore, satisfy the customer. An important feature of our design is that it will eliminate the use of a switchbox and a 15-foot cable; and with just a simple PLC and the push of the button on a remote, the motion of the hydraulic system on a vehicle will controlled 'hands-free'. Our design will give the *Lowrider* community a new technology option for the control of their *Lowrider's* hydraulic system.

Acknowledgement

I would like to acknowledge my partner, Sergio Beltran, for working with me on this senior design project. Together, we accomplished the initial goal of design with great success.

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Chapter 1: Introduction

PLCs are used in control engineering such as: HVAC, brake and clutch systems, and in many more industry applications. PLCs have a wide range of capabilities: space saving, ease of maintenance, system flexibility, and powerful programming features. They perform tasks that save: time, human labor, excess use of relays, and maintenance. Since most PLCs are found in the industry, a new question has been posed – can PLCs aid the entertainment industry? We intend to use the same ideas and design methods as in industry applications to control the hydraulic system of a "Lowrider" vehicle. The overall process will be the same. The PLC will control and execute the program; therefore, satisfying the customer. Our design application will be unique in various ways. First of all, there is no design currently in the "Lowrider" industry identical to ours. Secondly, our PLC design will serve as entertainment for the "Lowrider" community; while still being manufactured by industry and designed by electrical engineers. Thirdly, our design will be hands free, eliminating the use of a switchbox and a 15-foot cable. The hydraulic system on a vehicle will be controlled with just a PLC and the push of a button on a remote. Our design will give the "Lowrider" community a new technical alternative to control their hydraulic systems.

Chapter 2: PLC Background Information

Programmable Logic Controllers (PLCs) date back to the 1960's. The PLCs incorporate two basic sections; the central processing unit (CPU) and the input and output interface system. The CPU can be thought of as memory and as of a processor because it reads the input data, executes the control program, and it stores logic functions in its memory system prior to operation. The input/output interface system, which can be attached to field devices (sensors, switches, etc.), render the interface between the CPU, the information providers (inputs), and the controllable devices (outputs). The PLC will continue repeating the desired program without interruption, unless change is made to the control program.

The PLC was invented to replace sequential relay circuits that were traditionally used for machine control. Relays are a device that can implement a number of digital switching functions. Relay based systems were substituted for many reasons. Relays require maintenance and have a limited lifetime, while the PLC is a solid-state device that requires little maintenance because it has a long life. The PLC eliminates the cost of continuously replacing complicated relays. Troubleshooting was also a problem when many relays were involved; some applications required the use of hundreds or thousands of individual relays. They would have to be individually wired together to yield the desired outcome; therefore, time consuming. In addition to being time consuming, these large complicated systems would also be space consuming; something a PLC could resolve because they are smaller yet can control large systems. Also, since they are solid-state their counters and timers are internal while relays require separate hard-wired timers and counters.

Ladder logic is the primary programming language for programmable logic controllers. For editing programs it is convenient to group instructions into instruction-rungs. The word rung is taken from the fact that these instructions resemble the rungs of a ladder. Ladder logic uses contacts to represent switches or any other input and a coil symbol to represent an output. A complete program consists of several rungs, which will place input conditions on the left side of the rung and may be in series, parallel, or a combination depending on the desired logic. The output instructions are placed on the right side of the rung. The vertical line on the left side of the rungs represents the imaginary 'hot' power trail while the line on the right side is the imaginary 'neutral.' If any path left to right on a rung is 'closed' or 'made', then the rung is said to be 'true' and the output is energized. This is also known as logic continuity. The ladder logic programming language can incorporate similar commands/instructions used in assembly language; this gives the programmer a wider range of commands/instructions to build a successful ladder logic program.

During the early 70's, the advent of the microprocessor technology created a dramatic change in the PLC. With these new processors, PLCs were now capable of performing arithmetic and data manipulation functions, operator communication and interaction. PLCs became even more flexible during the 80's with larger memory capacity, remote input/output (I/O) capability, machine fault detection, and software enhancements. Today's PLCs are small, have rugged I/O enclosures, are programmable through personal computers and are available at a low cost. All of these factors make them ideal for virtually any type of manufacturing process or equipment.

Chapter 3: Hydraulic Background Information

The hydraulic systems have also been around for quite some time but the application of hydraulics to lower and raise a vehicle began in the early 60's. Vehicles with this application are called "Lowriders," which in the past few years has become a large industry. In the lowrider industry there are many hydraulic manufactures and distributors; all the systems are basically the same. The basic system includes one or more hydraulic pumps; 2 or 4 cylinders, one for each wheel; hydraulic hoses; switches to control the desired movement; and batteries to power the pumps. (See Figure 1) The "Lowrider" movement has now moved into the mainstream media. Lowriders have always been seen in music videos but now they have made many appearances on television commercials ranging from GM to Budweiser.

Chapter 4: Hydraulic Design

The pumps and dumps are the main components to a hydraulic system. The pump consists of an oil reservoir or tank. Fluid is drawn up and out by the pump head (prime mover) and through a check value located on the dump. (See Figure 2) The pump head is driven by the rotating electric motor. The fluid moves through the dumps and out to the cylinders that will completely fill with fluid, which causes the piston to move, which in turn, pushes down on the car's coil springs causing the car to lift. The dumps function as their name implies, they dump or return the fluid back into the reservoir causing the car to lower.

For our project we selected a hydraulic system made by CCE hydraulics. Our hydraulic system consists of two hydraulic pumps: four cylinders, six 12-volt solenoids, four 12-volt dumps and three batteries, our system will later be upgraded to six batteries. The batteries are connected in series to give us 36-volts, which will be used to power both pumps. Each pump will be activated by three 12-volt solenoids that are also in series. (See Figure 3) The switch box is what controls the pumps and dumps to achieve desired movement. The switch box will send 12 volts to the solenoids, which in turn will close the circuit and allow 36 volts to either pump. The dump will open when 12 volts are applied to it. Our switch box consists of 10 switches, providing 10 different movements.

Chapter 5: Design Method

As stated before, our project is the design of a hands-free wireless-remote activated automotive hydraulic system implemented with the use of a PLC. The design method for our project has required extensive research and teamwork. The following steps are a breakdown of our design methodology:

1. Investigate literature for previous designs; after intense research, we discovered that no such design exists.
2. Create a designed based on objectives using personal knowledge, experience and extensive engineering skills.
3. Find specifications for the fundamental components required for the design. These include the PLC, position sensors, remote control and the hydraulic system.
4. Learn how to program the PLC.
5. Select a hydraulic system for the design. We chose a 2-pump/4-dump solenoid activated hydraulic system.
6. Install a hydraulic system onto a vehicle.
7. Interface the PLC and the hydraulic system by using PLC the software and hardware.
8. Implement the final design.
9. Thorough testing will be done to ensure that our final design meets our proposed specifications and objective.

The overall final design consisted of several parts. Though, all the parts are unique in their own specific way, they all interface and depend on one another so the final design can function properly. The design is split up into two main sections: the hardware design and the software design. The hardware design—which is the larger of the two sections—consists of the inputs and outputs (i.e.- remote control, sensors, solenoids, and dumps) peripherals to the PLC. The software design consists of the ladder logic program.

There are many different routes one can take to accomplish our proposed design. But due to budget limitations, the final design is carried out to the maximum budget allowed and with great success. Of course, there were certain tasks that could have made the design more efficient and reliable if the proper components were available. But for our initial proposed objective, the final design is successful.

The implementation of the final design relied on the components to function properly at their required times. This was accomplished by selecting the ideal components that met our design requirements. For example, the PLC used in our design had to have the required number of inputs and outputs for our application; and had to be able to run on a 12-volt supply—which is the voltage supplied to the majority of the other components used in the design. Another critical example was the selection of the position sensors; they had to be compatible with the PLC and had to be able to operate under harsh and demanding conditions such as: hot/cold temperatures and rapid movement/vibrations. These are just a few of the component specifications that were considered in the completion of the final design.

Minimum troubleshooting and adjustments were required because the selected components were compatible with each other. Furthermore, the tasks performed by the final design met our proposed requirements. (See Figure 4) The following is a brief list of the components' operations:

1. Autoloc Remote will send a signal to the PLC. The signal can either start or stop the program.
2. Position sensors will be activated only when the magnet is present, and it is then that they will send a signal to the PLC. The sensors will operate independently of each other, though; at times they will work together to perform a specific task.
3. PLCs CPU will process the input signals. In addition, depending on the stage in the ladder logic program and the status of the inputs, it will deliver a signal to a certain output.
4. The outputs—solenoids/pumps and dumps—turned on and performed the required-programmed task.

The following sections will discuss in more detail the requirements and specifications of each of the components used in the final design.

PLC-Hardware

The PLC used in the design is an Automation Direct DL05 micro PLC (D0-05DR-D). This micro PLC is a complete self-contained system. The CPU, power supply, and Inputs/Outputs are all included inside the same housing. The PLC operates on a DC power supply with a voltage range of 12-24 volts VDC. It consists of 8 input points and 6 output points. (Refer to Appendix A)

For our design, we will operate the PLC at 12-volts DC and use 6 input and output points. The PLC Input/Output configuration will consist of the following:

6 INPUTS	6 OUTPUTS
START SHOW	FRONT SOLENOID
STOP SHOW	FRONT LEFT DUMP
FRONT RIGHT POSITION SENSOR	FRONT RIGHT DUMP
FRONT LEFT POSITION SENSOR	REAR SOLENOID
REAR RIGHT POSITION SENSOR	REAR LEFT DUMP
REAR LEFT POSTION SENSOR	REAR RIGHT DUMP

Table. 1- Input/Output configuration

The inputs and outputs are of sourcing I/O circuit types. The I/O types are convenient in the design because they help avoid any additional interfacing circuitry between the PLC and the input/output components.

PLC-Software

The software used to program the PLC is Automation Directs DirectSoft 32 programming software. The 32-bit windows-based package provides simple menu and icon choices that operate similarly to those found in the most standard Windows packages. The software can be used on any computer with Windows 95 or higher. DirectSoft 32 allows the programmer to program the PLC in its programming language—relay ladder logic.

The ladder logic program was written successfully using a special feature of DirectSoft 32 called Stage Programming (RLL Plus). Stage programming simply allows the programmer to divide and organize a relay ladder logic program into groups of ladder instructions called stages. Some of the advantages of using Stage Programming-RLL Plus over standard relay ladder logic are:

1. Save CPU scan time of rungs.
2. Use of state transitions diagrams to develop programs.
3. PLC only scans the rungs of activated stage. (JMP instruction is use to move from one stage to the next. In addition, JMP instruction will deactivate the stage it is jumping from and simultaneously activate the stage it is jumping to.)
4. Aids in troubleshooting. For example, when a process gets stuck, it is easier to find the rung where the error occurred.
5. Self-latching relays are easier to create.

Appendix B shows the complete ladder logic program (using Stage Programming) for our final design. The comments explain what each stage will perform and in addition, there is an explanation of what each rung is executing. There is a total of 12 stages in the program; equivalent to 65 rungs of ladder logic code.

Remote Control

In order for us to active our PLC we chose to use an aftermarket remote made by Autoloc (KL 4444). The KL 4444 is a 4-channel remote, for our design we will be using just two channels rated at (-) 500ma. Channel 1 will start our preprogrammed-hydraulic routine, while channel 2 will be used to stop our routine. The remote itself offers superior quality in an ultra-compact design that weighs in at about a 1 lb, which makes it ideal for our application. The wiring for our remote consists of just 4 wires: 12 volts, ground, channel 1 and channel 2. In our application channel 1(White/Green wire) of the remote will be wired into XO input of the PLC and channel 2(White/Red) will be wired into X1 input.

Position Sensors

The position sensor used in our design is a Honeywell SR4 Series Omnipolar Hall-Effect Digital Position sensor (SR4P2-A1). This sensor responds to the presence of a magnetic field by producing a digital output proportional to the magnetic field strength. The sensor operates on a DC voltage supply range of 6 to 24 volts and delivers a sinking output. (Refer to Appendix C)

The selection of this specific position sensor complies accordingly to specifications of other components used in the design. For example, the PLC, remote control and sensors all operate on 12-volts DC. Another example, the sinking output of the sensor, like that of the remote output, match and interface without error with the PLCs input. This saves the development of further circuitry to interface with the PLC. There are a total of four position sensors used in the design. A position sensor will be placed on each of the wheel's control arm—front and rear of automobile—system.

Chapter 6: <u>Results</u>

The overall assembly of our design performed well. All the components of the final design are stored in the trunk of the vehicle—except for the position sensors—for easier assembly and access. All the components responded with great accuracy to their specific duties. Though, minor problems were encountered, it was nothing extreme that had interfered with the completion of our design. The following sections discuss in detail the results of the major components use in our design.

PLC-Hardware

The PLC functioned ideally in the design. All the input and output points were wired using connectors; this helped avoid any false contacts or possible shorts. At the required times, the PLC received the signal from the sensors in the matter of microseconds and then process the desired output. This process was a success because the output points delivered the signal immediately to its desired solenoid/pump or dump. (See Photo 1) The only problem encountered was that our PLC was not receiving enough power. The automobile's battery was not supplying enough current to the PLC. We found that the generator was not charging the battery properly because of a broken support bracket. This was an external problem that was solved by using a brand new 12VDC car battery. Once the connections were made, the PLC received enough current to operate smoothly.

PLC-Software

The ladder logic program controlled the fluctuation of the hydraulic system with great success. Every stage in the program executed perfectly from the moment channel one (start show) was activated. Also, the program routine was able to be stop during any stage by activating channel two (stop show). All the stages in the ladder logic program performed a specific task without any problems at all. (Refer to Appendix B) The following is a list of the stage's tasks:

1. Stage 1: Lift Front of Car. (See Photo 2)
2. Stage 2: Lift Rear of Car. (See Photo 3)
3. Stage 4: Drop Left Side of Car to Ground Position. (See Photo 4)
4. Stage 5: Drop Right Side of Car to Ground Position. (See Photo 5)
5. Stage 6: Lift Entire Car from Ground Position. (See Photo 6)
6. Stage 7: Drop Entire Car to Ground Position. (See Photo 7)

Stages 10, 11, and 12 perform the same tasks as stages 2, 1, and 7 respectively. As seen from the stage sequence, the order of which stage executes next depends on the vehicle's position and on the specific ladder logic program instruction(s). This allows us to add more stages and control the fluctuation of the hydraulic system in other ways. But for our proposed design, we were able to control the fluctuation of the hydraulic system and start & stop the program/show at any time during the preprogrammed-routine.

Remote Control

The Autoloc remote control was used to send a signal to its receiver, which only worked at a close range of approximately 4 feet. Due to excessive wires and metal equipment, which produced excessive EMF that cut down our signal range. (See Photo 8) Simply removing the receiver from the trunk, which will give us a longer signal range, can solve this problem. Other then that, the remote control and PLC interfaced without any further problems.

Position Sensors

The position sensors required the most time to install. The entire car was lifted on a hydraulic lift to make the installation easier and quicker. Special brackets were welded onto the vehicle's suspension system to hold the position sensors and magnets in place. After the proper installation of the position sensors, they interfaced with the PLC flawlessly. The process of sending a signal from the position sensor to the PLC happens within approximately 2-3 microseconds. The Front Solenoid and Rear Solenoid were turned off immediately when their respective position sensors were activated. The Front Left and Front Right Sensors were easier to install because the control arms of the vehicle's suspension system provided easier access and more area for placement. (See Photo 9) Meanwhile, the Rear Left and Rear Right Sensors were more difficult to install because of the limited space and geometry on the vehicle's rear suspension. A trial and error method was used to construct special brackets that allowed us to install the position sensors and magnets at the best possible location. (See Photo 10)

Chapter 7: Conclusion

In conclusion, the overall outcome of our final design met our goal with sufficient success. We were able to use an everyday-industry PLC, remote control, and position sensors to control the fluctuation of an automobile's hydraulic system. All the components used in our design function properly and with precise accuracy after minimum troubleshooting. Though, our design was applied to the hydraulic system on a 1968 Chevrolet Impala, it can also be applied to other type of vehicles with minimal modifications. Actually, the majority of the modifications would be on the placement of the position sensors since not all vehicles have the same type of suspension system/frame. Other considerations would include a different PLC with more outputs: depending on the hydraulic system's set-up (number of solenoids/pumps and dumps), number of batteries used, and the user's defined ladder logic program. Above all the problems encountered, none detained us more from design improvements then budget limitations. Many improvements could have been included in our design if we had a bigger budget. For the future, the following improvements can make our design more efficient and reliable:

Safety Features

- Install an external emergency stop to be controlled by the remote control to kill the power to the hydraulic system as an added safety measure.
- Investigate and used specific sensors to detect the status of the solenoids/pumps and dumps at all times (temperature and pressure).

Performance

- Purchase more 12VDC car batteries to supply more power to the hydraulic system.
- Purchase more solenoids/pumps. This will allow the hydraulic system to perform faster; giving us additional fluctuation-movements (i.e. three wheel, pancake, side-to-side, etc.).
- Upgrade to a PLC with more input and output points.
- The use of on board touch screen for selecting preset programs.

Chapter 8: Cost Analysis

Quantity	List of Parts	Cost
1	DirectSoft 32 PLC Software	$100.00
1	Automation Direct PLC #D0-05DR-D	$100.00
4	Honeywell SR4 Position Sensors #SR4P2-A1	$100.80
4	BTN Magnets	$23.61
1	AutoLoc 4-Function Remote #KL 4444	$105.00
1	CCE Hydraulic System	$1,200.00
	Miscellaneous Items:	
	Metal, Wires, Connectors	$200.00
3	Batteries	$186.00
	Total Cost:	**$2,015.41**

Figure. 1 Basic Hydraulic Setup

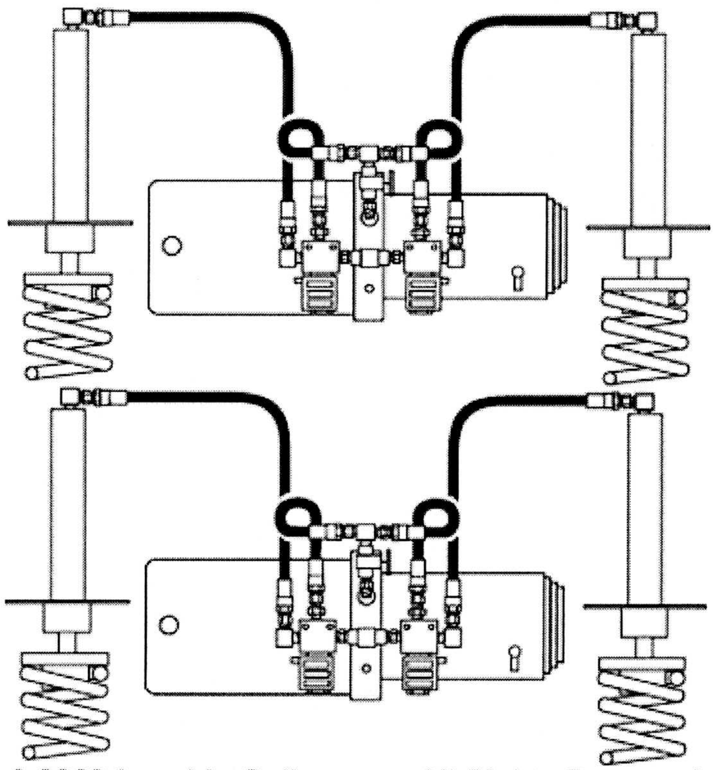


Figure. 2 **Fluid Flow To Cylinders**

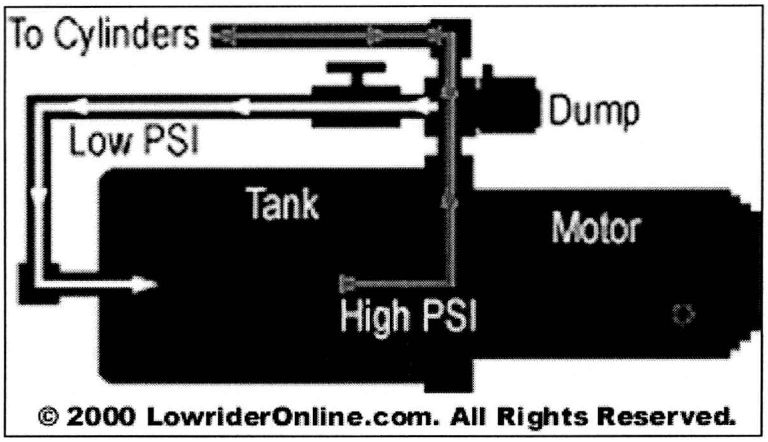
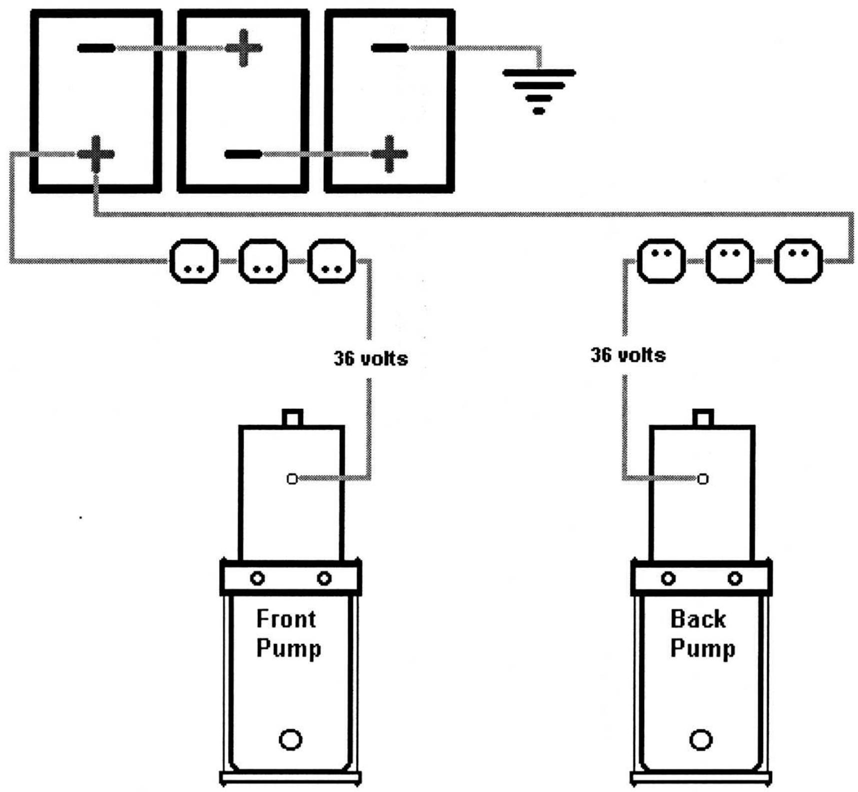
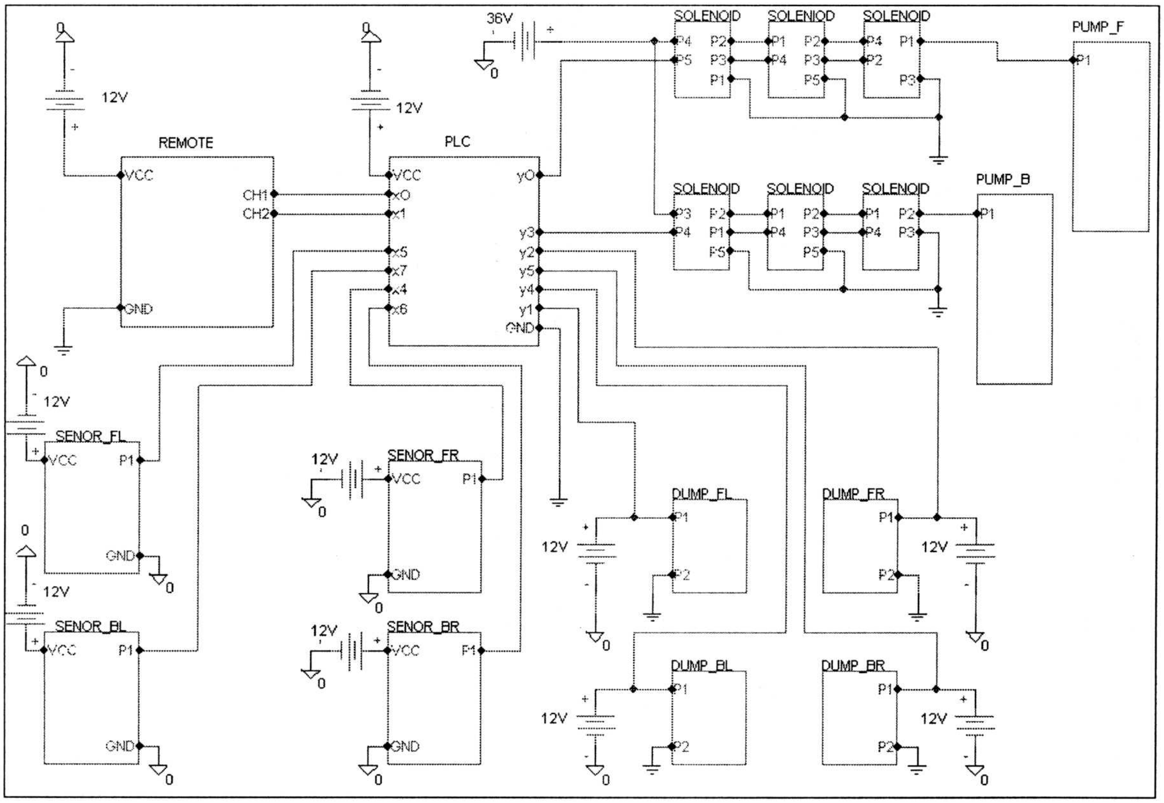


Figure. 3 Basic Hydraulic Pumps With Batteries



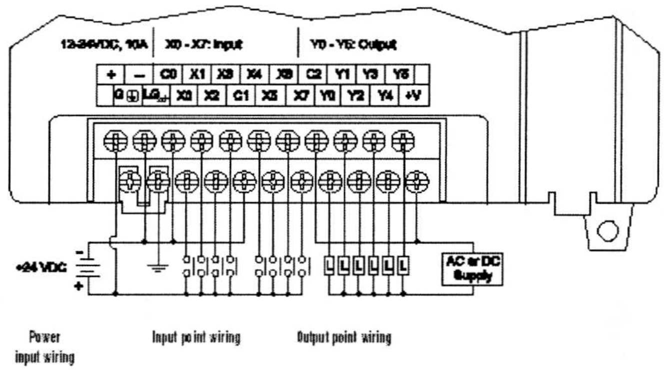
2 pumps with 3 batteries in 1 bay - Provided by copyright owner LayitLow.com

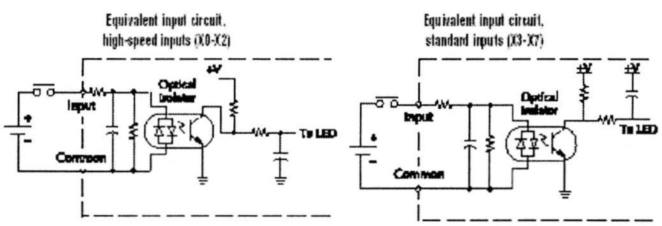
Figure. 4 Final Component Layout

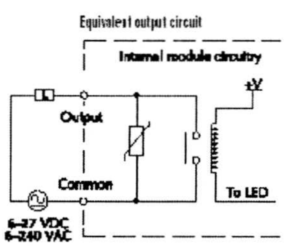


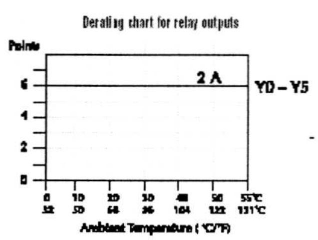
Appendix A: PLC Specifications Sheet.

DO-05DR-D Specifications			
DC Power Supply Specifications	Voltage Range	12-24VDC 20W max.	
DC Input Specifications	Number of Input Pts.	8 (sink/source)	
	Number of Commons	2 (isolated)	
	Input Voltage Range	12-24VDC	
	Input Impedance	(X0-X2) 1.8K @ 12-24VDC (X3-X7) 2.8K @ 12-24VDC	
	On Current/ Voltage Level	>5mA/10VDC	
	OFF Current/ Voltage Level	<0.5mA/<2VDC	
	Response Time	X0-X3	X4-X7
	OFF to ON Response	<100µ	<8ms
	ON to OFF Response	<100µs	<8ms
	Fuses	None	
Relay Output Specifications	Number of Output Points	6	
	Number of Commons	2 (isolated)	
	Output Voltage Range	6-240VAC, 47-63Hz 6-27VDC	
	Maximum Voltage	264VAC, 30VDC	
	Maximum Output Current	2A/point, 6A/common	
	Max.Leakage Current	0.1mA @ 264VAC	
	Smallest Recommended Load	5mA @ 5VDC	
	OFF to ON Response	<15ms	
	ON to OFF Response	<10ms	
	Status Indicators	Logic side	
	Fuses	None (external recommended)	

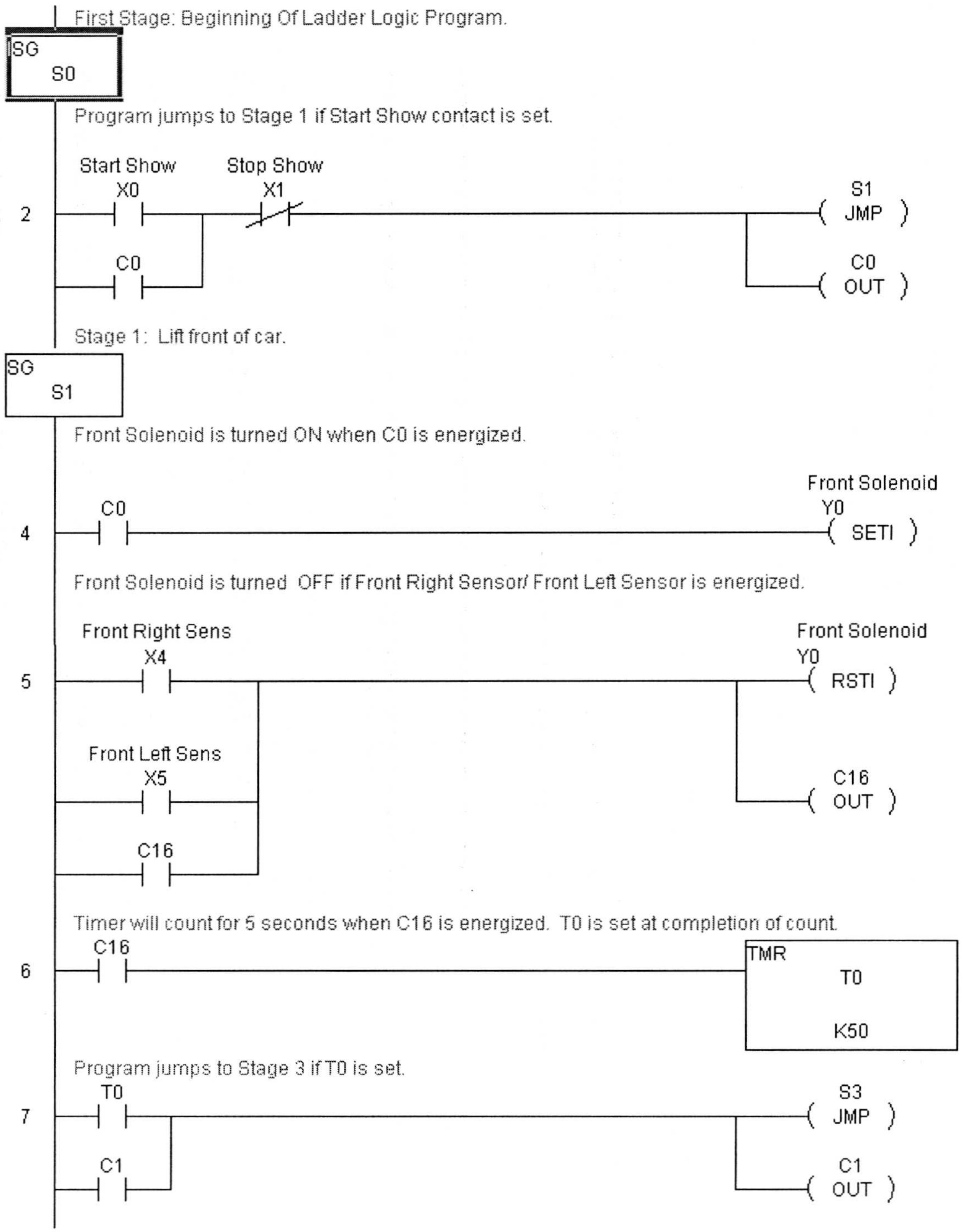


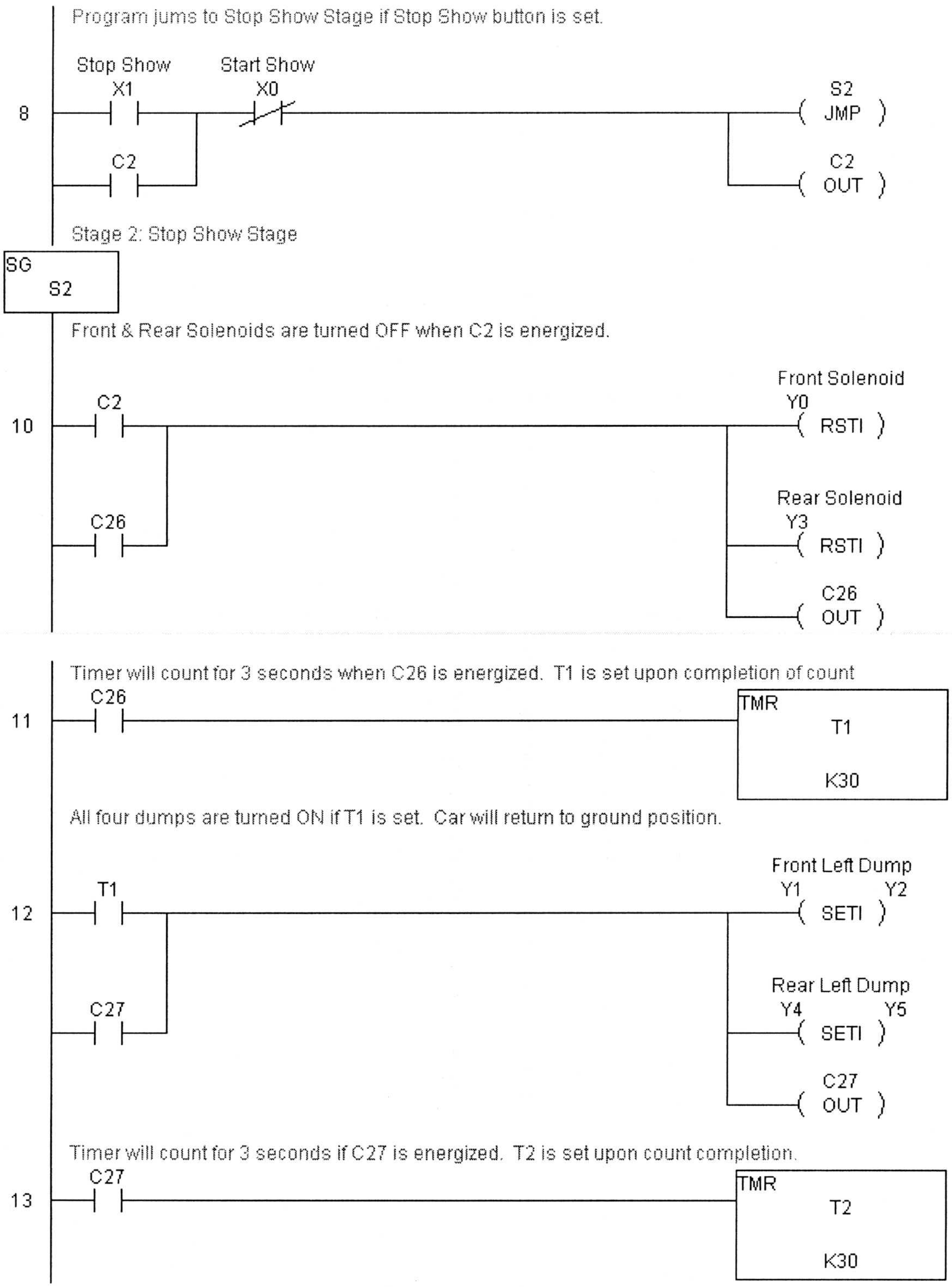


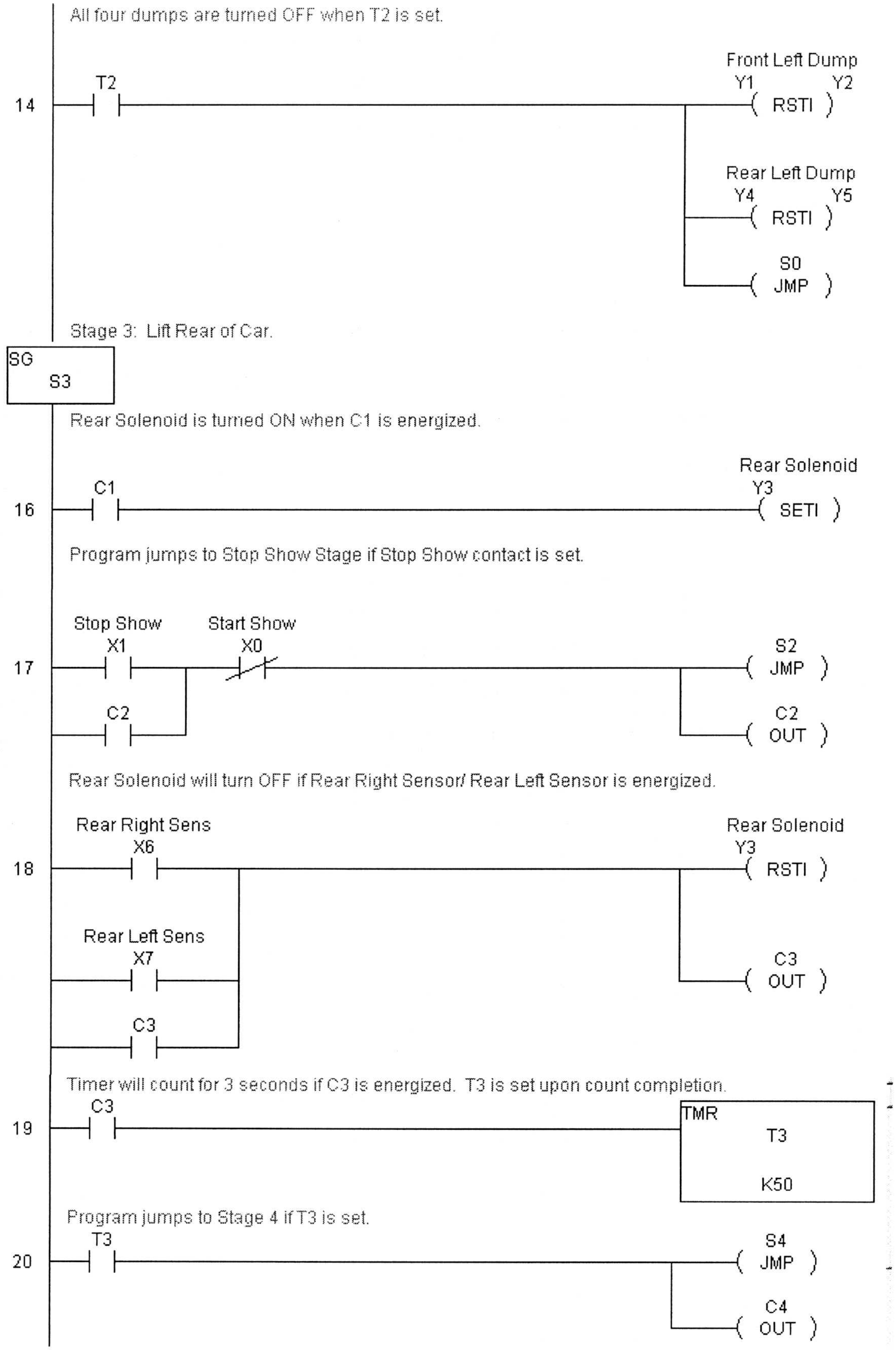


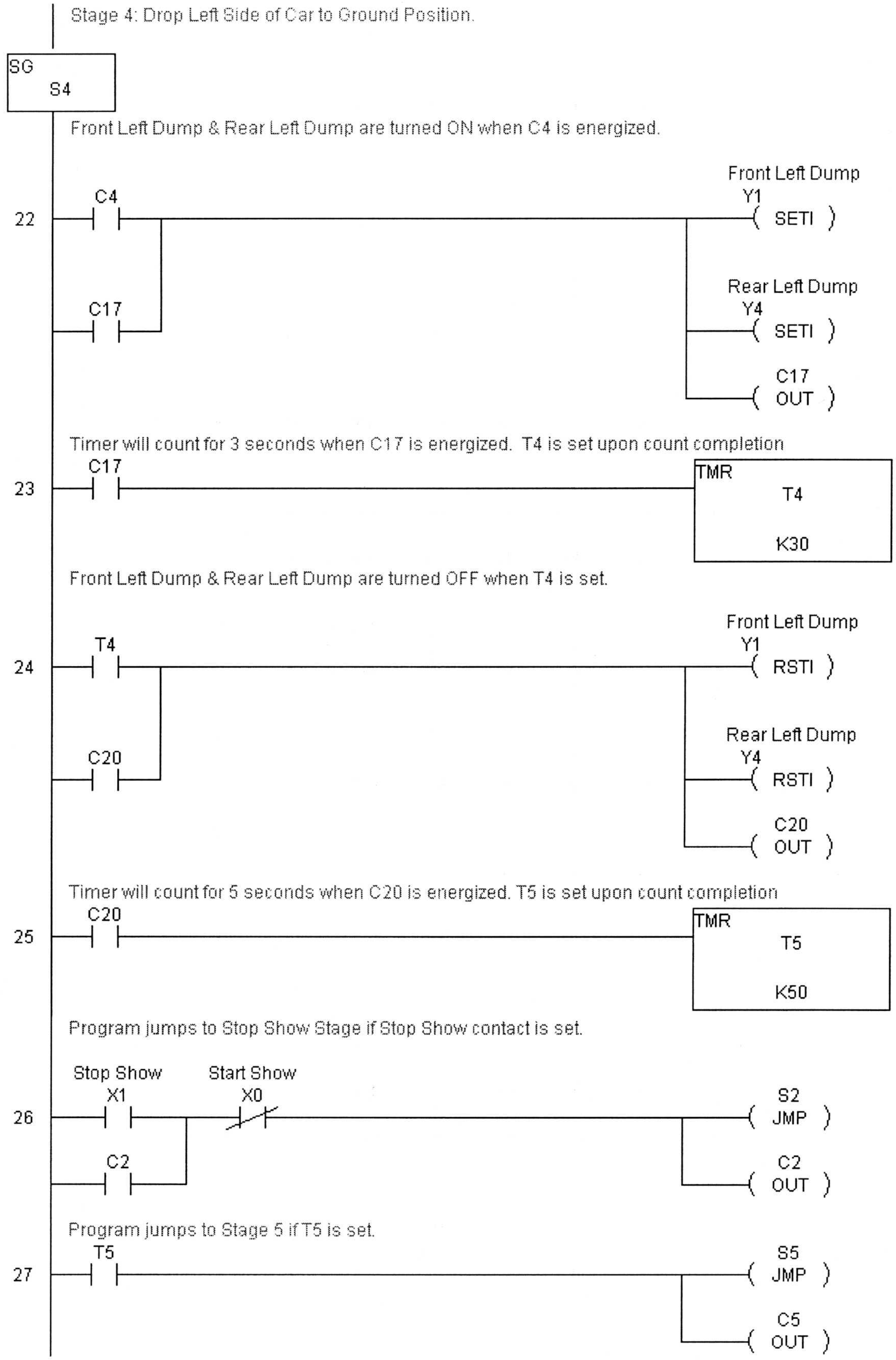


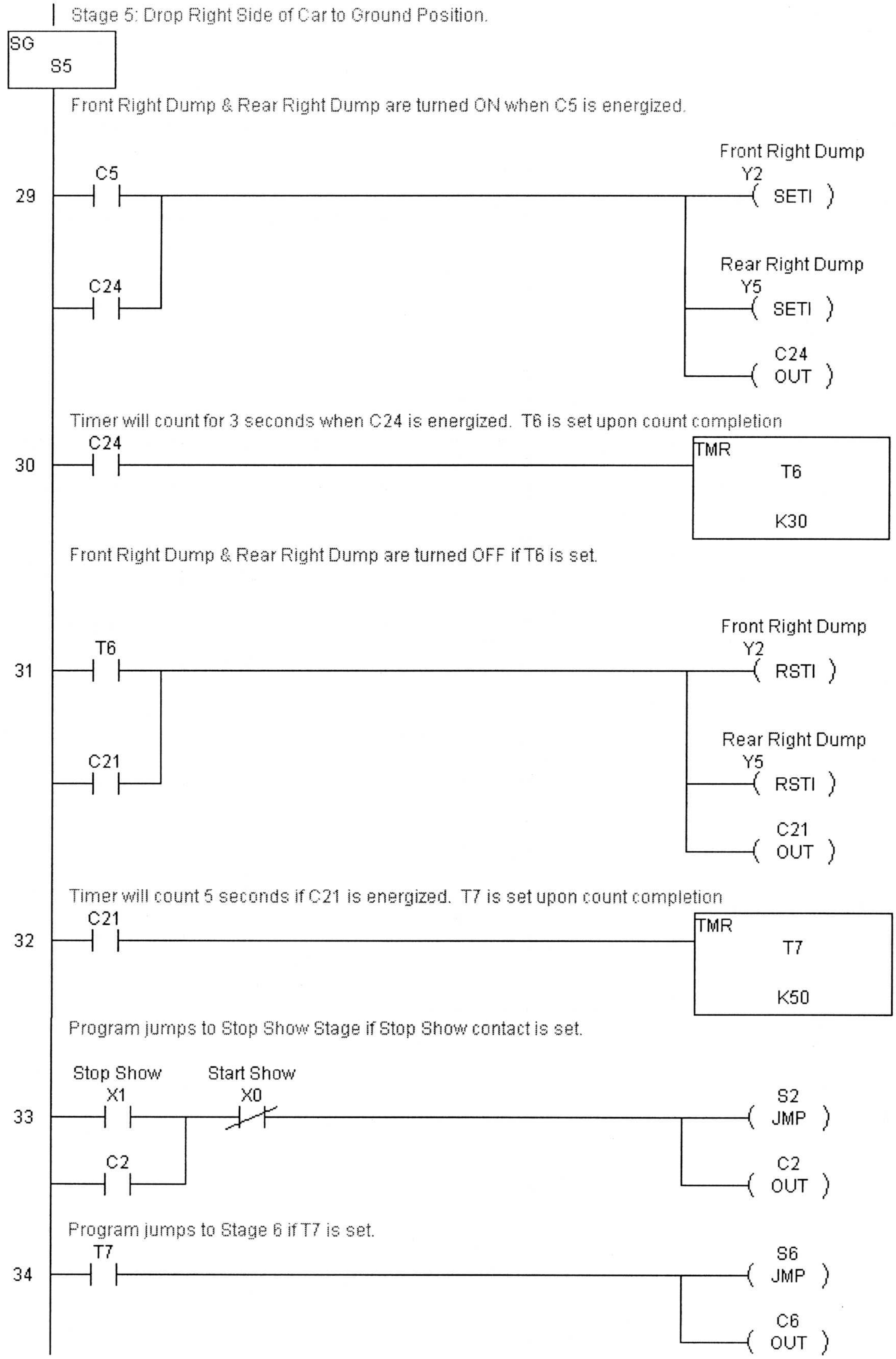
Appendix B: RLL Plus Ladder Logic Program

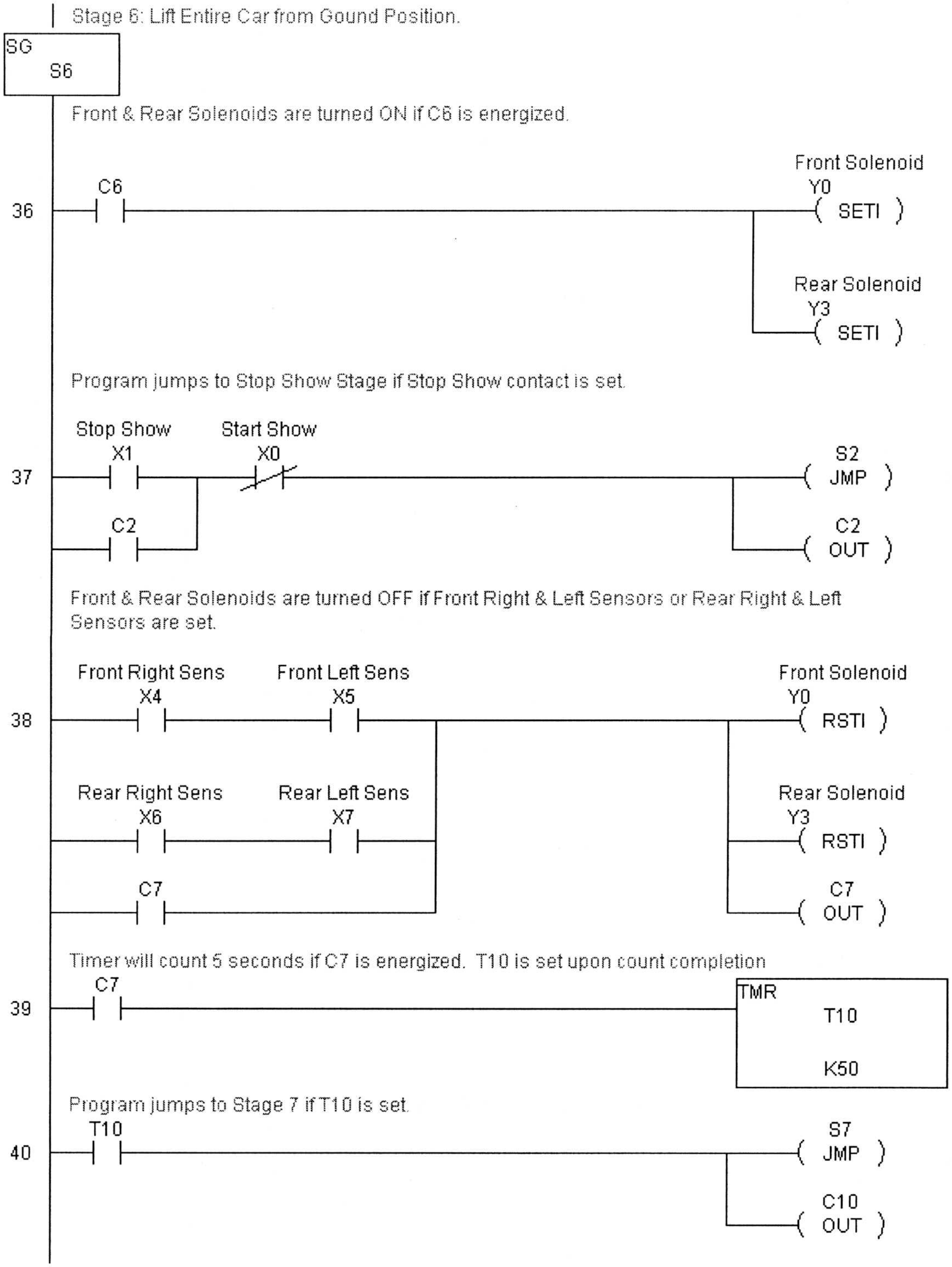



Program jums to Stop Show Stage if Stop Show button is set.
Stop Show
X1
Start Show
X0
8
C2
S2
JMP
C2
OUT
Stage 2: Stop Show Stage
SG
S2
Front & Rear Solenoids are turned OFF when C2 is energized.
10
C2
C26
Front Solenoid
Y0
RSTI
Rear Solenoid
Y3
RSTI
C26
OUT
Timer will count for 3 seconds when C26 is energized. T1 is set upon completion of count
11
C26
TMR
T1
K30
All four dumps are turned ON if T1 is set. Car will return to ground position.
12
T1
C27
Front Left Dump
Y1
Y2
SETI
Rear Left Dump
Y4
Y5
SETI
C27
OUT
Timer will count for 3 seconds if C27 is energized. T2 is set upon count completion.
13
C27
TMR
T2
K30

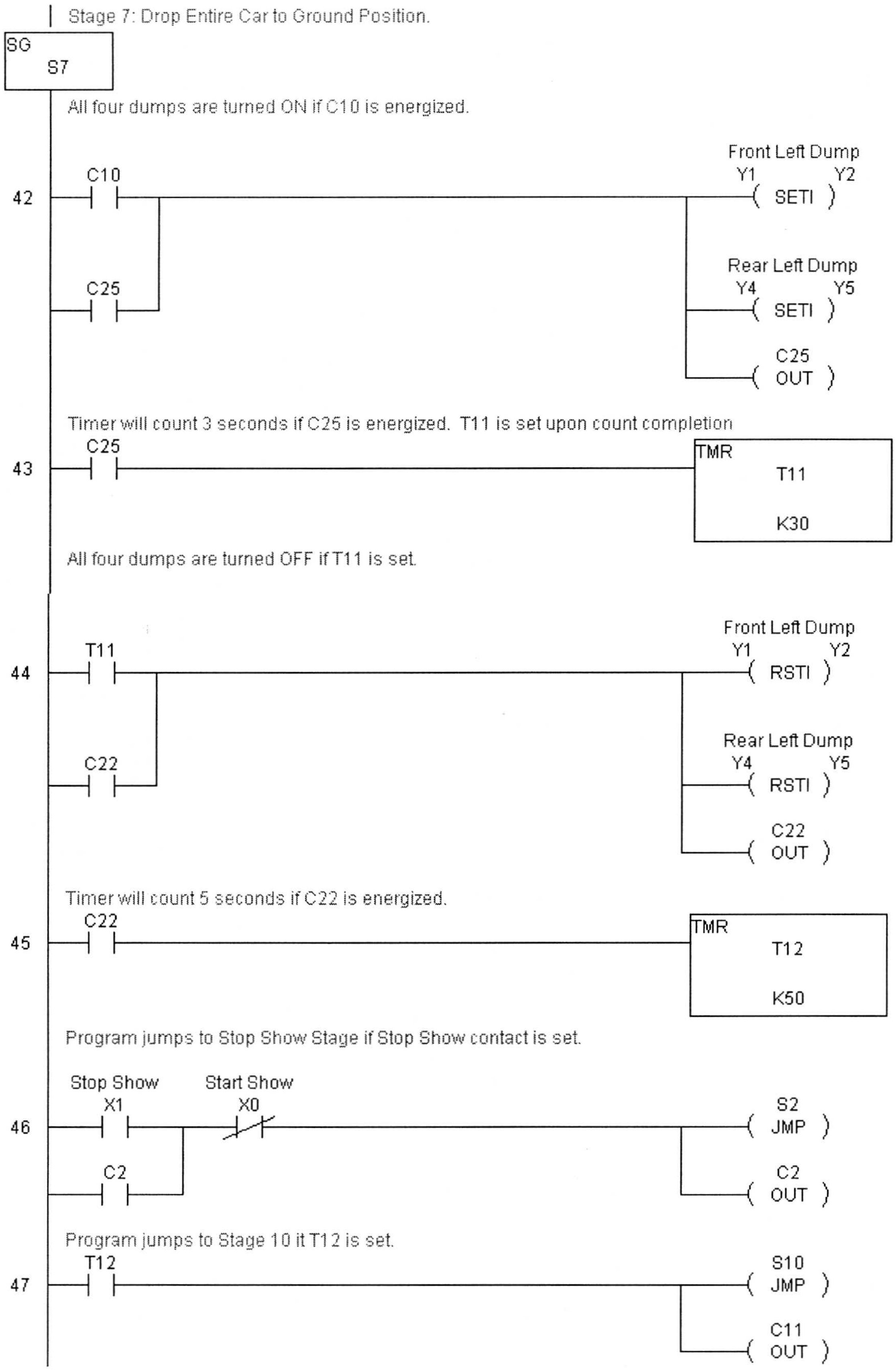

All four dumps are turned OFF when T2 is set.
14
T2
Front Left Dump
Y1 Y2
RSTI
Rear Left Dump
Y4 Y5
RSTI
S0
JMP
Stage 3: Lift Rear of Car.
SG
S3
Rear Solenoid is turned ON when C1 is energized.
16
C1
Rear Solenoid
Y3
SETI
Program jumps to Stop Show Stage if Stop Show contact is set.
17
Stop Show
X1
Start Show
X0
C2
S2
JMP
C2
OUT
Rear Solenoid will turn OFF if Rear Right Sensor/ Rear Left Sensor is energized.
18
Rear Right Sens
X6
Rear Left Sens
X7
C3
Rear Solenoid
Y3
RSTI
C3
OUT
Timer will count for 3 seconds if C3 is energized. T3 is set upon count completion.
19
C3
TMR
T3
K50
Program jumps to Stage 4 if T3 is set.
20
T3
S4
JMP
C4
OUT

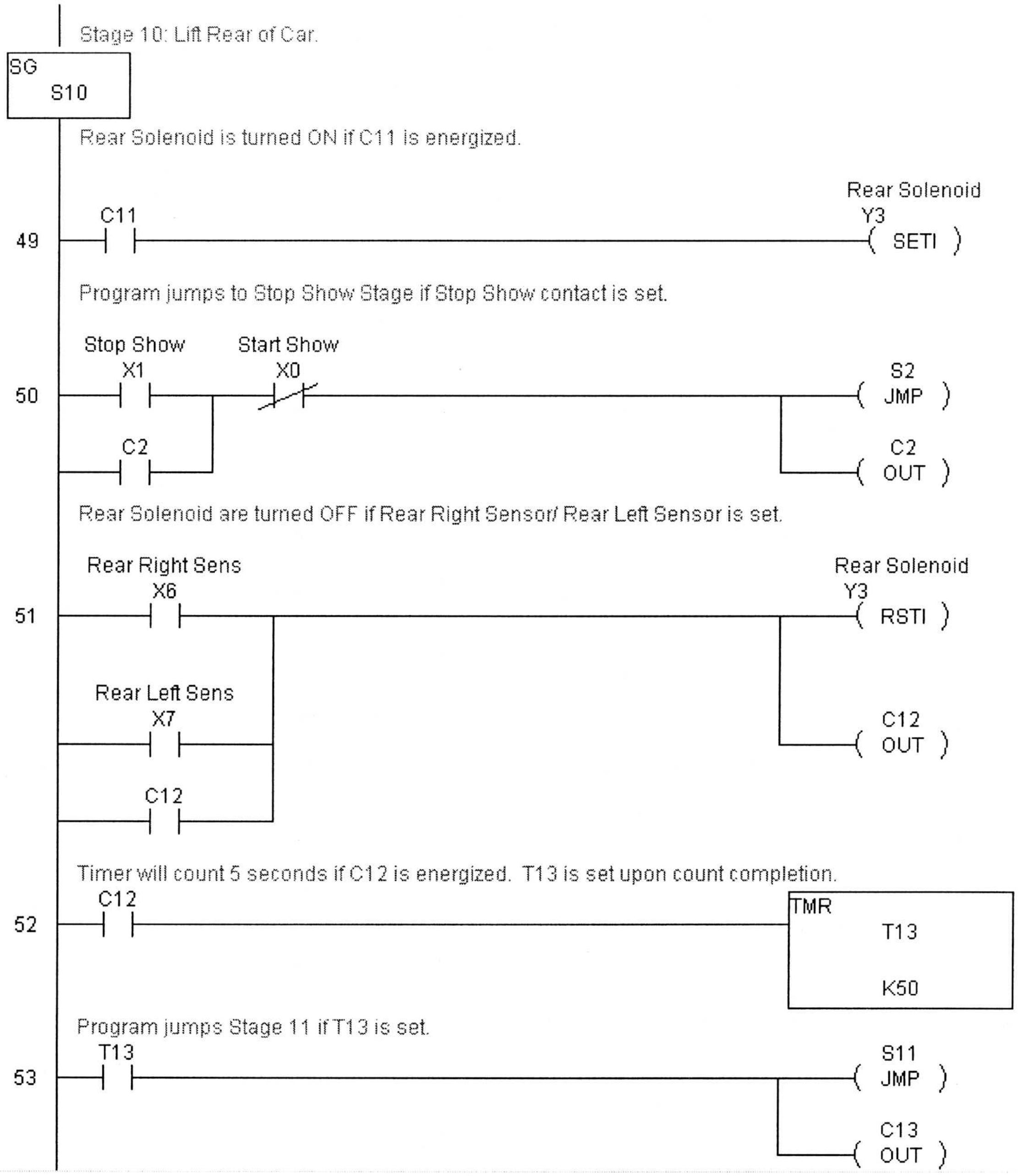

Stage 4: Drop Left Side of Car to Ground Position.
SG
S4
Front Left Dump & Rear Left Dump are turned ON when C4 is energized.
22
C4
C17
Front Left Dump
Y1
(SETI)
Rear Left Dump
Y4
(SETI)
C17
(OUT)
Timer will count for 3 seconds when C17 is energized. T4 is set upon count completion
23
C17
TMR
T4
K30
Front Left Dump & Rear Left Dump are turned OFF when T4 is set.
24
T4
C20
Front Left Dump
Y1
(RSTI)
Rear Left Dump
Y4
(RSTI)
C20
(OUT)
Timer will count for 5 seconds when C20 is energized. T5 is set upon count completion
25
C20
TMR
T5
K50
Program jumps to Stop Show Stage if Stop Show contact is set.
26
Stop Show
X1
Start Show
X0
C2
S2
(JMP)
C2
(OUT)
Program jumps to Stage 5 if T5 is set.
27
T5
S5
(JMP)
C5
(OUT)


Stage 5: Drop Right Side of Car to Ground Position.
SG
S5
Front Right Dump & Rear Right Dump are turned ON when C5 is energized.
29
C5
C24
Front Right Dump
Y2
SETI
Rear Right Dump
Y5
SETI
C24
OUT
Timer will count for 3 seconds when C24 is energized. T6 is set upon count completion
30
C24
TMR
T6
K30
Front Right Dump & Rear Right Dump are turned OFF if T6 is set.
31
T6
C21
Front Right Dump
Y2
RSTI
Rear Right Dump
Y5
RSTI
C21
OUT
Timer will count 5 seconds if C21 is energized. T7 is set upon count completion
32
C21
TMR
T7
K50
Program jumps to Stop Show Stage if Stop Show contact is set.
33
Stop Show
X1
Start Show
X0
C2
S2
JMP
C2
OUT
Program jumps to Stage 6 if T7 is set.
34
T7
S6
JMP
C6
OUT

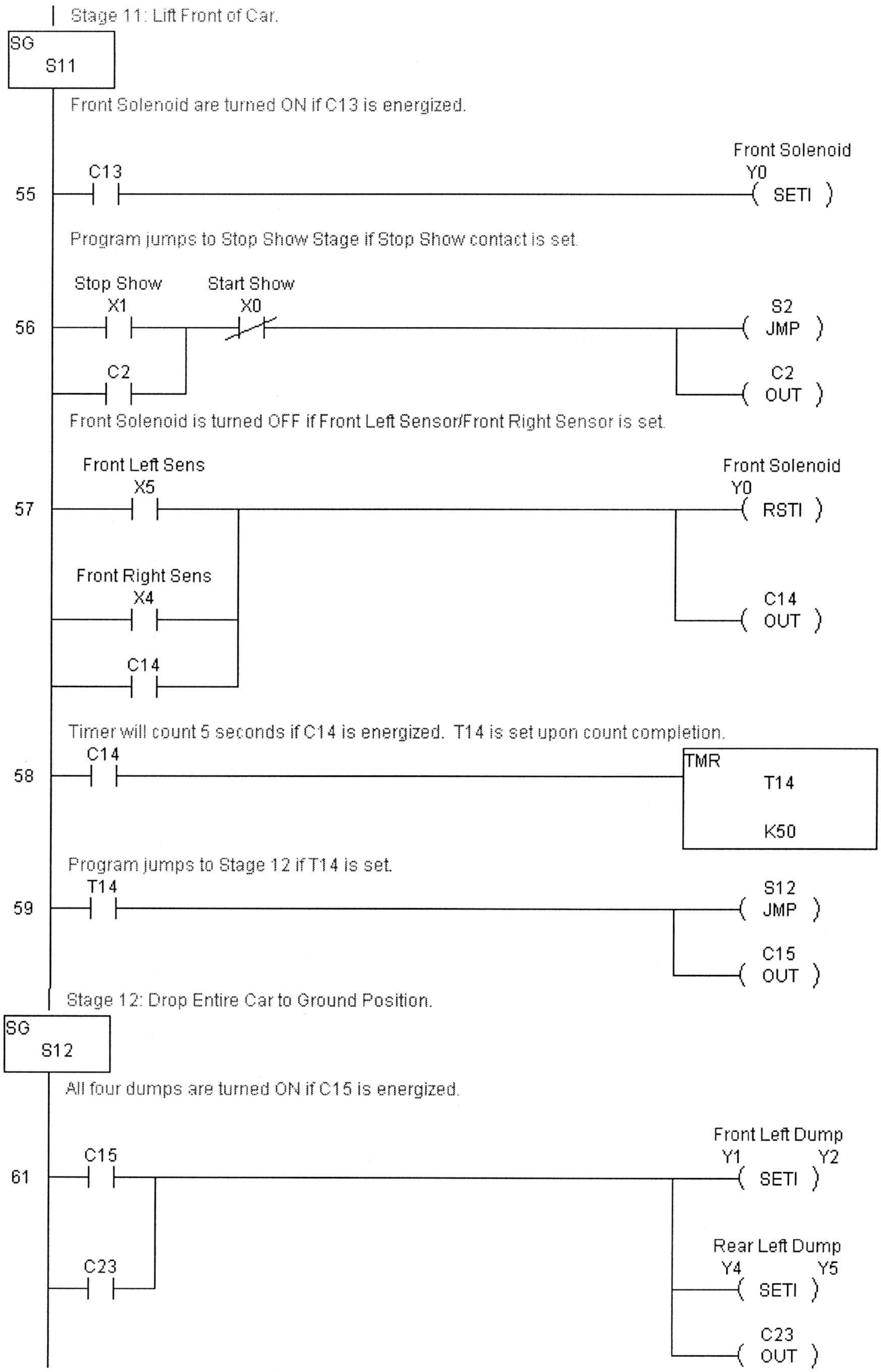


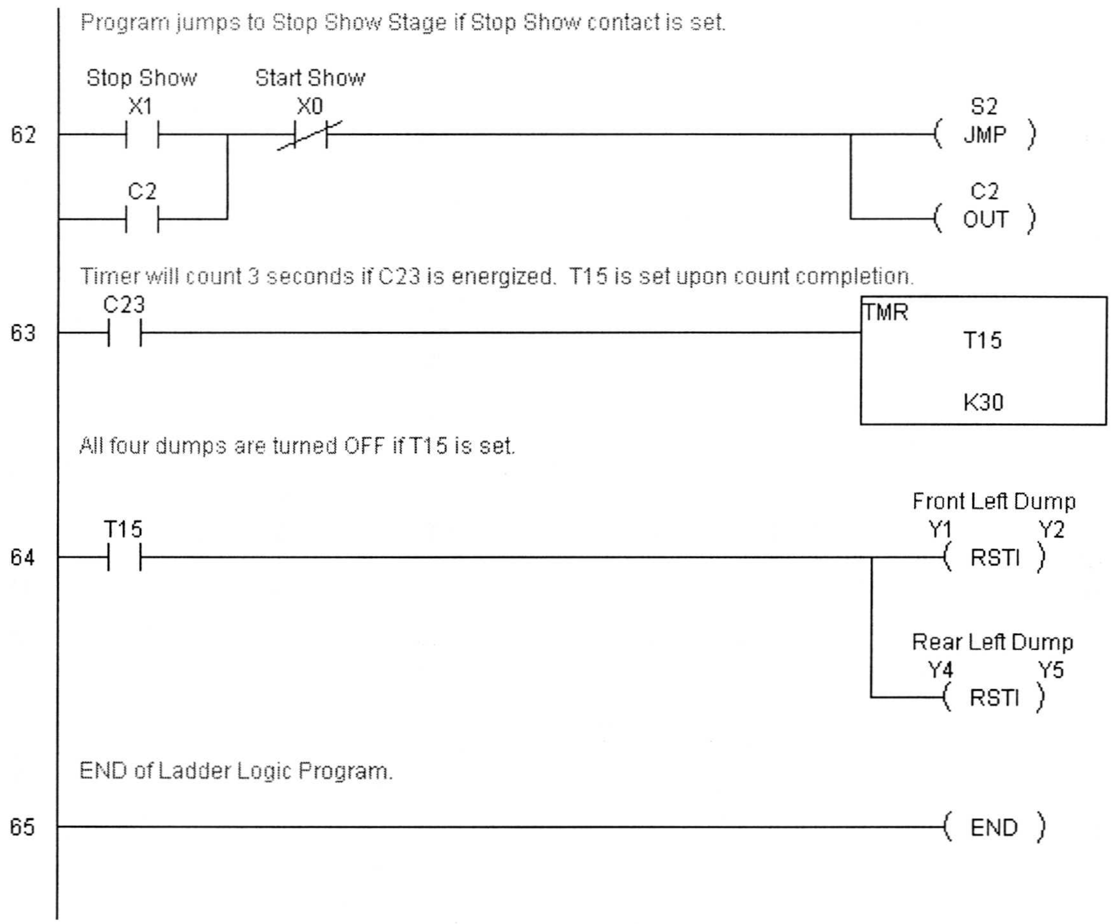
Stage 6: Lift Entire Car from Gound Position.
SG
S6
Front & Rear Solenoids are turned ON if C6 is energized.
36
C6
Front Solenoid
Y0
(SETI)
Rear Solenoid
Y3
(SETI)
Program jumps to Stop Show Stage if Stop Show contact is set.
37
Stop Show
X1
Start Show
X0
C2
S2
(JMP)
C2
(OUT)
Front & Rear Solenoids are turned OFF if Front Right & Left Sensors or Rear Right & Left Sensors are set.
38
Front Right Sens
X4
Front Left Sens
X5
Rear Right Sens
X6
Rear Left Sens
X7
C7
Front Solenoid
Y0
(RSTI)
Rear Solenoid
Y3
(RSTI)
C7
(OUT)
Timer will count 5 seconds if C7 is energized. T10 is set upon count completion
39
C7
TMR
T10
K50
Program jumps to Stage 7 if T10 is set.
40
T10
S7
(JMP)
C10
(OUT)


Stage 7: Drop Entire Car to Ground Position.
SG
S7
All four dumps are turned ON if C10 is energized.
42
C10
C25
Front Left Dump
Y1 Y2
SETI
Rear Left Dump
Y4 Y5
SETI
C25
OUT
Timer will count 3 seconds if C25 is energized. T11 is set upon count completion
43
C25
TMR
T11
K30
All four dumps are turned OFF if T11 is set.
44
T11
C22
Front Left Dump
Y1 Y2
RSTI
Rear Left Dump
Y4 Y5
RSTI
C22
OUT
Timer will count 5 seconds if C22 is energized.
45
C22
TMR
T12
K50
Program jumps to Stop Show Stage if Stop Show contact is set.
46
Stop Show
X1
Start Show
X0
C2
S2
JMP
C2
OUT
Program jumps to Stage 10 it T12 is set.
47
T12
S10
JMP
C11
OUT



Stage 10: Lift Rear of Car.
SG
S10
Rear Solenoid is turned ON if C11 is energized.
49
C11
Rear Solenoid
Y3
SETI
Program jumps to Stop Show Stage if Stop Show contact is set.
50
Stop Show
X1
Start Show
X0
C2
S2
JMP
C2
OUT
Rear Solenoid are turned OFF if Rear Right Sensor/ Rear Left Sensor is set.
51
Rear Right Sens
X6
Rear Left Sens
X7
C12
Rear Solenoid
Y3
RSTI
C12
OUT
Timer will count 5 seconds if C12 is energized. T13 is set upon count completion.
52
C12
TMR
T13
K50
Program jumps Stage 11 if T13 is set.
53
T13
S11
JMP
C13
OUT


Stage 11: Lift Front of Car.
SG
S11
Front Solenoid are turned ON if C13 is energized.
C13
55
Front Solenoid
Y0
SETI
Program jumps to Stop Show Stage if Stop Show contact is set.
Stop Show
X1
Start Show
X0
56
S2
JMP
C2
C2
OUT
Front Solenoid is turned OFF if Front Left Sensor/Front Right Sensor is set.
Front Left Sens
X5
57
Front Solenoid
Y0
RSTI
Front Right Sens
X4
C14
OUT
C14
Timer will count 5 seconds if C14 is energized. T14 is set upon count completion.
C14
58
TMR
T14
K50
Program jumps to Stage 12 if T14 is set.
T14
59
S12
JMP
C15
OUT
Stage 12: Drop Entire Car to Ground Position.
SG
S12
All four dumps are turned ON if C15 is energized.
C15
61
Front Left Dump
Y1
Y2
SETI
Rear Left Dump
Y4
Y5
SETI
C23
C23
OUT


Program jumps to Stop Show Stage if Stop Show contact is set.
Stop Show
X1
Start Show
X0
62
S2
JMP
C2
C2
OUT
Timer will count 3 seconds if C23 is energized. T15 is set upon count completion.
C23
63
TMR
T15
K30
All four dumps are turned OFF if T15 is set.
Front Left Dump
Y1
Y2
T15
64
RSTI
Rear Left Dump
Y4
Y5
RSTI
END of Ladder Logic Program.
65
END

Appendix C: Sensor Specifications Sheet.

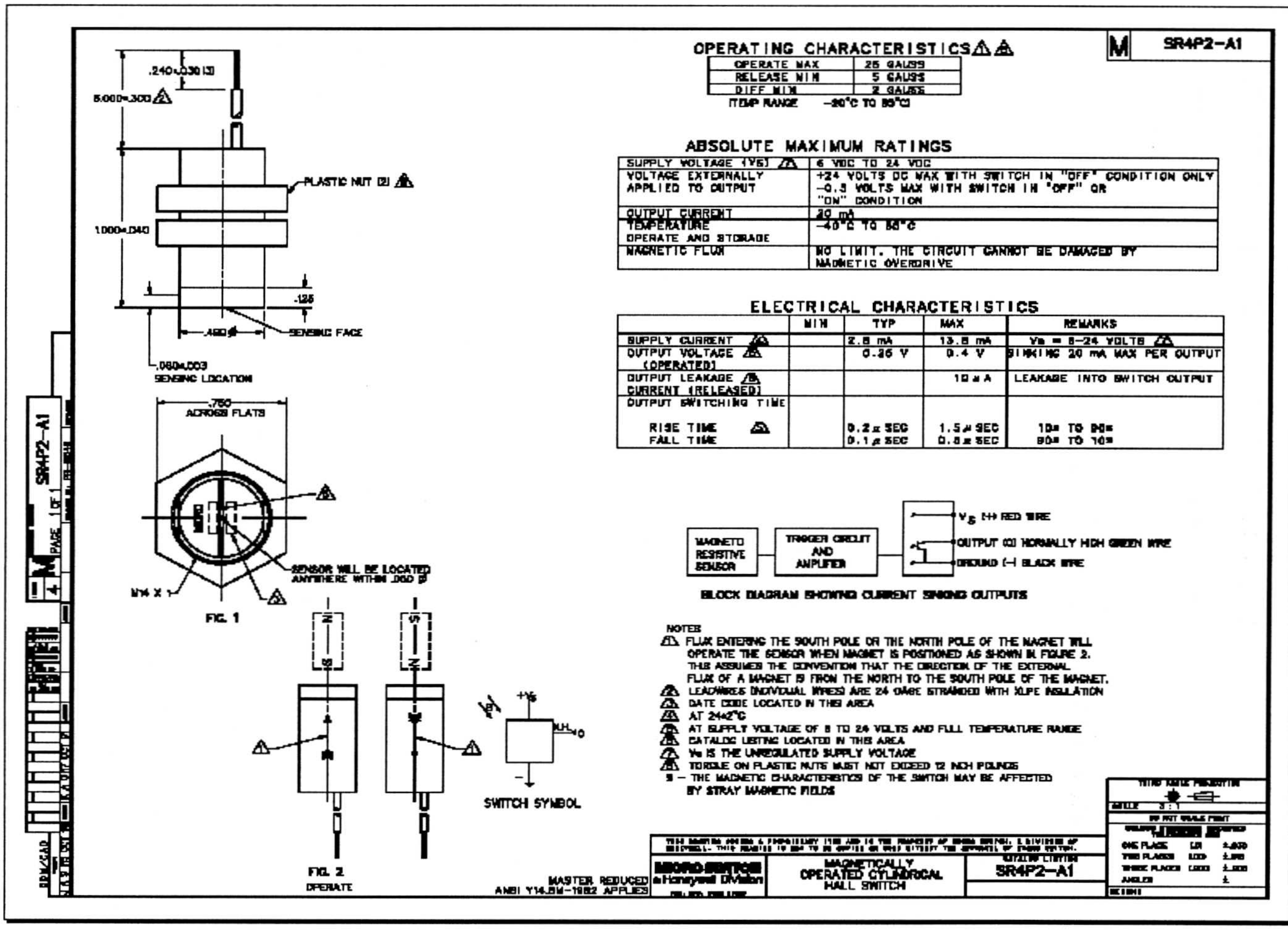


Photo.1 PLC and Remote

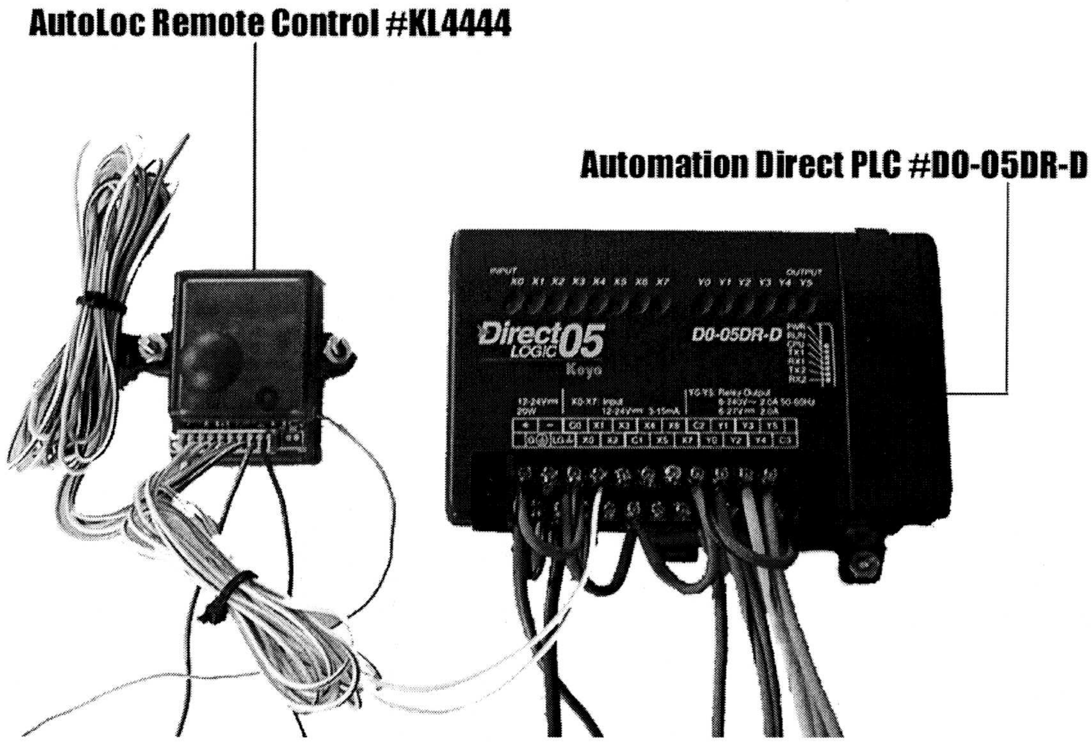


Photo. 2 **Front of Vehicle Up**

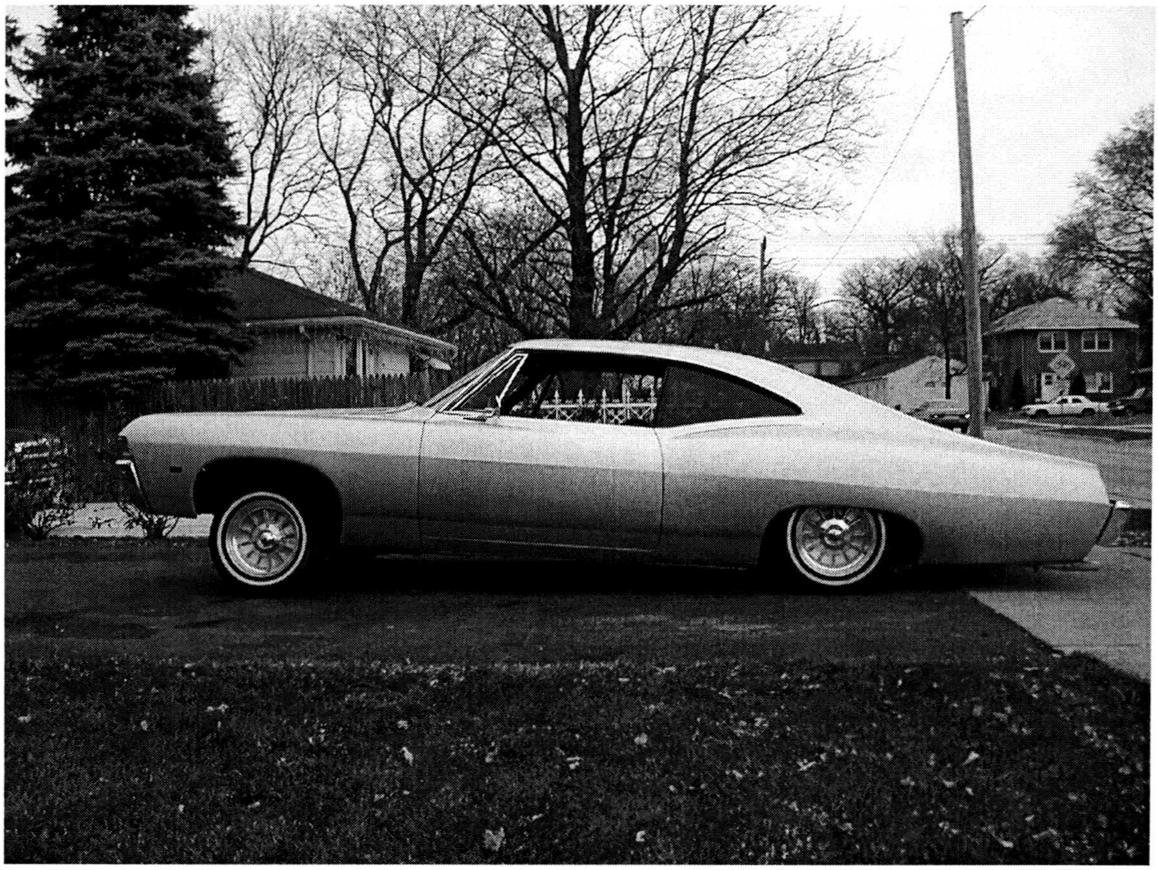


Photo. 3 <u>Rear of Vehicle Up</u>

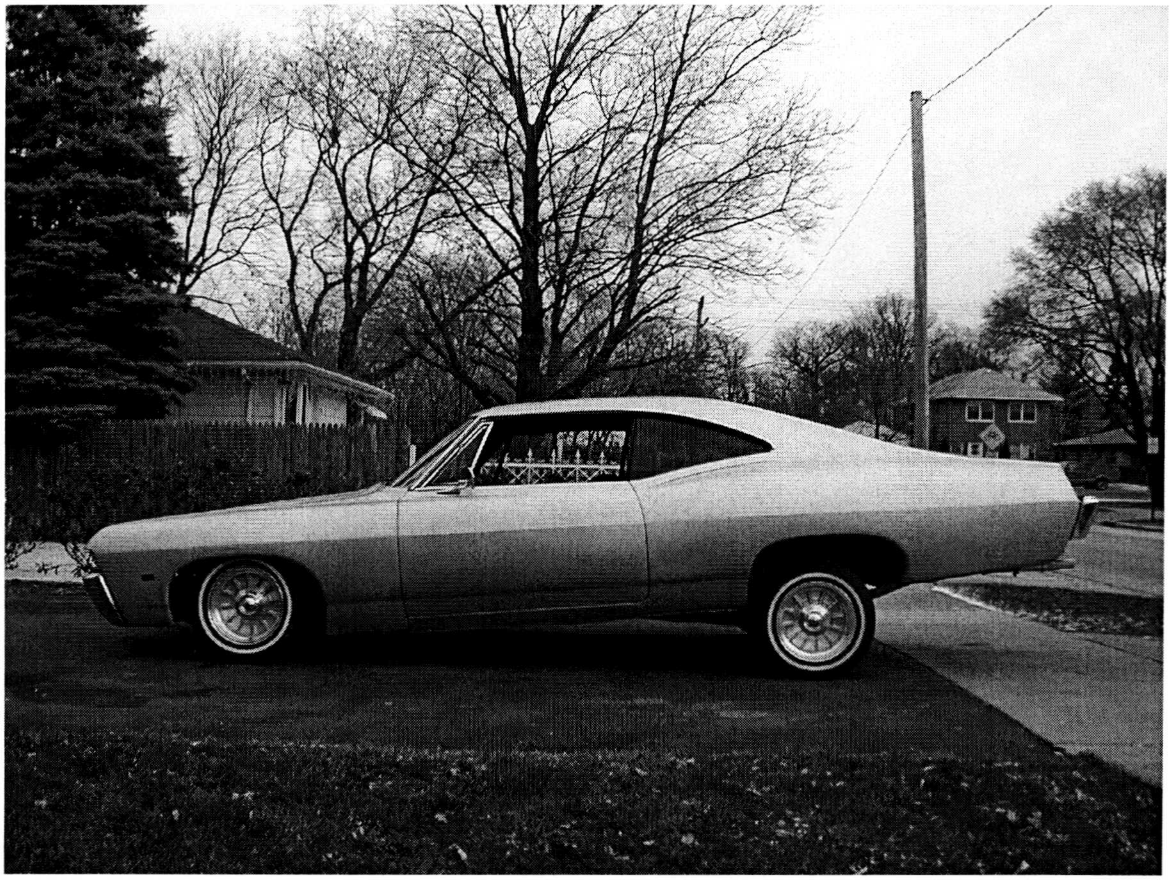


Photo. 4 **Left side down to ground position**

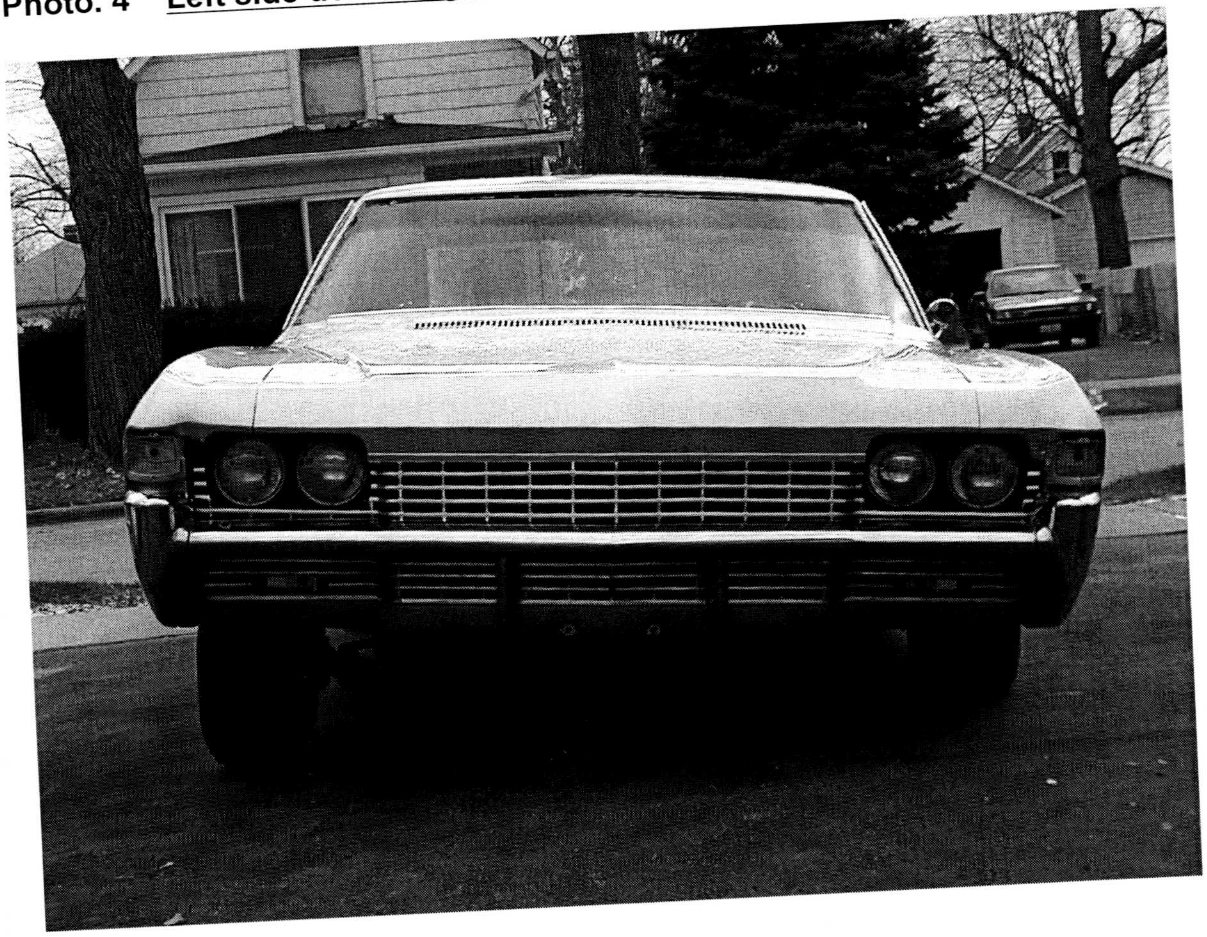


Photo. 5 <u>Right side down to ground position</u>

Photo. 6 **<u>Front and Rear up</u>**

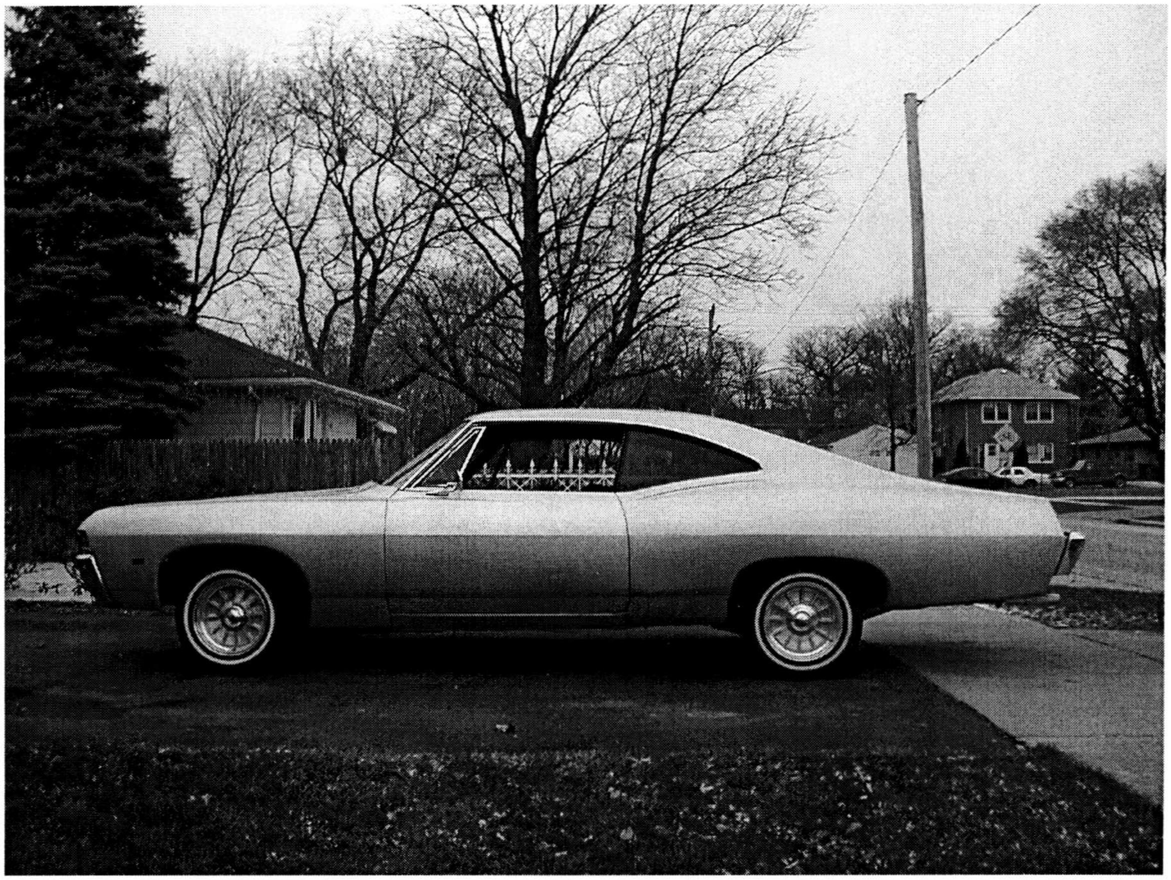


Photo. 7 **Front and Rear down**

Photo. 8 <u>Installed Final Design</u>

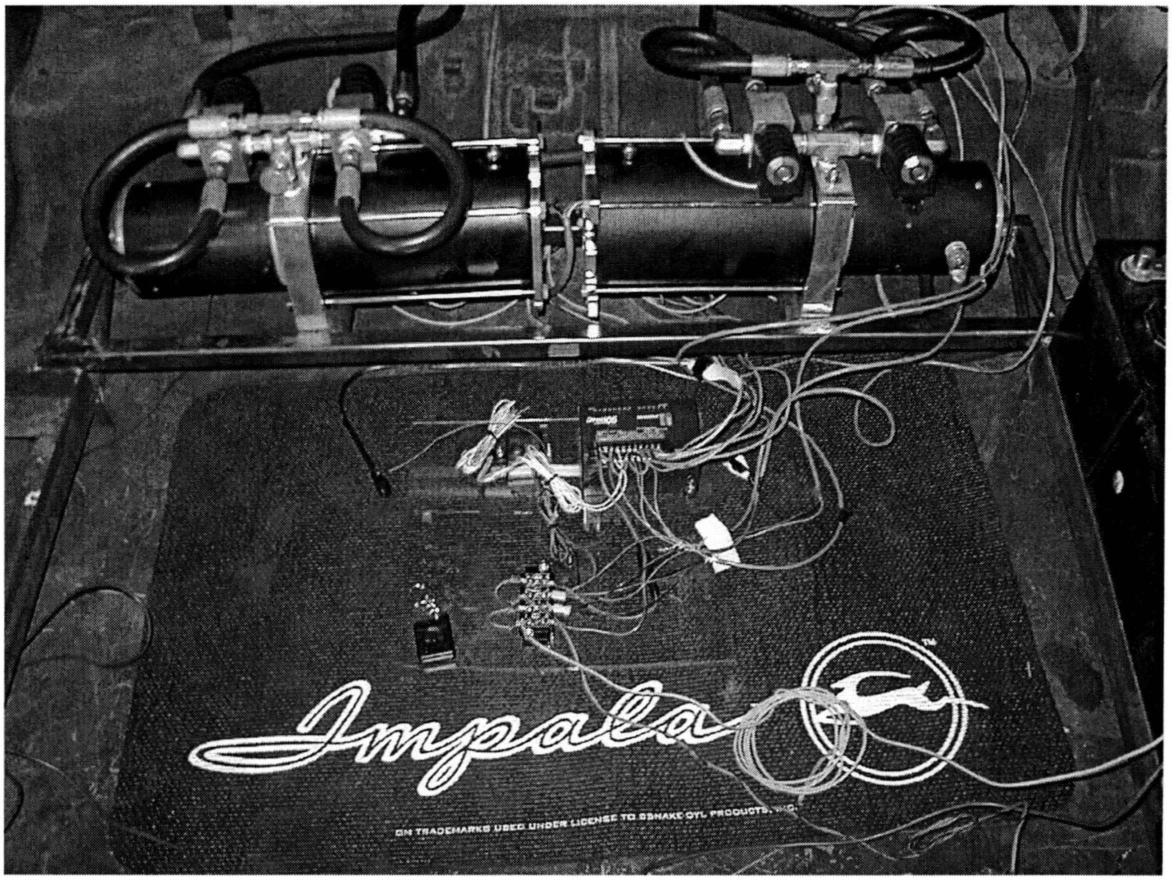


Photo. 9 Installed Front Sensor

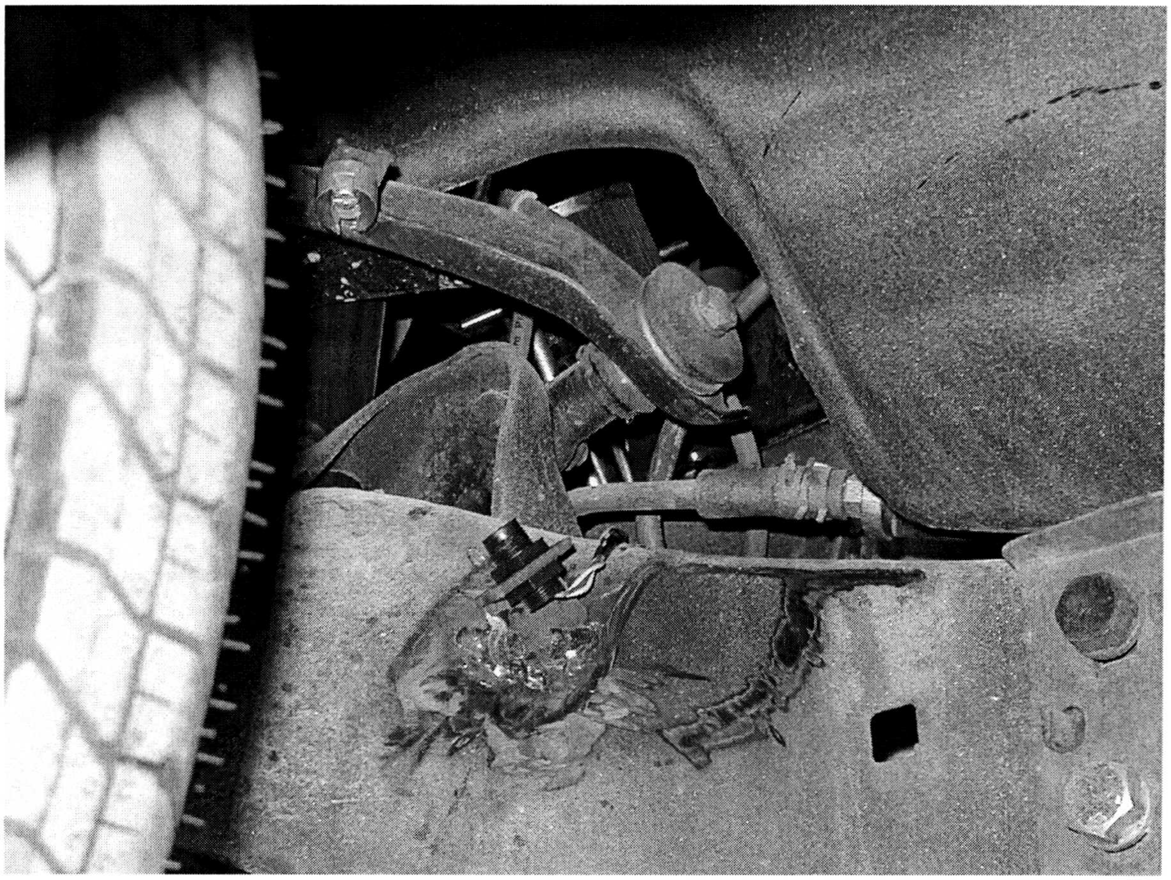
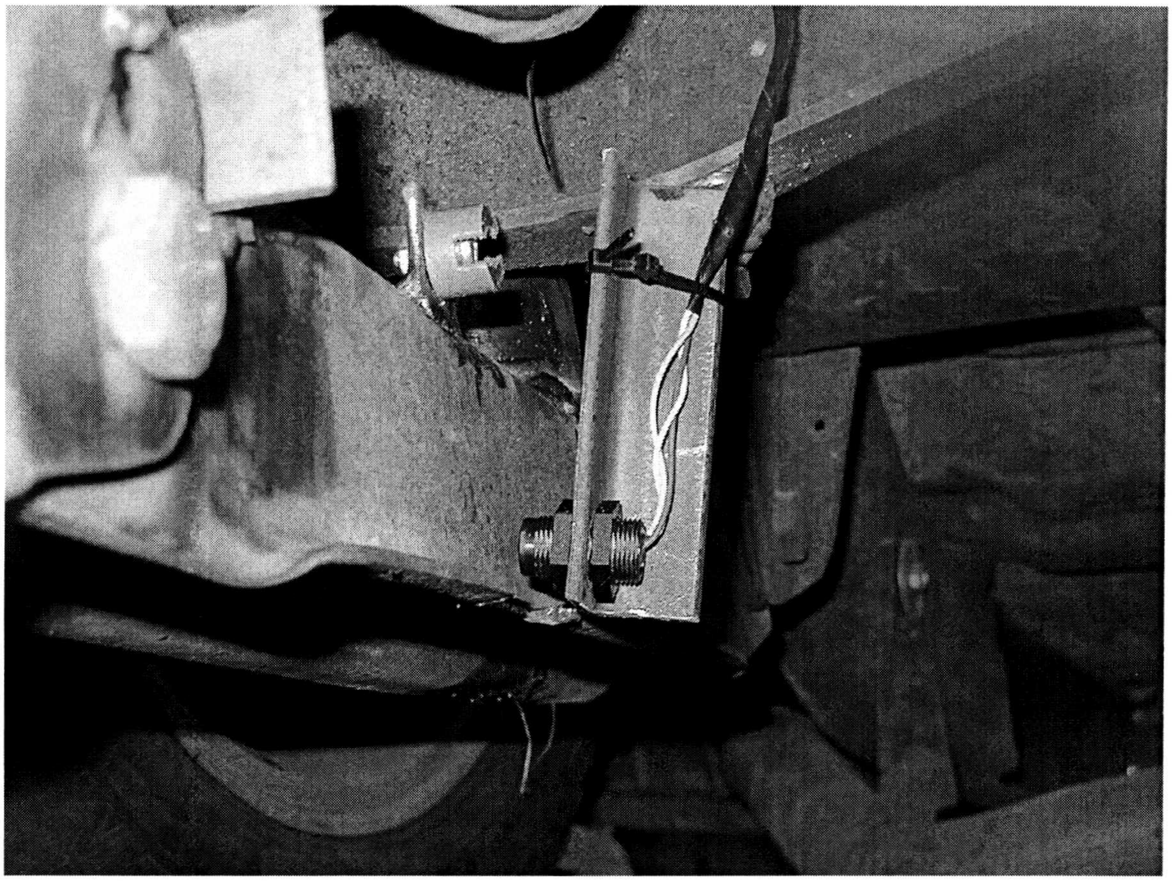


Photo. 10 Installed Rear Sensor



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