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Simulation analysis of anti-rollover mechanism for vehicles

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ABSTRACT

SIMULATION ANALYSIS OF ANTI-ROLLOVER MECHANISM FOR VEHICLES

by
Mohib L. Raid

Rollover accidents are considered the most significant safety problems for all classes of light vehicles, especially pickups, *Sport Utility Vehicles* (SUV), *Light Truck Vehicle* (LTV) and vans. The main objective of the research is the design of a new mechanism able to keep the vehicle stable under various road conditions and high speeds, to prevent the vehicle from rolling over and to maintain the stability for the vehicle by creating an anti-rolling torque on the vehicle body capable of turning the vehicle smoothly to stable position.

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by
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APPROVAL PAGE

SIMULATION ANALYSIS OF ANTI-ROLLOVER MECHANISM FOR VEHICLES

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- "A hydromatic device to prevent the elevator from sudden drops in cases of lifts malfunctions." Patent application No: 96100946, Academy of Science and Technology of Egypt, October 24, 1996.

- "An automatic lathe" Patent application No: 5050442, Academy of Science and Technology of Egypt, May 31, 1995.

- "An automatic floor sweeping machine" Patent application No: 95050440, Academy of Science and Technology of Egypt, May 31, 1995.

- "An improvement of petrol double-stroke internal-combustion engine". application Patent No: 920100034, Academy of Science and Technology of Egypt, January 19, 1992.

Dedicated to the memory of my mother Mrs. Amera Louis

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I thank for the Lord Jesus Christ who said " I will be with you all days and forever" and thank Him for keeping His promises.

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CHAPTER 1

PROBLEM DEFINITIONS

Rollover crashes are among the most significant of all safety problems for all classes of light vehicles, especially pickups, *Sport Utility Vehicles* (SUV), *Light Trucks Vehicle* (LTV) and vans. About 10,142 people were killed in light vehicle rollover crashes, which constitutes almost the quarter of 41,717 crash victims in USA, in 1999. This is problem for United States and possibility for entire world.

In most rollovers, the vehicle starts by leaving the roadway and then tipping. One cause of tipped rollover can be easily explained as an impact of a suitable tipping mechanism with sufficient lateral velocity

Figure 1.1 A rollover accident in Atlanta, April 2002.

During 1995-1999, 7 percent of light vehicle crashes involved rollover, but these crashes accounted for 31 percent of light vehicle occupant fatalities [Kratzke 2001]. The risk of death or injury is particularly high for passengers in a single vehicle rollover, which represent approximately 80 percent of light vehicle crashes [Garrott and Boyd, 2001]. During this period, an average of 19,000 people annually suffered severe injuries in such crashes [Garrott and Boyd ,2001]. The percentage of people killed classified by vehicle crash type is shown in Figure 1.2.

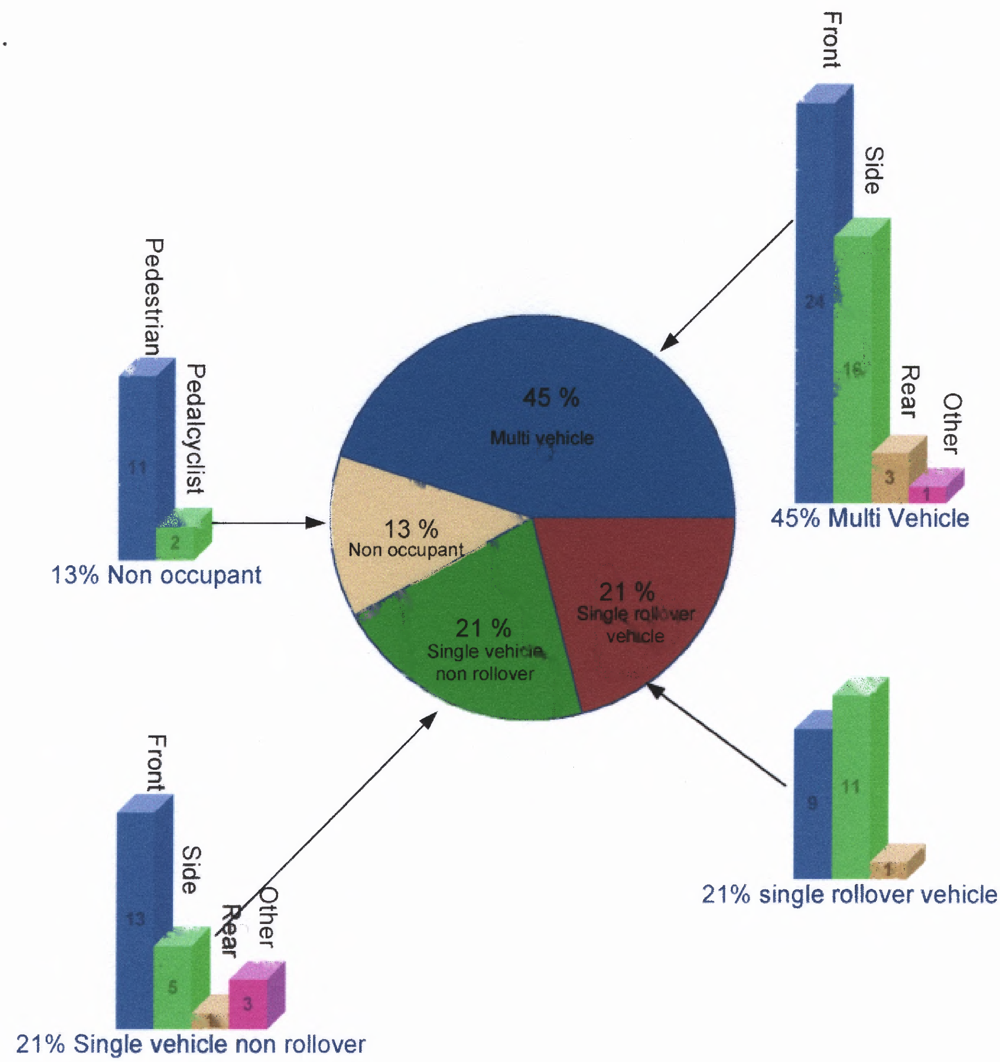


Figure 1.2 Persons Killed in 2000 by Crash Type [NHTSA, 1999].

- **Rollovers: Death, Brain Damage and Quadriplegia**

Roof failure is the most likely failure to cause death or permanent injury in cars and trucks. However, the roof is, without any doubt, the least crashworthy part of a vehicle. In fact, roofs are so soft that when tested by dropping it upside-down for a mere 12 inches, the result was a total crush that can cause death, permanent brain and spinal cord injuries.

Most rollovers occur due to tipping. SUVs, because of vehicle instability, will "tip" when a mild turning movement in one direction is followed by a quick correction in the opposite direction. The roll that follows causes the vehicle to be tossed and to land on its roof on the side opposite to the roll. That is why SUV drivers and passengers are twice as likely to be killed in a rollover as those in a standard vehicle.

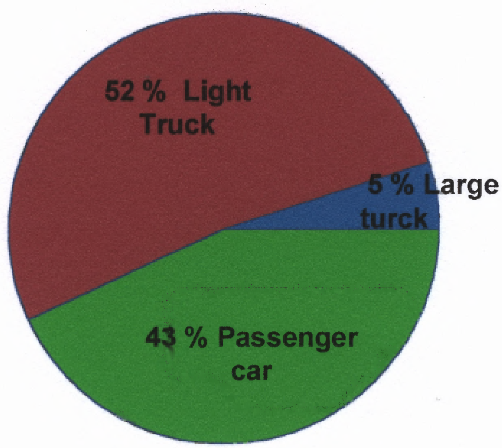


Figure 1.3 Single Vehicle Rollover Fatalities (NHTSA).
1999 annual report file & 2000 early assessment files

The rollover rate for passenger vehicles in injury crashes according to a *National Highway Traffic Safety Administration* (NHTSA) study is shown in Figure 1.4. As noted in the Washington D.C. report [Transportation Research Board, 2002]

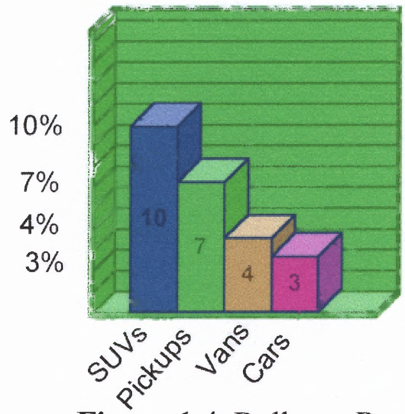


Figure 1.4 Rollover Rate for Passenger Vehicles in Injury Crashes [NHTSA, 1999].

Due to large number of SUV rollover cases, it is well know that SUVs are inherently unsafe when drivers engage in life-saving maneuvers. In fact NHTSA, plans to incorporate a new rollover rating of new cars and light trucks into its existing *New Car Assessment Program* (NCAP). Currently gives consumers are provided with crashworthiness ratings. These ratings are based on vehicle performance with respect to occupant injury criteria gathered in crash tests and are presented using scale of one to five stars, one star for the highest risk and five for the lowest. Table (1-1) shows a sample.

Table 1.1 Sample of Rollover Resistance Rating [NHTSA, 1999].

New Car Assessment Ratings Chart

Make & Modle	Rollover Resistance
TOYOTA COROLLA 4DR	★★★★
DODGE NEON 4DR	★★★★
CHEVROLET BLAZER 4DR 4X2	★
FORD EXPLORER (REAR)	★★
FORD EXPLORER (4X4) (XLT)	★★
GMC JIMMY	★

By using same star rating system to present the risk of rollover in the event of a single-vehicle crash, one star would represent a *Static Stability Factor* (SSF) corresponding to a 40 percent or greater risk of a single-vehicle crash resulting in rollover, and five stars would represent an SSF corresponding to a risk of less than 10 percent.

Five Stars	★★★★★	Has a risk of rollover of less than 10 percent
Four Stars	★★★★	Has a risk of rollover between 10 percent and 20 percent
Three Stars	★★★	Has a risk of rollover between 20 percent and 30 percent
Two Stars	★★	Has a risk of rollover between 30 percent and 40 percent
One Star	★	Has a risk of rollover greater than 40 percent

Static Stability Factor is one-half the track width of a vehicle divided by the height of its center of gravity. As part of the rating based on SSF, the agency also has to consider vehicles that are equipped with "electronic stability control" technology, which may reduce the risk of a vehicle getting into an incipient rollover situation.

CHAPTER 2

LITERATURE REVIEW

During the 1960s, increased safety awareness of crashworthiness, seat belt restraint systems, headrests, and gas tank safety, safety engineers focused on protecting the passenger compartment to increase survivability by balancing the interplay of controlled crush and occupant restraint. Different methods and techniques published in the literature and their limitations are described in this chapter.

2.1 Field Techniques to Reduce Rollover Fatalities

The New Car Assessment Program NCAP rates the risk of rollover in the event of a single-vehicle crash. Most of these single-vehicle crashes involve hitting a curb or running off the road accidentally and encountering soft soil, a ditch or something that tips the vehicle. NCAP adopts the following techniques.

2.1.1 Stiffening Roof Supports

Even though it is well known that roofs are extraordinarily soft, even belted passengers are at great risk for serious injury in a rollover, and the greater the roof crush the more severe the injury, the government has never mandated a dynamic roof crush test. Even U. S. Government safety consultants have reported that a "roof has to be strong enough to resist severe compression when the car rolls over. [NHTSA DOT HS 807 849, 1989]

Materials perform differently when subjected to dynamic forces found in a real world collision. But the government's static test standard ignores this longstanding and well-known engineering fact.

Because making roofs stronger increases the weight of vehicles decreases the number of "miles per gallon" and increases vehicle cost, *Original Equipment Manufacturers* (OEM) refuse to strengthen roofs. Instead, OEMs defend roof failure claims by arguing that high speeds and impacts are responsible for deaths and injuries, not the amount of roof crush. This convenient argument plays on the simple argument that "speed kills" while the truth is that the rate of deceleration is the controlling factor. It is not how fast the user goes, but rather, how quickly the user can stop that is critical.

When 50 pounds are added to a vehicle and it will cost approximately $250, but could prevent 5,000 deaths and 5,000 spinal cord injuries a year [Friedman, et al, 1999]. OEMs have claimed that death, brain damage and spinal cord injuries are caused before the roof collapses into the passenger's headroom and that the victims are thrown into the roof by centrifugal force before the vehicle landed on its roof [NHTSA DOT HS 807 849, 1989].

2.1.2 Pillar Roll Bars Extending Across the Roof of the Vehicle

The roll the roof would not crush down to the level of the door handles and would provide passengers with a safety zone free from roof crush intrusion using pillar roll bars extending across the roof of the vehicle [NHTSA DOT HS 807 849, 1989].

2.1.3 Link-X Stability System

The patented Link-X Stability System (Link-X) is a simple, elegant OEM-installed suspension [J. Todd Wagner, 2002]. By inverting the loads; stabilizing the roll center and rotating the line of intersection, the Link-X system controls the vehicle body. Thus the vehicle is less dependent upon springs and shocks for body control, allowing those to be tuned for desired ride quality. It improves rollover safety by improving emergency handling capabilities and reducing rolling velocity. Independent testing performed by an experienced professional driver at the Transportation Research Center (TRC, East Liberty, OH) indicated that a 2001 Ford Expedition (Baseline) could traverse a double-lane-change (or "Moose" test) at 57.20 MPH. The 1999 Link-X Expedition (Prototype) negotiated the same course at 62.05 MPH. Through the same course at same speed, the Baseline displayed a rolling velocity of 32 degrees per second. The Link-X Prototype showed 19 degrees per second; thus, 40% less rolling velocity than the Baseline. Moreover, Link-X is compatible with and a compliment to active shock. The improvement in double-lane-change test speed translates into enhanced handling during everyday driving as well as during emergency maneuvers. This is accomplished by keeping the tires more upright during cornering (90- 100% camber compensation) and eliminating anti-roll bars.

The key design of the 1997 Chevrolet Corvette is that Link-X inverts the overturning moment at each tire and applies the inverted moment to the chassis [SAE 1997]. Changing the vertical distances, between the attachments points on the chassis or the spindle, changes the amount of anti-roll generated. Additionally, Link-X yields a high and very stable roll center. Anti-dive and anti-squat are created by shifting the line of intersection of the control arms towards the vehicle's center of gravity.

2.1.4 RollGard Suspension Stabilizer

RollGard Suspension Stabilizer [Amtech Corporation, 2002], produces anti-sway around turns and curves while allowing greater steering control and overall vehicle stability. By maintaining the wheels to the ground, RollGard dramatically reduces the risk of rollover. RollGard extends the life of the shocks absorbers, reduces tire wear and improves braking performance. Independent tests prove RollGard effectiveness. Karco Engineering Automotive Research Center in Adelanto, California tested RollGard using out riggers. According to Peter E. Bryant, Society of Automotive Engineers, use of RollGard Suspension Stabilizer provides a significant improvement in vehicle handling.

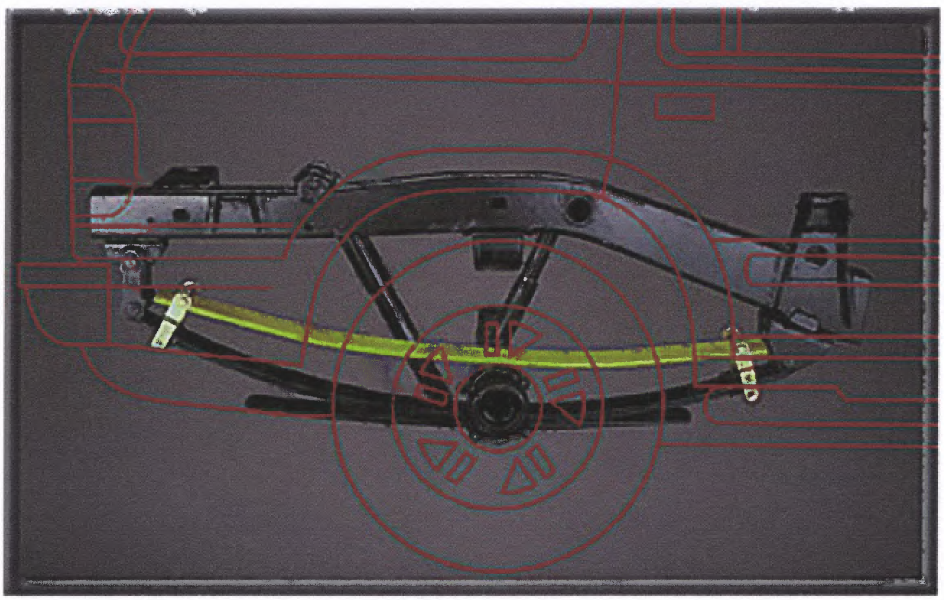


Figure 2.1 RollGard Suspension Stabilizers.

Best of all, RollGard is easy to install and can be done in less than 30 minutes with a C-clamp, jack and crescent wrenches. More than an "overload" or "helper spring", the

RollGard system enhances the overall suspension performance of customer vehicle. RollGard consists of a pair of leaf springs that easily attach to a vehicle's existing rear leaf spring system by means of two simple shackles connected to its ends. They act in unison with the vehicle's spring system to keep the vehicle's body stabilized and level.

2.1.5 Mechanism Solution to Rollover Problem

Previous methods have not had any practical action to prevent or trim down the number of rollover accidents; ESC is the first mechanism intended to prevent rollover accidents [Washington D.C: Transportation Research Board, 2002].

2.1.5.1 Electronic Stability Control ESC: Most rollovers occur when a vehicle runs off the road and strikes a curb, soft shoulder, guard rail or other object that "tips" it. The Rollover Resistance Ratings estimate the risk of rollover in event of a single vehicle crash, usually when the vehicle runs off the road Electronic Stability Control (which is offered under various trade names) is designed to assist drivers in maintaining control of their vehicles during extreme steering maneuvers.

Electronic Stability Control senses when a vehicle is starting to spin out (over steer) or plow out (under steer), and it turns the vehicle to the appropriate heading by automatically applying the brake at one or more wheels. Some systems also automatically slow the vehicle with further brake and throttle intervention. What makes *Electronic Stability Control* (ESC) promising is the possibility that with its aid many drivers will avoid running off the road and having a single vehicle crash in first place. However, ESC cannot keep a vehicle on the road if its speed is simply too great for the available traction and the maneuver the driver is attempting or if road departure is a result of driver inattention. In these cases, a single vehicle crash will happen, and the Rollover Resistance Rating will apply as it does to all vehicles in the event of a single vehicle crash.

2.1.5.2 ESC Highlights: [Washington D.C: Transportation Research Board, 2002], objected the decision use of SSF to Rate Rollover Resistance because the ratings would not reward manufacturers for equipping vehicles with Electronic Stability Control (ESC). It was also dissatisfied with language in the notice promising consumer information about ESC as part of the rating presentation, after there was some evidence of its effectiveness. BMW, Toyota, Isuzu, Tenneco and the Alliance. All expressed confidence that ESC technology would reduce the number of on-road loss-of-control situations that often result in off-road tipped rollovers. The Alliance suggested that ESC may also reduce the risk of untipped rollover, and Continental believes that it may help drivers regain control after they leave the roadway. Many commented that ratings based on SSF would stifle and undercut advanced vehicle technology. The notice specifically asked commentator to share any data they may have on the effectiveness of stability control technologies in preventing single-vehicle crashes, but none unfortunately did so.

2.1.5.3 Why ESC is Significant? The NCAP program rates the risk of rollover in the event of a single-vehicle crash. Most of these single-vehicle crashes involve hitting a curb or running off the road accidentally and encountering soft soil, a ditch or something that tips the vehicle. To repeat, 95 percent of rollovers are tipped. Once a vehicle is in this situation and strikes a tipping mechanism, its chances of rolling over depends heavily on its SSF.

The promise of ESC is not that it can change what happens when a vehicle hits a tipping mechanism but that it may help the driver to avoid going off the roadway in the first place. ESC can apply one or more brakes automatically to keep the yaw rate of the vehicle proportional to its speed and lateral acceleration. Essentially, it corrects for vehicle under steer or over steer, and some systems may override a driver's failure to brake when in fear of losing control. This benefit could minimize the driver's chances of compounding driving errors in a panic situation. However, it cannot keep a vehicle from leaving the roadway if the vehicle is going too fast for the maneuver the driver is attempting.

2.5.1.4 Shortcomings of Present Rating: Like frontal and side NCAP ratings, the Rollover Resistance Rating is concerned with vehicle attributes that affect the outcome of a crash. None of the present ratings attempt to describe the probability of a vehicle's involvement in a crash. For example, the frontal crashworthiness star rating does not reward manufacturers who equip vehicles with advanced braking systems. Also, the agency cannot rely on skid pad demonstrations to determine the effectiveness of a safety device in the hands of the public. Anti-lock brakes were once considered likely to reduce rollover crashes because they had the potential to reduce the number of vehicles exiting the road sideways as a result of rear brake lock-up. This expectation has not been realized in passenger cars according to years of crash statistics. There has actually been an increase in the rollover rate of passenger cars equipped with anti-lock brakes that researchers have not yet been able to explain.

The commentator suggest that NHTSA should abandon *Static Stability Factor* (SSF) as a basis for rollover rating because it does not reward ESC in the star rating and that without such a reward the use of the technology would be in doubt. The importance of SSF to rollover resistance is supported by abundant real-world evidence, while there is no data on the effectiveness of ESC. Based on the relative data available, it would not be appropriate to abandon SSF. The commentators encourage manufacturers to assist us in determining the effectiveness of ESC by identifying optional ESC systems by VIN codes and sharing available data. The commentators will continually monitor data on the real-world effectiveness of ESC and make appropriate changes based on that data. The commentators do not expect that manufacturers will abandon ESC, since they express so much confidence in its ultimate effectiveness.

NHTSA wants to encourage technological applications that enhance vehicle stability, provide drivers with more control of their vehicle, and help prevent rollover and other crashes. For ESC in particular, it is reasonable to assume that it will help some drivers use the available traction to stay on the road in circumstances that would otherwise result in panic-driven errors and roadway departure. The commentators have asked the National Academy of Sciences to recommend ways of combining the effect of ESC on exposure to single-vehicle crashes, with the effect of *Static Stability Factor* (SSF) on rollover resistance in a single-vehicle crash, as part of its Congressionally-mandated study of rollover consumer information. The commentators do not expect that a recommendation can be implemented without some determination of ESC's real-world effectiveness, but in the meantime The commentators will identify the vehicles for which ESC is available and provide an explanation of these systems. The identification of

Vehicles with ESC was first identified in the December 2000 issue of Buying a Safer Car. The April 2001.

2.2 Public Awareness

2.2.1 Consumer Information on the Rollover Risk

Congress requested a study National Academy of Sciences [Washington D.C., 1994] on the communication of vehicle safety information to consumer and required NHTSA to review the results of that study before issuing a final rule on vehicle rollover labeling, [Shopping for Safety, TRB 1996]. NHTSA has concluded that consumer information on the rollover risk of passenger cars, light multipurpose passenger vehicles and trucks will reduce the number of rollover crashes and the number of injuries and fatalities from rollover crashes [NHTSA, 1999].

This information will enable prospective purchasers to make choices about new vehicles based on differences in rollover risk and serve as a market incentive to manufacturers in striving to design their vehicles with greater rollover resistance. The consumer information program will also inform drivers, especially those who choose vehicles with poorer rollover resistance, that their risk of harm can be greatly reduced with seat belt use to avoid ejection.

Alternative Programs for Rollover Consumer Information:

The Request For Comment (RFC) presented ideas for consumer information programs to be used in place of the agency's proposal to use SSF to rate vehicles. The Alliance had four suggestions:

1 Cause drivers to obey the speed limits

2 Be alert and unimpaired

3 Use proper restraints

4 Provide driver training in off-road recovery and crash avoidance maneuvering.

Figure 2.2 Speed Limits in Some Roads.

Every vehicle has different dimensions and weights so the speed limit may not be applicable to all kinds of vehicle.

It is also hard to get a respect from drivers, Crashes on curves that kill people and destroy SUV's and buses result from excessive speed often when rain or snow has made the road slippery. Every banked curve has safe design speed, see Figure 2.2, in good weather the posted speed is safe for a regular vehicle, but it may be too high for many SUV's and buses with good traction. Otherwise if they rollover due to poor traction, they might slide off the curve. Recommendations for addressing this problem include:

- Improve the roadways with paved shoulders to eliminate road edge drop-offs and provide road edge rumble strips to help alert drivers.
- Promote Electronic Stability Control.

- Promote crashworthiness improvements including active restraint systems, tubular and side curtain air bags, new belt reminder systems, structural crashworthiness improvements, FMVSS 201 interior protection, new locks and latches and alternative glazing.

Ford and Suzuki commented that *Static Stability Factor* (SSF) should be used only to rate vehicle classes and should not be used to show distinctions between make/models in the same class. These comments also believed that the program should not present the risk of rollover quantitatively

The NCAP recommended that NHTSA [Washington D.C., 2002] put more emphasis on the seat belt message in the context of rollover, including child safety restraints and suggested that manufacturers include in their vehicles' owners manuals material about (crash avoidance) driving practices. The manufacturers' association, the Alliance, on the other hand, wanted to see seat belt information only in a general sense, not specifically referring to rollover.

The major flaw with all of these suggestions is that they do not deliver what the consumer wants - definitive, comparative, information about the relative risk of rollover in specific vehicles. It has shown, in previous sections of this notice and the proceeding notices, that there is link rollover risk to the *Static Stability Factor* (SSF) of specific make/models. Any rollover-specific consumer information product that NHTSA develops in the future will mention driving habits that contribute to rollover prevention and emphasize the importance of seat belt use. However, the focus of the present action is on allowing consumers to make an informed choice about the safety of the vehicles they purchase, both by class and by model.

2.2.2 Recommendations after Determining Rollover Factors

[Shopping for Safety, TRB, 1996] SUV can be Dangerous when the vehicle is essentially empty, where the center of gravity is as low as it can be. If a vehicle is fully loaded for a vacation, with six people riding in it, the effective center of gravity of the vehicle actually rises. Seated up on the seats, a human's weight would have a "personal center-of-gravity" The effect is to RAISE the net center-of-gravity of the vehicle. A few hundred pounds of luggage up on top of the roof luggage carrier similarly greatly raises the effective center-of-gravity of the vehicle. These things each make the vehicle even unstable.

Once a rollover has begun, the geometry actually gets even more complicated, involving the dynamic rotational inertia of the vehicle and the fact that the less the effective weight of the vehicle becomes, the worse the problem gets as the rollover proceeds. These complicating effects all act to make the rollover effect even worse.

- Some vehicles tend to have very harsh suspensions, and so the "ride" is very rough. Manufacturers chose to give a recommendation of an unusually low air pressure for the tires of such vehicles, in order to create a smoother ride. The many deaths caused by accidents of their vehicles in association with brand name tires, were directly related to this, for at least two very clear reasons. [Garrott and Boyd ,2001].

- First since the tires had such low pressure, they have a tendency to "roll" (distort) more due to the centrifugal force exerting a side force on the tire treads in causing the vehicle to turn. The low pressure actually allows the tread portion of the tire to shift inward sideways a fraction of an inch, relative to the rim of the wheel. This act to LOWER the wheels a substantial amount.

This effect both tilts the vehicle sideways and changes the basic geometry of these calculations above, resulting in greatly increasing the vertical lifting force on the vehicle due to a specific centrifugal force.

This greatly increases the rollover danger. That aspect has nothing to do with any inherent flaws in the tires, but in the extremely poor engineering advice involved in recommending low tire inflation pressures for vehicles that were so unstable to begin with.

- Second each time a tire rotates; its sidewalls have to bend/deform as that part in contact with the road, must briefly support the weight of the vehicle.

This causes the sidewalls of the tire to flex every single revolution. This flexing ALWAYS creates frictional heat within the sidewalls of the tires. When the tire pressure is low, this flexing is greatly exaggerated, resulting in much more internal heating of the sidewalls of the tires. This is why a tire that is extremely low on air pressure quickly blows out, because the sidewalls flex so much that they overheat and then fail, permitting the internal pressure of the tire to suddenly burst out.

- When tires have abnormally low air pressure in them, on long trips of high-speed highway driving, they are especially susceptible to the sidewalls overheating in this way. For this reason, it is arguably understandable that many tires failed and caused terrible accidents on those Ford vehicles and on all other SUV vehicles that recommend low tire pressures. This is actually an effect whether the vehicle is traveling straight or turning. If a particular tire had even a hint of a problem on its own, that situation would ensure that it would fail. So, whether or not the Firestone tires had any drastic flaw, even if they have a tiny additional inclination of a flaw as compared to other brands, the effect would have been tremendously magnified by the circumstances of the low recommended tire air pressures in those vehicles. The natural instability of the high center-of-gravity vehicles added to the problem, to cause the many rollovers once the vehicle got turned a little sideways.

- The Request For Comment (RFC) was published June 1, 2000. The comment period closed August 30, 2000. Twenty-five commentators replied. The respondents were vehicle manufacturers and their associations, testing laboratories, independent researchers, consumer safety groups, an insurance association, a trial attorney, and two consumers. Two commentators agreed with the inclusion of rollover rating in NCAP as it was presented in the RFC. The other commentators were divided among those who opposed the plan (manufacturers, dealers, testing labs) and those who thought it did not go far enough; that a minimum standard, based on a dynamic test, is needed for rollover (trial attorney, consumer groups). The commentators raised issues in four areas:

- The suitability of SSF as a measure of rollover risk.
- Whether NHTSA statistical analysis-linking SSF to single-vehicle rollover rates was correct.
- Whether consumers are capable of understanding the concept of single-vehicle crash as exposure to rollover.
- The need for a minimum standard, or consumer information, for rollover based on a dynamic test.

Alternative consumer information programs were offered for rollover prevention. Those four issues and the alternative programs are discussed in this section. SSF as measure of rollover risk many respondents to the RFC believe that SSF is not a good measure of rollover risk for various reasons:

- NHTSA has exaggerated the importance of SSF in rollover crashes. Vehicles have little to do with rollover; the driver and road conditions bear so much of the blame that the vehicles should not be rated for rollover. The Alliance of Automobile Manufacturers (Alliance), Association of Import Automobile Manufacturers (AIAM), Isuzu
- SSF is too simplistic. SSF ignores tire properties, suspension compliance, handling characteristics, antilock brakes, electronic stability control, vehicle shape and structure (post-impact rollover), and tipping factors (tires). - Alliance, University of Michigan Transportation Research Institute, JCW Consulting, SiSan, Automotive Testing Inc., Toyota, Isuzu, Honda.

2.2.3 Origin of Static Stability Factor

Static Stability Factor is not a measure of rollover resistance invented by the agency. Vehicle manufacturers introduced it to the agency in 1973 as a scientifically valid potential substitute for the dynamic maneuver tests the agency wanted to develop regarding not tipped on-road rollover. The Motor Vehicle Manufacturers Association (which has evolved into the present Alliance of Automobile Manufacturers) stated the following about SSF, "Although this method does not embrace all vehicle factors relating to rollover resistance, it does involve the basic parameters of influencing resistance."

In 1973, all of the manufacturers opposed NHTSA plans for a standard regarding rollover prevention in extreme accident avoidance maneuvers because of their expectation of negligible benefits, concerns about banning vehicle types, degradation of vehicle capabilities including braking traction and handling performance, and unresolved problems with maneuver testing.

General Motors presented a very detailed set of comments that remain relevant today. For example, its observations on the effect of restraint use on rollover fatality rates and on the breakdown of the rollover problem between multi-vehicle and single-vehicle crashes and on-road and off-road incidences are largely supported by present data. Likewise, its discussion of the problems of maintaining consistent pavement surface and tire traction properties, the use of automatic controls and outriggers, the types of maneuvers and their relationship to real crashes is still meaningful. The comments regarding SSF (which it called geometric stability measurement) are still accurate.

General Motors announced the following:

- Resistance to rollover is mainly influenced by the following factors:

    1. Height of the center of gravity.

    2. Horizontal distance from center of gravity to wheel track.

    3. Capability for generating large forces in the lateral

    4.Direction of the tire contacts due to high tire friction.

- Lateral forces sufficient for rollover can result from severe maneuvers under high tire-road friction conditions; from collisions with other vehicles, curbs, or road furniture (signs, lamp posts, guard rails), and from maneuvers in roadside soil capable of sustaining high lateral forces.

General Motors qualified the discussion as pertaining to relatively simple maneuvers, but cautioned against the use of "special" braking and steering inputs for rollover maneuver tests as unrepresentative of vehicle operation. It also discussed the relative importance of secondary vehicle characteristics other than those above which are the components of SSF.

This comment was made before the NCAP program was established to provide consumer information on safety performance and before the consumer was faced with such a large range of geometric stability (SSF) in non-commercial passenger vehicles. Also, most of the practical difficulties in seeking objective, relevant and repeatable driving maneuver tests discussed by General Motors in 1973 remain unsolved. Note that GM suggested the static laboratory measurement as a substitute for maneuver tests when only on-road untripped rollover was under consideration. This is an even stronger endorsement of static measurements than that represented by NHTSA reasons for using SSF for consumer information on all single-vehicle rollovers, tipped and untipped.

The rollover safety problem divides into 95 percent a problem of tripped rollover and five percent a problem of on-road untripped rollover. Maneuver tests do not represent tipped rollover. Once the vehicle is in a tipping situation (e.g., has left the road), tire traction is largely irrelevant to tipped rollover. Center of gravity height and track width (and to a much lesser extent roll moment of inertia) are the only vehicle properties with general applicability to tipped rollover situations. So, in 95 percent of rollovers, these vehicle properties would be the most relevant vehicle influences on the likelihood of rollover. In the five percent of the problem involving untipped rollover, a choice exists between using static measurements and performance in maneuver tests. To get data to make an informed choice between the two, NHTSA conducted a maneuver test program using 12 vehicles in 1998. That testing confirmed General Motors' opinion of 25 years earlier that the static measurements correspond well to dynamic maneuver tests. It also confirmed that the problems with maneuver testing identified by GM in 1973 are still largely unresolved today. Accordingly, it's concluded in June 2000 that there were no practical improvements in rating overall rollover resistance to be gained at this time by using something other than static measurements.

2.3 Latest Design Techniques for Suspension Systems

The purpose of this research, is the development of a new suspension system mechanism, the following is the description of the latest developed techniques in suspension systems. It also demonstrates the significant difference between the existing suspension mechanisms and the proposed mechanism developed in the research.

2.3.1 Porsche First SUV Target USA

News Europe Magazine has headline news about Porsche] the first development suspension system has received some attention from a few automotive companies and all these companies focused on how one can make adjustments to the suspension system based on the terrain, they have not proposed research on dynamic balance adjustment

SUV target USA. The Cayenne gets many unique features that are firsts for Porsche:

- A pneumatic suspension changes height (six levels) based on terrain and speed

- Porsche Active suspension Management allows the driver to choose
  " comfort ", "normal" or "sports" suspension and acts on individual shocks to stabilize the vehicle.
- Porsche Traction Management varies distribution of power to front or rear wheels according to driving conditions.
- Porsche Traction System, with a flip of switch on the center console, helps the Cayenne adapt to off-road conditions.

2.3.2 Delphi Build on Strong Relationship with Ford Premier Automotive Group

The new Range Rover Delphi [PARIS SEP 24, 2002], presented the world's most sophisticated air strut module. The new technology is a key element in the independent air suspension system that helps give the vehicle its outstanding combination of on road and off road ability.

2.3.3 ABS Service Takes Care

Grand Marquis has air suspension; the electrical circuit to the system must be shut down before hoisting or jacking up the car by turning off the air suspension switch in the trunk. Failure to do this can result in unexpected inflation or deflation of the air spring.

[PARIS SEP 28, 2002]

2.3.4 Electronic Air Suspension System

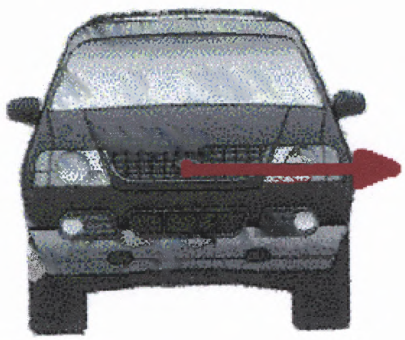
A fully independent electronic air suspension system keeps the passengers comfortable in their leather and wood wrapped cabin. Despite the car bulk the Range Rover suspension also "kneels" for access lowering the vehicle's ride height by 43 mm. For heavy duty off-road the suspension can also be raised. The Land Rover line up will be complete with the Freeland V6 including the luxury HSE Version, defender 90 and update Discovery, which mimics its bigger Rover in style Luxury. The new discovery has more than 700 changes better and more equipment. Brakes and suspension have both improved, and a center differential lock is now available [Show & Tell ,2002]

2.4 Limitations

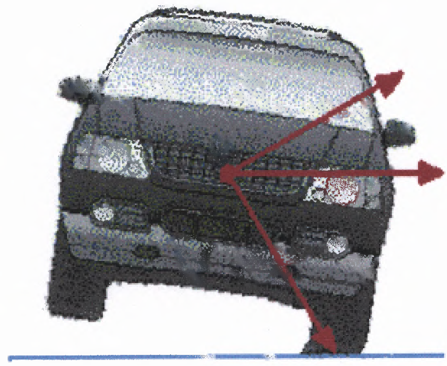
The studies are obviously focused on recommendations for both drivers and automotive companies. Some automotive companies had addressed rollover issues by design a new mechanisms, these mechanisms maintain to stability of the vehicle.

Apparent drawbacks in these mechanisms are present below:

- If a vehicle starts to tip over reducing engine speed and holding the brake does not make any differences in this situation and the vehicle will continue to roll over, even if the driver shuts down the engine and completely holds the brake, because the vehicle when being tip over the stable is going be worth and worth.
- While ESC has value in preventing vehicle from getting into situations (e.g., running off the road) that might eventually lead to a rollover, it is not necessarily of value in preventing an on road vehicle in the midst of fishhook-type turn from rolling over. ESC is not the miracle system some people contend it is. It is possible to spin out a vehicle that has ESC.
- When the vehicle beings tip over on two wheels the friction force has magnitude and direction. Two of the wheels have fraction and other will be in the air, from the equations the friction force F= 4 R before the vehicle tips over and F= 2 R after the vehicle tips. Many other feature different anti-rollover technologies hard to deal with this situation.



Before tip over



Start tipping over

These features was disapproved by many American and Japans automotive manufactures and all decided not to make these ideas applicable in the vehicle because the road requirements at this time were unknown and may be the deriver need speed to survive

CHAPTER 3

RESEARCH OBJECTIVES AND PROCEDURES

As illustrated in the literature review of previous studies, many researches failed to eliminate the rollover accidents. Therefore, the purpose of this research is to eliminate rollover accidents and maintain the vehicle stabilization for different roads shape and maximum speeds.

The proposed approach is to carry out new mechanism; the procedures to fulfill the required objective follow:

1. Framework of rollover using Newton's first law to get all impact factors that contributes to rollover.
2. Develop a mechanical design to stabilize the vehicle.
3. Design the mechanical parts using Pro/E software.
4. Design the control unit and model simulation using Lab View software.
5. Develop the relationship between different performance parameters.

CHAPTER 4

FRAMEWORK OF ROLLOVER MECHANISM

When a vehicle turns, Newton's first law indicates that it wants to go straight, so the tires must therefore create a lateral "centripetal force". This is entirely due to friction between the tires and the roadway. If the road is icy and slick, there is generally not a high enough "static frictional coefficient" to cause the force described here. The vehicle would then not roll over but slide straight, possibly having different problems! A rollover situation can only occur if there is enough friction between the tires and road to create sufficient centripetal force.

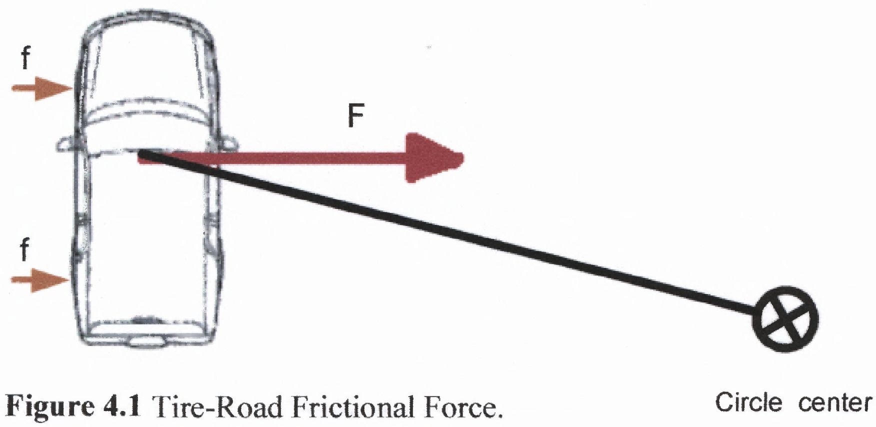


Figure 4.1 Tire-Road Frictional Force.

The tire-road frictional forces are shown as the red arrow to the right in Figure 4.1. That force, acting on the vehicle, is just the simple **F** = **ma**, expressed for a curved motion.

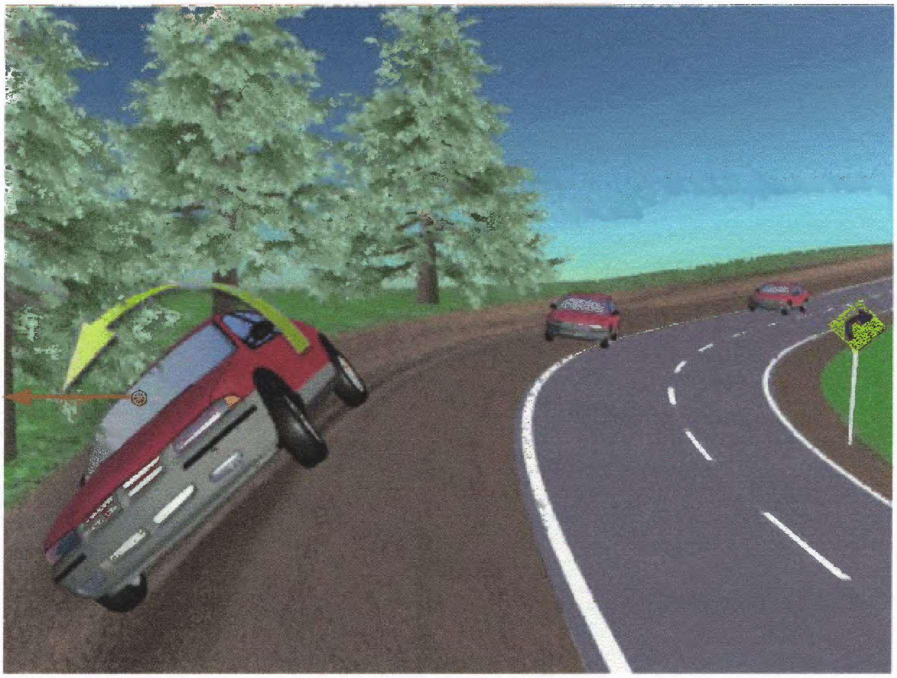


Figure 4.2 Centrifugal Forces.

The force due to the tire-road friction being to the right, often called centrifugal force that also exists to the left as shown in Figure 4.2. It is actually just the condition of the vehicle aiming to go straight (in accordance with Newton's Laws) and so this centrifugal force (to the left) is exactly equal in size with the centripetal force making the vehicle turn the corner.

When a vehicle turns, centrifugal force acts on the vehicle and tries to push it to the outside of the curve. The formula is:

Centrifugal Force = (mass) * $(\text{velocity})^2$/ radius of turn (4.1)

This shows that centrifugal force increases as the square of velocity increases. Also, at a given speed, small (tight) radius turns produce more force than large radius turns. Large amounts of centrifugal force require equally large amounts of counteracting force from the tires if the vehicle is to remain on the road. The tires can be thought of as strings from each end of the vehicle to the center of the turn. If the centrifugal force is higher than the tires can counteract, one or both of the strings break. The vehicle will then leave the turn.

The F = ma for a circular motion is in the form **F = (w * v^2)/(g * R).**

w = vehicle weight. **R**= curve radius.

V = velocity/speed. **G** = acceleration due to gravity

That version of Newton's Law is very straightforward regarding, the force that the tires traction must exert sideways on the vehicle to make it turn in the circle rather than going straight the way it would have normally wanted to go, this force acting at center-of-gravity. Since the vehicle is one solid object, it can be mathematically treated as though all of its weight is at that one point. Figure 3.3 the red spot that indicates the center-of-gravity.

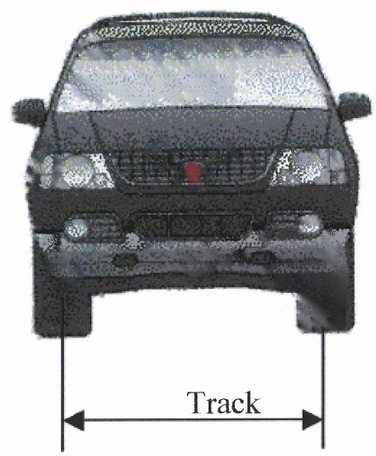


Figure 4.3 Shows the Center of Gravity.

This is the sideways force that has to be acting on the vehicle, in order for it to go around that-sized circle at that speed. The points where the tires contact the road, the distance between them is called the "track".

That center of gravity is also above the ground. For a fairly tall vehicle like an SUV, it can commonly be 30" (or more) above the ground. Vehicle manufacturers used to divulge the height of the center-of-gravity of their vehicles, but they no longer do. For the vehicle illustrated, the center-of-gravity is probably around 34" above the road surface. Rather than using that value, by use a more generous (and more stable) 30" height for our example calculations.

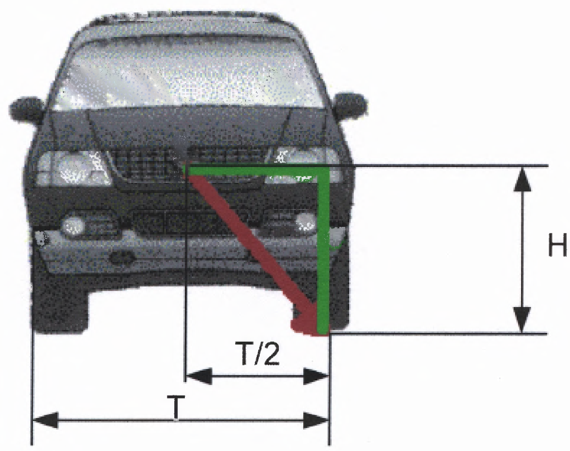


Figure 4.4 All Forces.

Figure 4.4 illustrates the force acting between the tire tread and the center-of-gravity of the vehicle (in red). This force is at an angle, which has a horizontal component (in green) proportional in length to half the track of the vehicle. It also has a vertical component that is exactly proportional to the height of the center-of-gravity above the roadway. The both of these distances, the angle at the CG (it has been calling (θ), between the H and T, is the angle whose TANGENT is equal to (T/2)/ (H) horizontally there

4.1 The Relationship Between the Vehicle Dimensions and Rollover

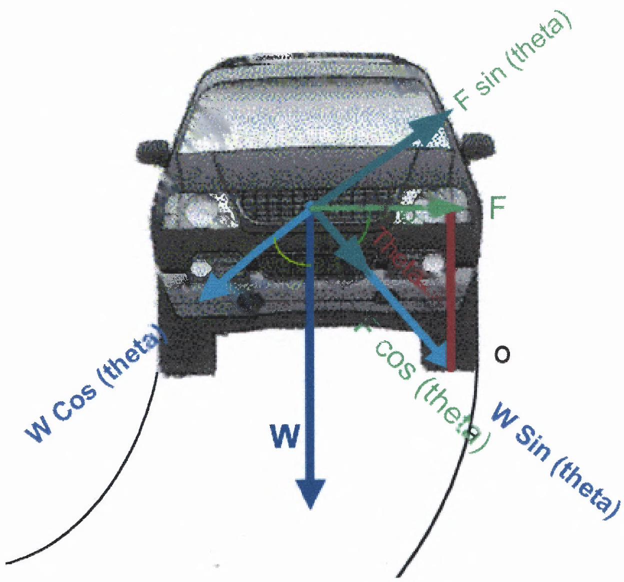


Figure 4.5 Analyses of Force Components.

There is a moment that is due to the weight of the vehicle, and that moment is a Vector aimed toward the W * r * cos (θ). The moment that is due to the centrifugal force is a Vector aimed toward the REAR of the vehicle of **F * r** which has a magnitude F * r * cos (90° - θ) or F * r * sin (θ). In the situation of being just about to roll over

Σ moments O =0

$$F * r * \cos(90° - \theta) = W * r * \cos(\theta) \quad (4.2)$$

Where r is the distance between the center-of-gravity and the tire tread

$$Fc * \sin(\theta) = W * \cos(\theta). \quad (4.3)$$

Where $Fc = mV^2/R$ (4.4)

$$mV^2/R \ \sin(\theta) = W * \cos(\theta). \quad (4.5)$$

$$F * \sin(\theta) / \cos(\theta) = W \quad (4.6)$$

$$mV^2 * \tan(\theta) = W * R \quad (4.7)$$

The equations above shows the relationship between **θ and V.**

$F_c * \sin(\theta) = F_{unknown}$ in Figure 4.5, upward angled force gets a leverage advantage around the tire tread, and so it is able to have a lifting effect greater than its own strength, actually, equal to its strength divided by the cosine of (θ). If the vehicle is about to roll over, this lifting effect must be equal to the weight of the vehicle. $F_{unknown}$ therefore equals Weight * cos (θ), {or Weight = $F_{unknown}$ / cos (θ)}.

The force $F_{unknown}$ is equal to the centrifugal force times the sine of the angle barely rolling over, We find that $F_{centrifugal} * \sin(\theta) = Weight * \cos(\theta)$.

The cos (θ) can never be more than 1.00, so this means that its leveraged effect is always greater than its true force.

Writing this differently, now that the actual upward lifting force on the vehicle is equal to the centrifugal force times the sine/cosine or the tangent of the (θ) angle we have been describing.

For a rollover to begin to occur,

$$mV^2 * \tan(\theta) > Weight * R \quad (4.7)$$

From equations above its illustrated θ is significant factor to stabilize the vehicle.

In Figure 4.6, Rollover Stability Chart, an easy chart to determine if any vehicle is safe or not by simply

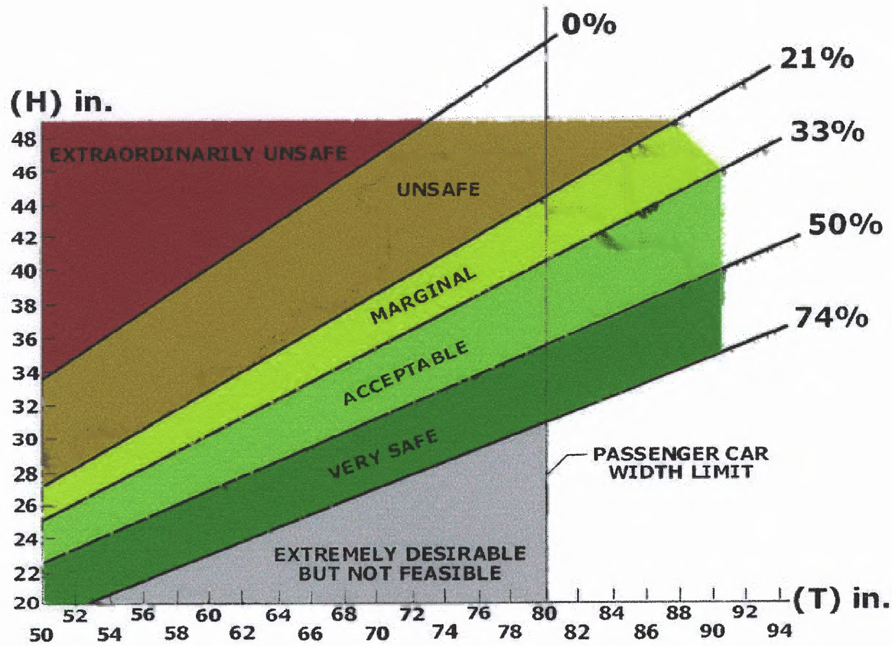


Figure 4.6 Rollover Stability Chart [six bullets Inc manufacturer, 2002].

Plotting the two variables, H and T on the Cartesian coordinates and read out the safety factor directly. No calculations are necessary.

4.2 The Equilibrium Equations for Vehicle that has Anti-Rollover Mechanism.

Figure 4.7 illustrates all forces within the vehicle before starting rollover in right hand side that drive to neglecting the reaction force in left hand side N_L, the centrifugal force F_C is able to sliding the vehicle in right hand side, the additional balance force required comes from friction $\mathcal{F}$.

P the force come from anti-rollover mechanism by other hand this force come from special suspension which immediately creates an anti-rolling torque on the vehicle body even though the body is leaning slightly to the right and also which is responsible to make rollover angle Φ

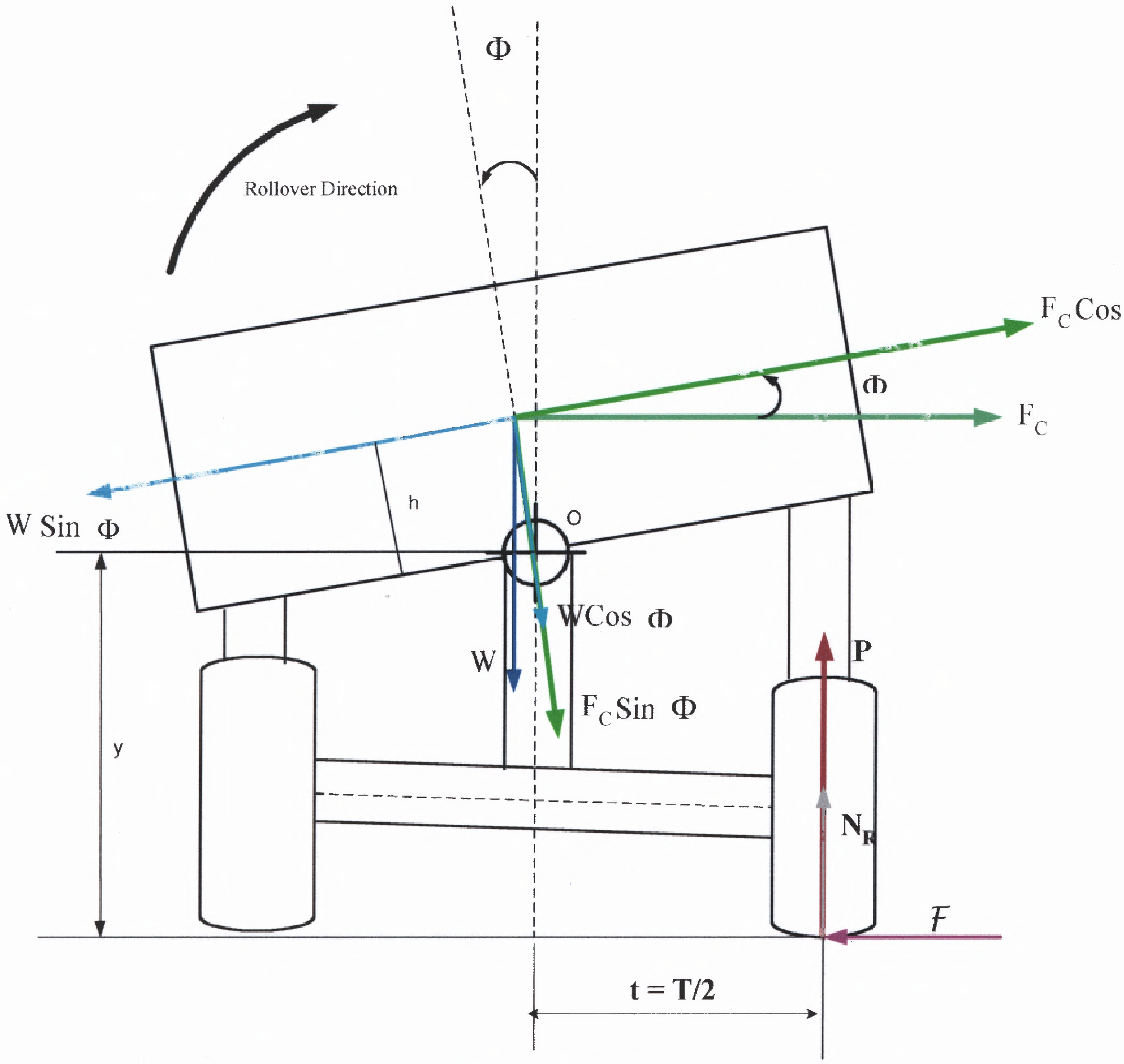


Figure 4-7 The Relationship between all Forces When the Rollover Start Act the Vehicle.

Equilibrium equations before anti-rollover mechanism acting

$$P = W \tag{4.8}$$

$$N_R = W \tag{4.9}$$

Equilibrium equations at anti-rollover mechanism acting

The $\sum$ moment O

$$N_R * t - f\,y - F_C \cos \Phi\, h + W \sin \Phi\, h = 0 \tag{4.10}$$

$$W * t - f\,y - F_C \cos \Phi\, h + W \sin \Phi\, h = 0 \tag{4.11}$$

$$f = \eta\, W \tag{4.12}$$

Where η coefficient of friction

Φ the required angle to keep the balance of the vehicle may this angle come from the anti- rollover mechanism

CHAPTER 5

PROPOSED METHODOLOGY

Using anti-rollover mechanism "Electro Hydromatic system" that has special suspension attack immediately by creating an anti-rolling torque on the vehicle body enough to leaning the vehicle slightly to stabile position.

5.1 The Anti-Rollover (Electro Hydromatic) Balance Structure.

The electro hydromatic system consists of three units

1. Mechanical Unit (MU).
2. Electronic Unit (EU).
3. Hydraulic Unit (HU).

All units are homogeneous and work together in sequence, as shows in Figure 5.1, in order to maintain the stability of vehicle on the road, which is denoted by the red arrow.

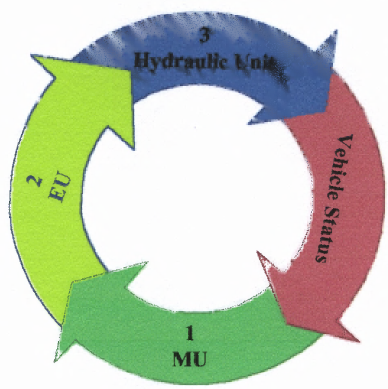


Figure 5.1 System is Working Cycle.

Where MU and HU are indicators, EU controller and Vehicle status is resulting of working three units together

5.2 CAD Software

Using software Pro/ENGINEER to design the technical parts and assembly, the Pro/ENGINEER [PTC Manual, 2002]. Actually Pro/Engineering is a suite of programs that are used in the design, analysis, and manufacturing of a virtually unlimited range of products Pro/E deals only with the major front-end module used for part and assembly design and model creation, and production of engineering drawings. There are wide ranges of additional modules available to handle tasks ranging from sheet metal operations, piping layout, and mold design, wiring harness design, NC machining, and other functions. An add-on package

5.2.1 Feature-Based

Create mechanical parts and assemblies by defining features like extrusions, sweeps, cuts, holes, slots, rounds, and so on, instead of specifying low-level geometry like lines, arcs, and circles. The designer can specify features and attributes of elements such as reference planes or surfaces, direction of creation, pattern parameters, shape, and dimensions.

5.2.2 Parametric

The physical shape of the part or assembly is driven by the values assigned to the attributes (primarily dimensions) of its features. The user may define or modify a feature's dimensions or other attributes at any time (within limits!). Any changes will automatically propagate through the model. Also the designer can relate the attributes of one feature to another. For example, if the user has design intent such that a hole be centered on a block, the user can relate the dimensional location of the hole to the block dimensions using a numeric formula; if the block dimensions change, the centered hole position will be re-Could the user machine shop make this? The 3-Pronged Blivot A Non-realizable Object computed automatically.

5.2.3 Solid Modeling

The developed computer model contains all "information" that a real solid object would have; such as volume, mass and inertia (if density of the material is provided). Unlike a surface model, if the user makes a hole or cut in a solid model, a new surface is automatically created and the model "knows" which side of this surface is solid material. The most useful thing about solid modeling is that it is impossible to create a computer model that is ambiguous or physically non-realizable. With solid modeling the user should not create a "model" that could not physically exist.

Pro/E will let the user make this model, but concerns of manufacturability are up to the designer. An important aspect of feature-based modeling in Pro/E is the concept of parent/child relationships. A child feature is one that references a previously created parent feature. For example, the surface of a block might be used as a reference plane to create a slot. A change to the parent feature will potentially affect the child. For example, deleting a parent feature will delete all its children since one or more references required to create the children would no longer exist. Pro/E has special functions available to manage parent/child relationships. This can get pretty complicated with a complex model. However, the user should keep parent/child relations in mind when the user is specifying feature references for a new feature the user is creating.

If the parent feature is temporary or is likely to change, what effect will this have on the children? Will the references still correctly capture the user design intent? Once the user model is created, it is very easy to get Pro/E to produce fully detailed standard format engineering drawings almost completely automatically.

In this regard, Pro/E also has bidirectional associatively – this means the user can change a dimension on the drawing and the shape of the model will automatically change, and vice versa. Of course, few parts live out their existence in isolation. Thus, a major design function accomplished with Pro/E is the construction of assemblies of parts.

Assembly is accomplished by specifying physically based geometric constraints (insert, mate, align, and so on) between part features. Of course, drawings of assemblies can also be created.

5.3 Mechanical Unit Components

Mechanical Unit "MU", shown in Figure 5.2, consists of: (1) Ball Weight moving in (2) arc track which is always facing down by the weight force and (3) bracket fixed under the vehicle in safety place defined as MU as shown in Figure 5.1. This is the unit that senses the stability status of the vehicle, which is sent to the EU that turns the hydraulic unit on/off as needed.

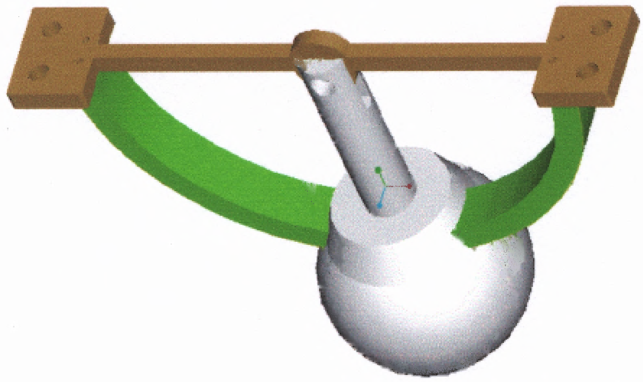


Figure 5.2 MU-Mechanical Unit which Attachment Under the Vehicle Frame.

Figure 5.2.a to 5.2.d illustrate the detailed design of the MU it's three components of the MU, respectively.

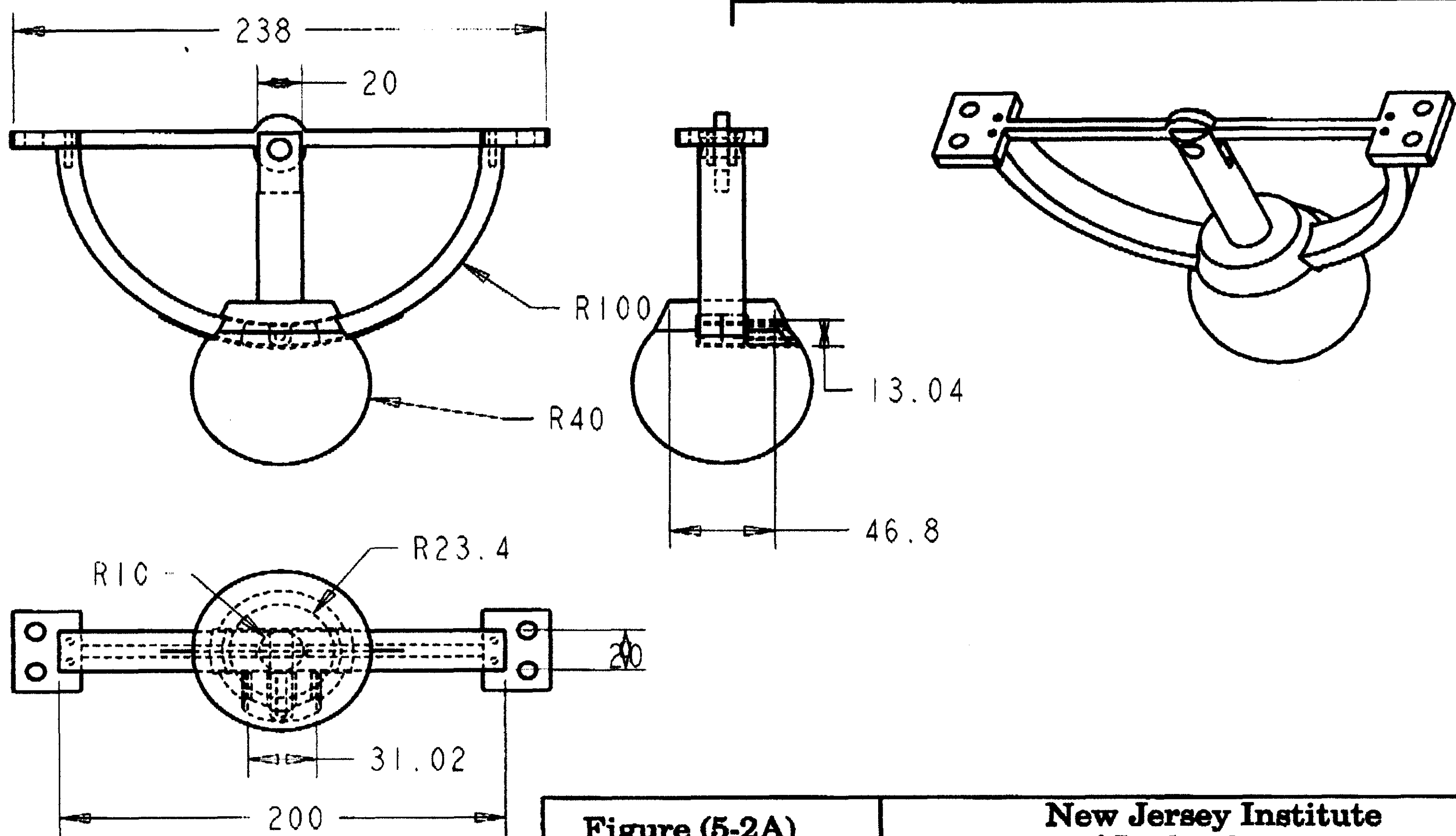
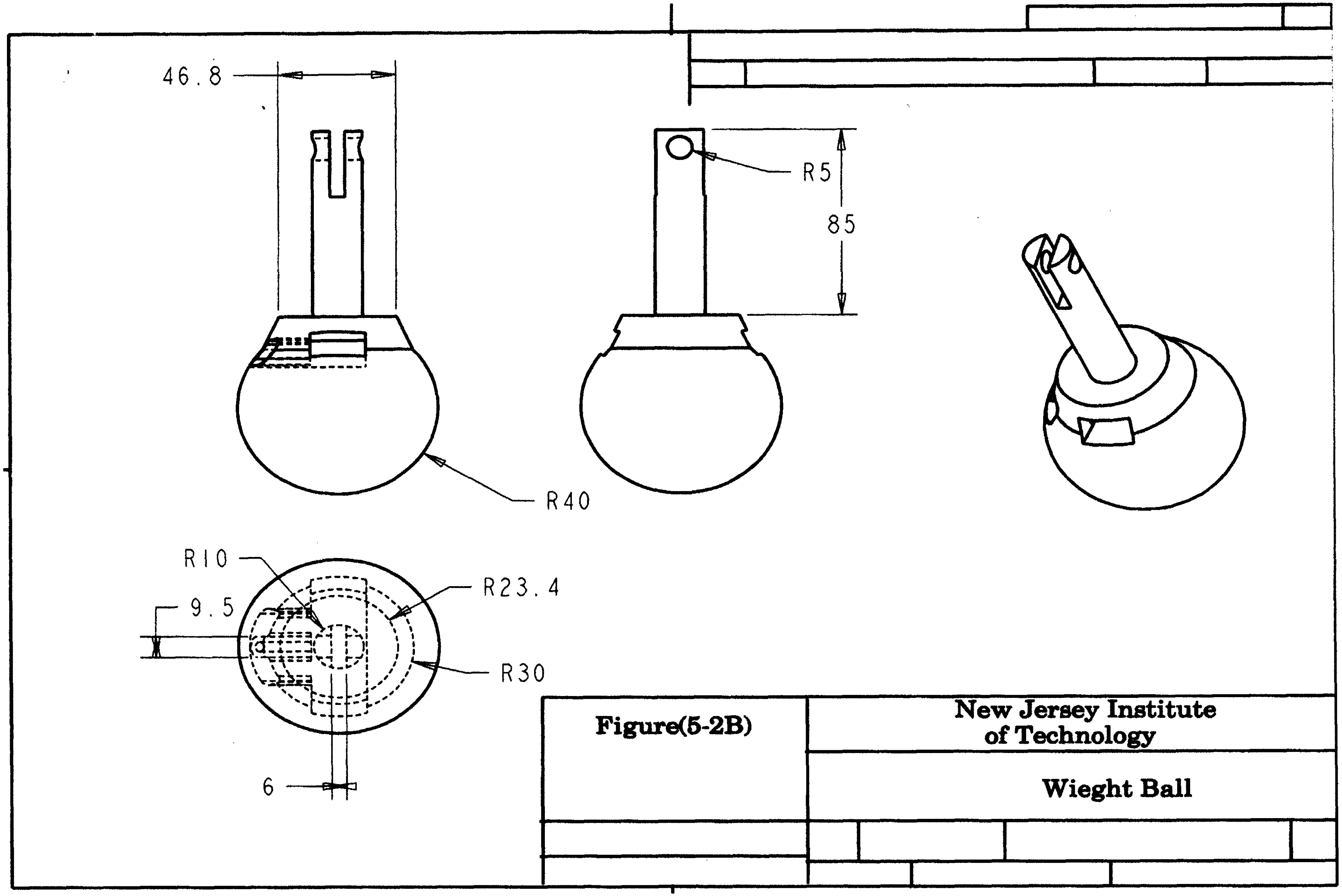


Figure (5-2A)

New Jersey Institute of Technology

MU Assembly


46.8
R5
85
R40
R10
R23.4
9.5
R30
6
New Jersey Institute of Technology
Wieght Ball
Figure(5-2B)

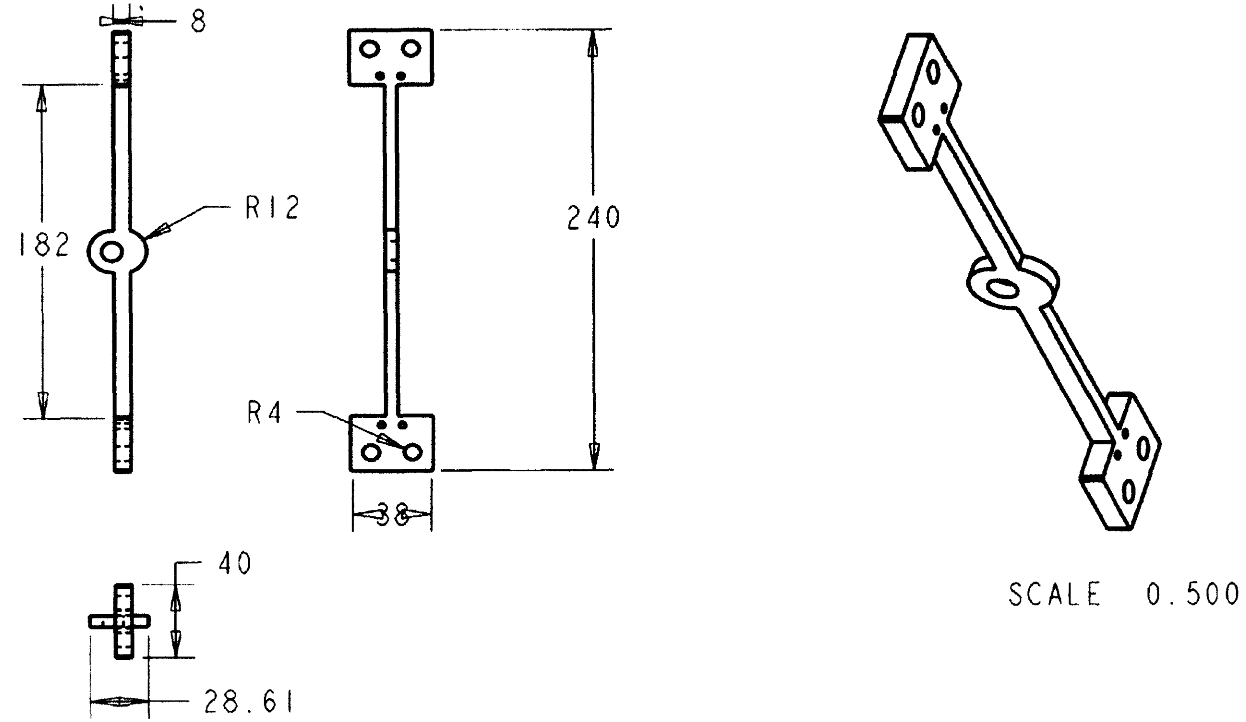


Figure (5-2D)

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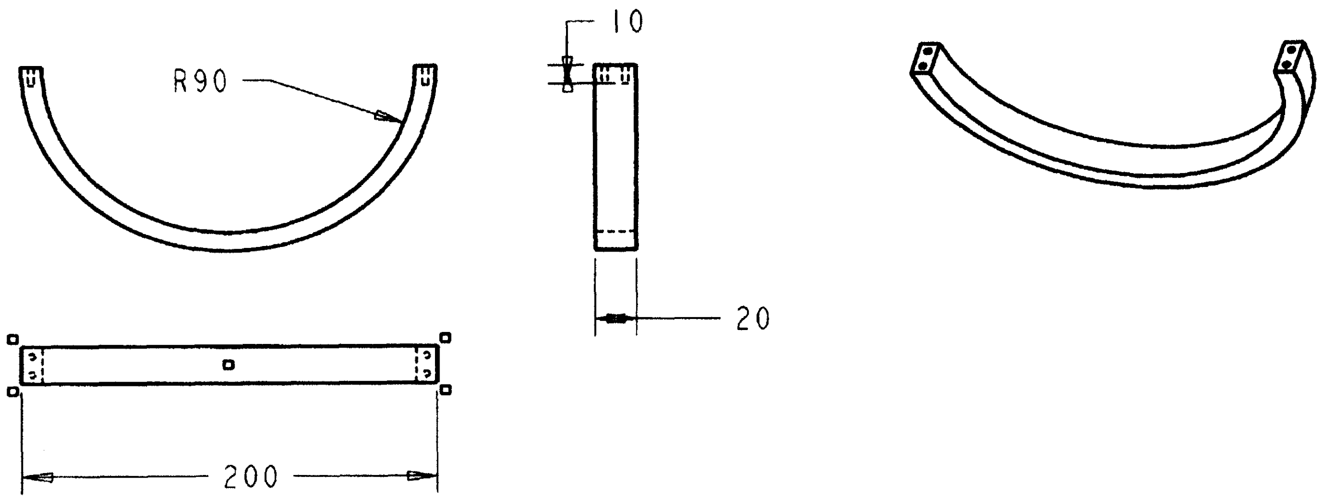
Bracket



Figure(5-2C)

New Jersey Institute of Technology

Arc Track

5.4 Operation Principle

When the vehicle starts losing balance, by tipping in either side, it's hard to find any accurate reference to turn the vehicle to a balanced status at variable conditions, except for the power of gravity to be the reference of all anti-rollover mechanisms including the Weight Ball.

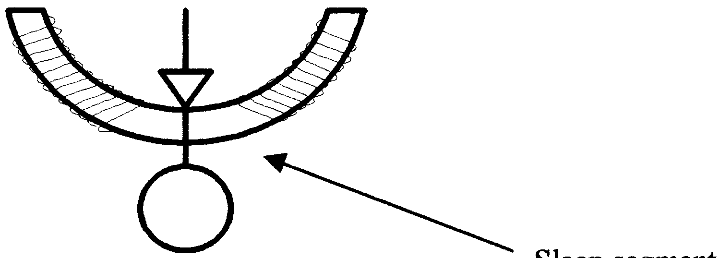


Figure 5.3 Two Electric Coils are Around Arc Part.

Due to the power of gravity, as shown in Figure 5.3 and 5.4, the Weight Ball always faces down in any vehicle status; expect if the vehicle turns upside down.

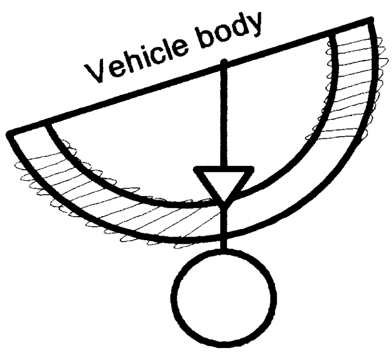


Figure 5.4 The Status of Ball Weight when Vehicle Sloped Right.

On the Arm Track of the MU, there is two sets of coils one each side, as shown in Figure 5.5, one for the left side of the vehicle and the other for the right side. The coils are used to sense the vehicle status received from the MU and send the status information to EU.

- **Sleep Segment**

Sleep segment this is the time which is the system in neutral at vehicle speed under 30 miles per hour, that mean the oil pump is on and all valves to hydraulic cylinder so the hydraulic circle going from pump to main tank and back again to main tank. Until the vehicle speed increase up 30 miles per hour system now on alert and ready rebalance the vehicle.

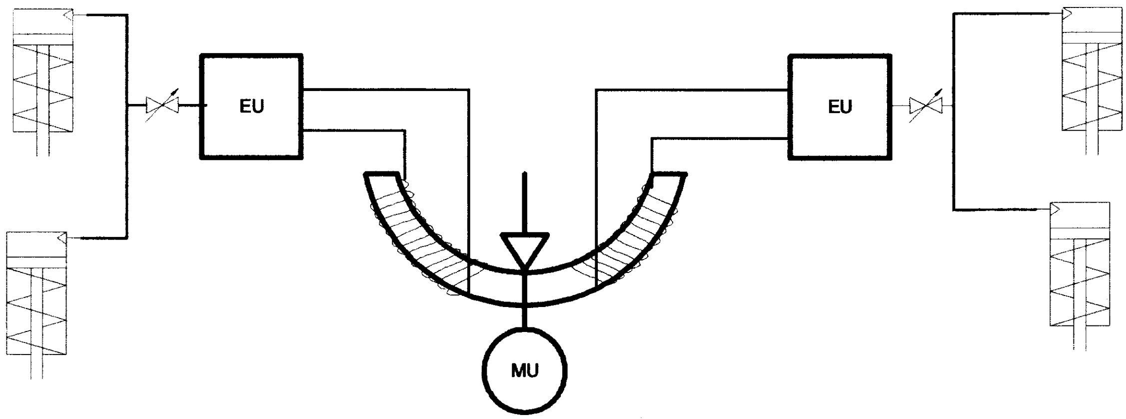


Figure 5.5 EU- Electronic Unit Connections.

5.5 Electronic Unit (EU)

In the EU the vehicle status information received from the MU is analyze and accordingly, different are made and different commands to hydraulic unit are sent. These commands are sent to hydraulic unit by electrical signals to open and closed the solenoids.

The proposed simulation model base on two conditions to activate HU

1. If the vehicle rollover angle exceeds it's critical value

2. If the vehicle speed exceeds its critical value and one side of the vehicle runs over an obstacle.

5.6 Proposed Simulation Model

Simulation model is a regulator that can modify its behavioral response in two conditions, from previous analysis the proposed model has been developed to regulate the rollover angle and to achieve stability of the vehicle by preventing the rollover. Lab View software is used as a mean to turn the simulation model. The basic structure of proposed simulation model as shown in Figure 5.6 consists of three loops: info loop, main loop, and simulation loop.

5.6.1 Introduction to Software Lab View

Lab View software incorporates graphical programming language that uses icons instead of lines or text to create applications. In contrast to text based programming languages, where instructions determine program execution, Lab View uses dataflow programming, where the flow of data determines execution. In Lab View, using a set of tool and objects, which is known as the front panel, develops a user interface. Then a code using graphical representations on functions to control the front panel objects can be added.

5.6.2 Front Panel

The front panel, as shown in Figure 5.7, is the user interface of the VI, which can be built using Control and Indicator, as the interactive input and output terminals of the VI, respectively. Control can be one of the knobs, push buttons dials, and other input devices, where as Indicator can be either one of the graphs and/or displays that simulate instrument input devices which supply data to the block diagram of the VI Also, they simulate output devices and display data of the block diagram acquires or generates.

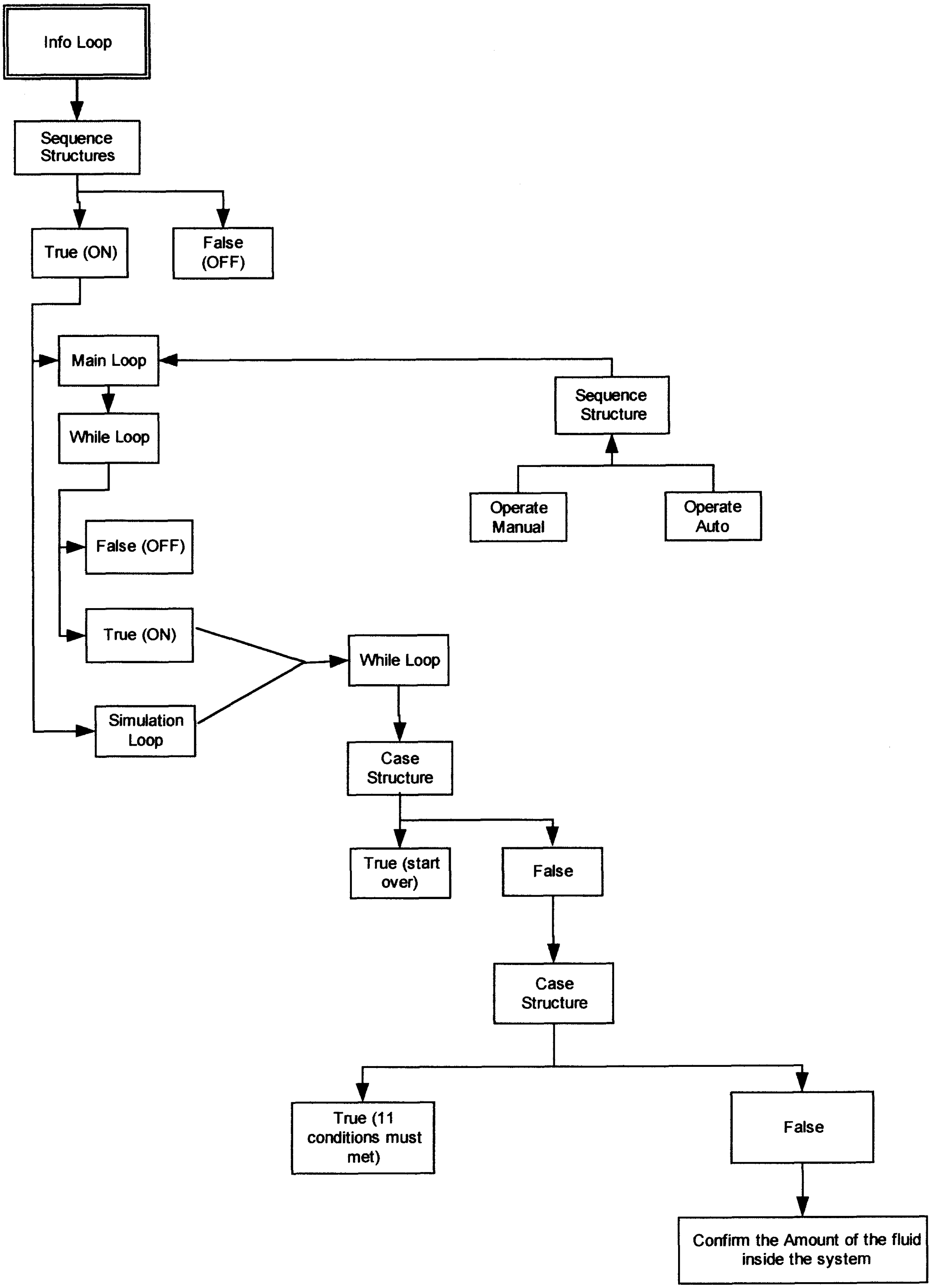
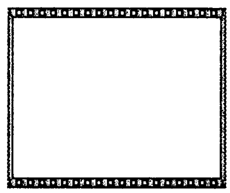


Figure 5.6 Lab View Block Diagram: Proposed Balancing System.

5.6.3 Block Diagram

In some ways, the block diagram resembles flowchart. Using Lab View, test and measurement, data acquisition, interment control, dialoging, measurement analysis and report generation applications, can be formulated. Every Control or Indicator on the Front Panel has corresponding terminal on the block diagram. Additionally, the block diagram contains functions and structures from built-in lab view libraries. Wires are connecting to each of the nodes on the block diagram, including Control and Indicator terminals, functions and structures.



5.6.3.1 Info Loop: consists of one or more sub diagrams, or loops that execute sequentially. As an option, one can add sequence locals that allow the user to pass information from one frame to subsequent frames by popping up on the edge of the structure.

In EU have two loops:

5.6.3.1.1 Main Loop: consists of the actual activates for the whole system and any incorrect wiring or information with this frame may cause the shout down the unit.

5.6.3.1.2 Simulation Loop: consists of sub-loops to monitor the actual mechanism work.

5.6.3.1.3 While Loop: allows repeating the sub diagram inside it until the conditional terminal (an input terminal) receives a FALSE or TRUE Boolean value. The default behavior and appearance of the conditional terminal is Continue if True. When a conditional terminal is Continue if True, the While Loop repeats its sub diagram until a FALSE value is passed to the conditional terminal. The user can change the behavior and appearance of the conditional terminal by right-clicking the terminal or the border of the While Loop and selecting Stop if True, when a conditional terminal is Stop if True, the While Loop repeats its sub diagram until a TRUE value is passed to the conditional terminal.

The "While Loop" in EU is represented by stop knob in front panel to turn on or off the unit. Stop if true, shown at right hand side. When a conditional terminal is Stop If True, the While Loop executes its sub diagram until the conditional terminal receives a TRUE value, because the VI checks the conditional terminal at the end of each iteration, the "While Loop" always executes at least one time.

The VI does not run if the conditional terminal is not wired. Also, basic error handling using the conditional terminal of the "While Loop" can be performed. When the user wires an error cluster to the conditional terminal, only the TRUE or FALSE value of the status parameter of the error cluster passes to the terminal. Also, the Stop If True and continue If True shortcut menu items change to Stop If Error and Continue while Error.

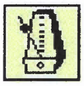
The iteration terminal (an output terminal), shown at left hand side, contains the number of completed iterations. The iteration count always starts at zero. During the first iteration, the iteration terminal returns zero .Add shift registers to the While Loop to pass data from the current iteration to the next iteration.

5.6.3.1.4 Shift Registers in Loops: Use shift registers on for loops and while Loops to transfer values from one loop iteration to the next. A shift register appears as a pair of terminals, as shown above, directly opposite each other on the vertical sides of the loop border. The right terminal contains an up arrow and stores data on the completion of iteration. Lab VIEW transfers the data connected to the right side of the register to the next iteration. Create a shift register by right-clicking the left or right border of a loop and selecting add shift register from the shortcut menu.

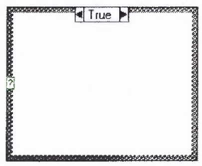
A shift register transfers any data type and automatically changes to the data type of the first object wired to the shift register. The data wired to the terminals of each shift register must be the same type. The user can create multiple shift registers on a structure, and more than one left terminal to remember more than one previous value, can be found. After the loop executes, the last value stored in the shift register remains at the right terminal. If the user wires the right terminal outside the loop, the wire transfers the last value stored in the shift register.

Unable to initialize the register, the loop uses the value written to the register when the loop last executed or the default value for the data type if the loop has never executed. Use a loop with not initialized shift register to run a VI repeatedly so that each time the VI runs, the initial output of the shift register is the last value from the previous execution. leave the input to the left shift register

terminal unwired for not initialized shift register to preserve state information between subsequent executions of a VI.



5.6.3.1.5 Controlling Timing to control the speed at which a process executes, such as the speed at which data are plotted to a chart, the Wait function in the loop can be used: in order to reduce the length of time in milliseconds that would be able to wait before the loop re-executes.



5.6.3.1.6 Case and Sequence Structures: contain multiple sub diagrams, only one of which is visible at a time. A Case structure executes one sub diagram depending on the input value passed to the structure. A Sequence structure executes all its sub diagrams in sequential order.

5.6.3.1.7 Case Structures: as shown in Figure 5.7 has two or more sub diagrams or cases. Only one sub diagram is visible at a time, and the structure executes only one case at a time. An input value determines which sub diagram executes. The case selector identifier at the top of the Case structure, as shown in case structure contains the case selector identifier in the center and decrement and increment buttons on each side. Use the decrement and increment buttons to scroll through the available cases.

In EU, there are case structures in each frame of the main loop and the simulation loop. Wiring an input value or selector to a selector terminal, determines which case is executed. The wire must be an integer, Boolean value, string, or enumerated type value to the selector terminal. Also the selector terminal can be position anywhere on the left border of the Case structure

In EU has a default case for 11 Case structures. As a default, to handle out-of-range values or explicitly to list every possible input values, it was specified as case 1, 2 and 11. Also, each case structure can never shift to the next case structure before all conditions must be met. The following pages illustrate the Lab view design, as follows:

1. Figure 5.6 Vehicle components in simulation model
2. Figure 5.6 (a) Block diagram of model Simulation
3. Figure 5.6 (b) Front Panel of model simulation
4. Figure 5.6 (c) Relationship between vehicle and road conditions
5. Figure 5.6 (d) Block Diagram of this relationship

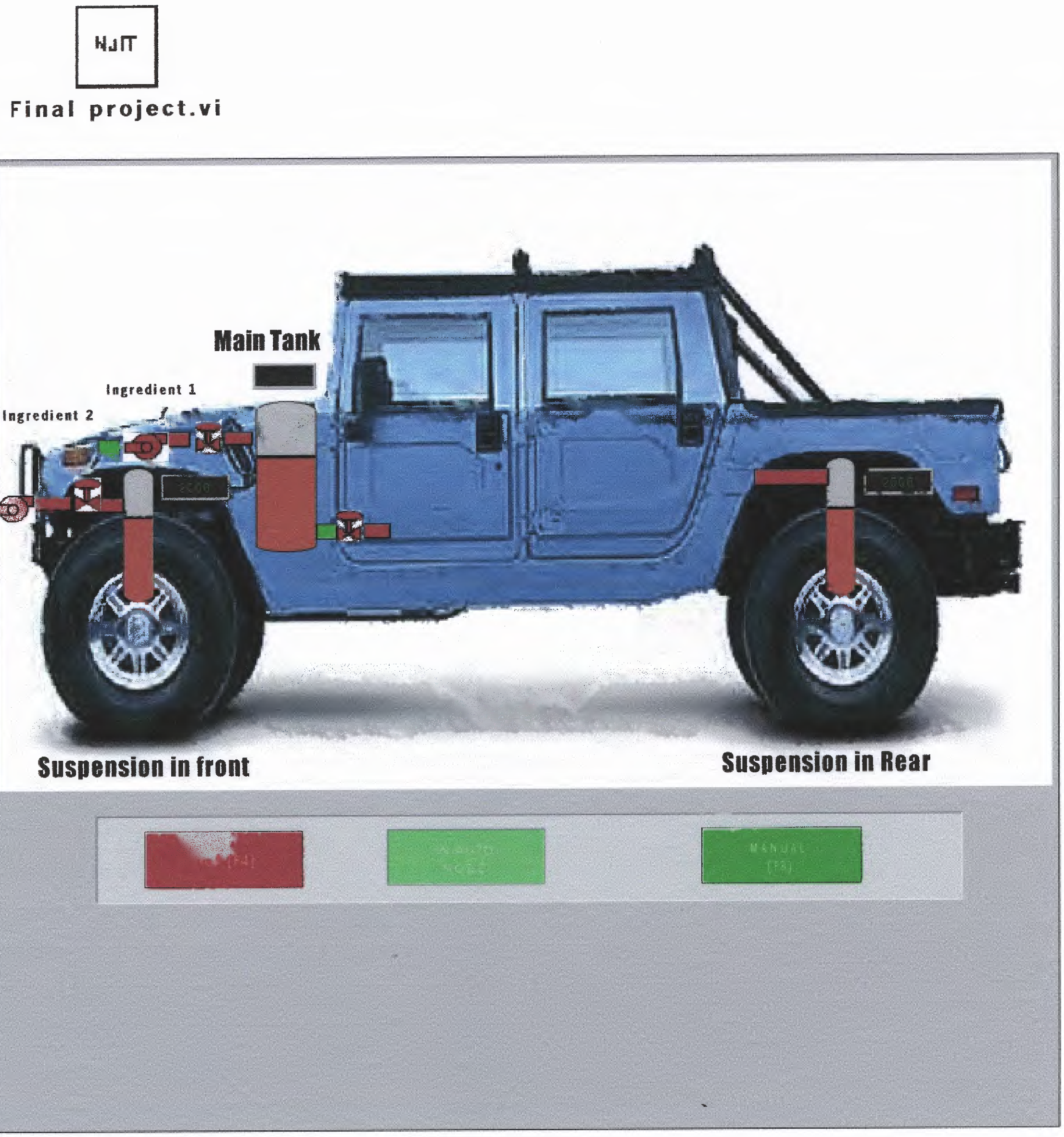


Figure 5.6 (a) The Block Diagram of Model Simulation.

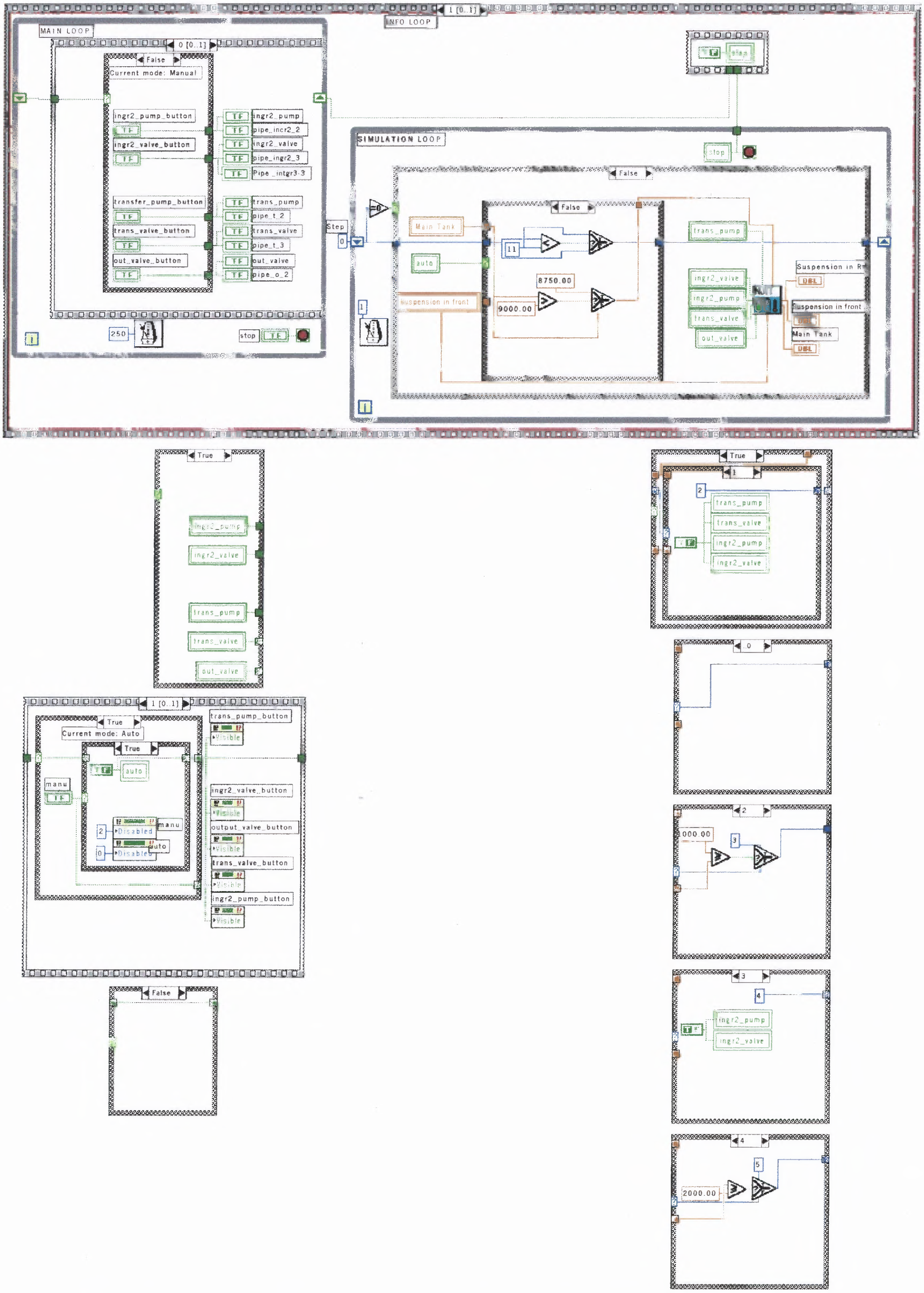


Figure 5.6 (a) The Block Diagram of Model Simulation (Continued).

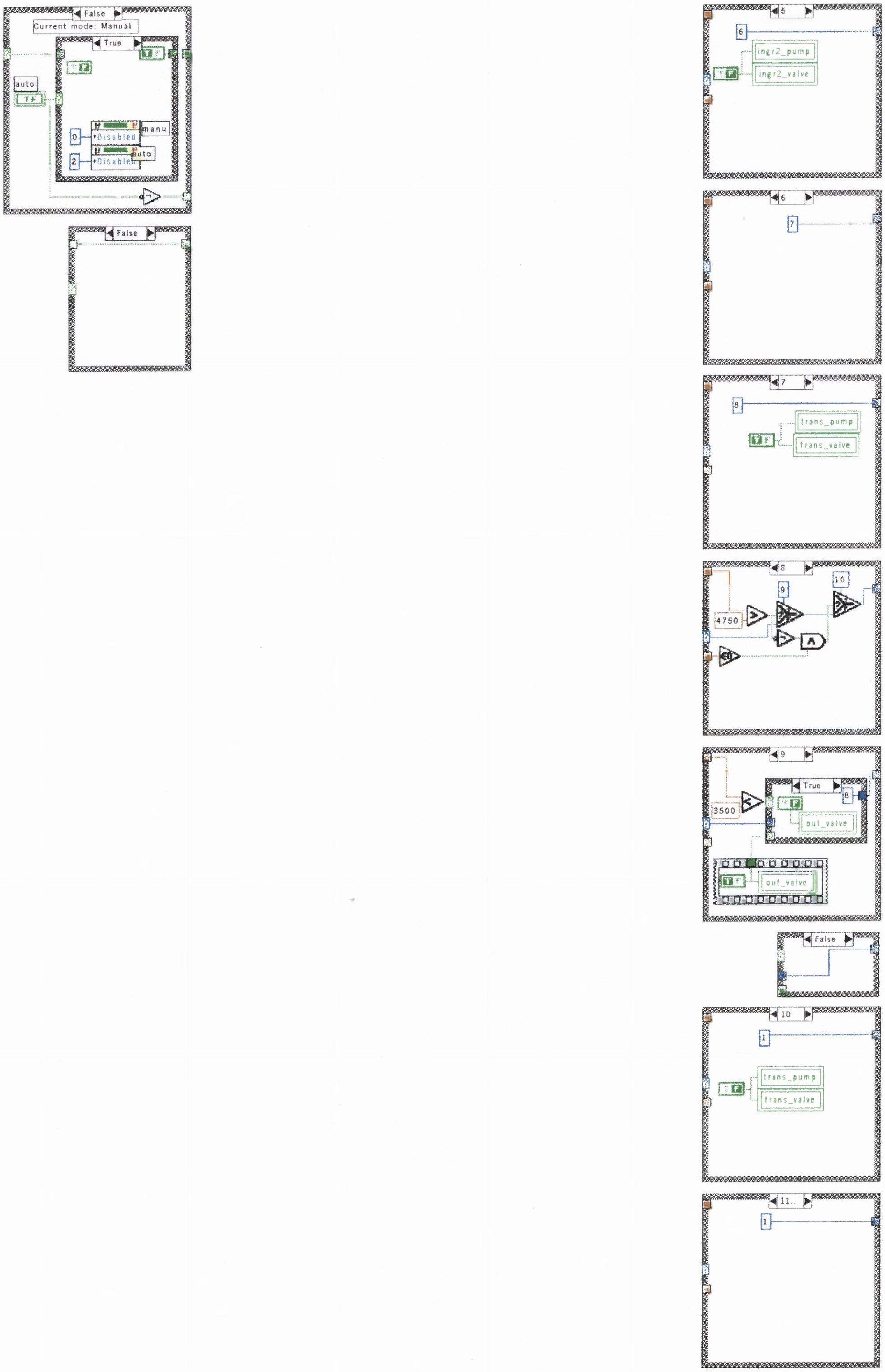


Figure 5.6 (a) Block Diagram of Model Simulation (Continued)

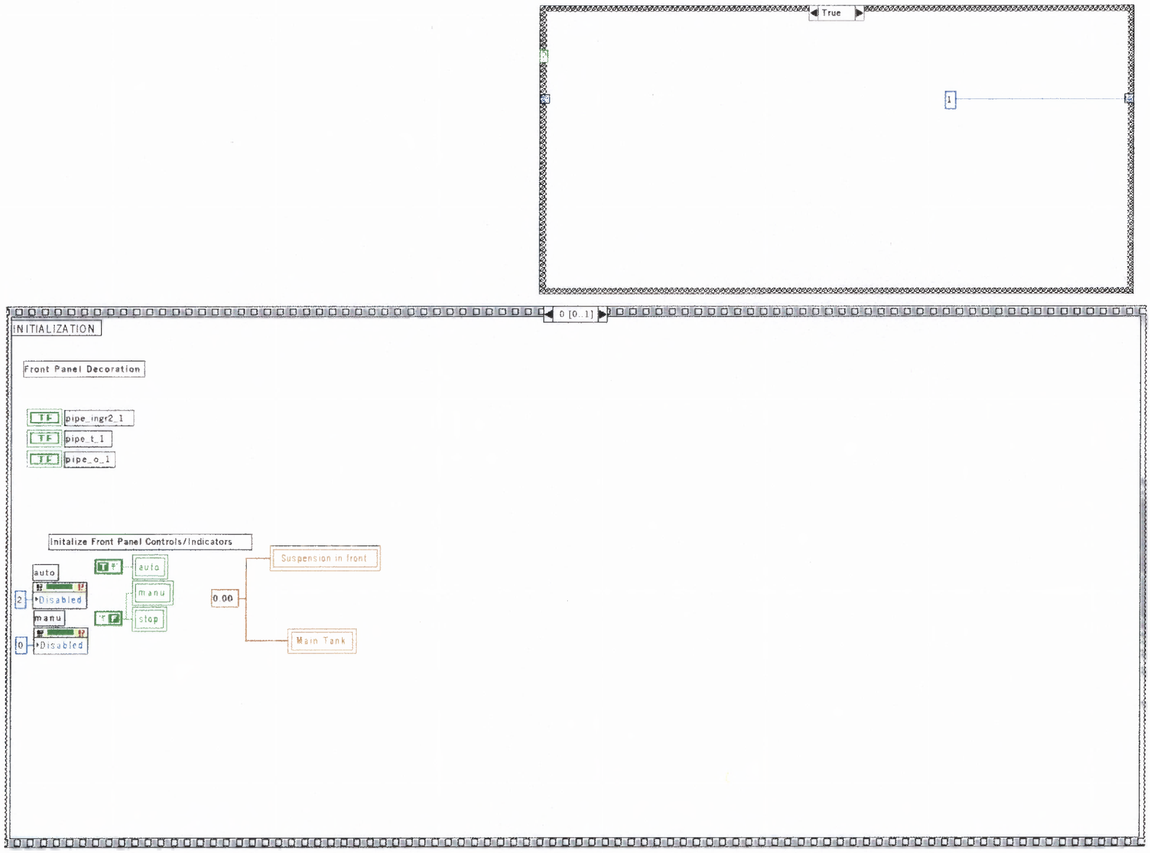


Figure 5.6 (a) The Block Diagram of Model Simulation (Continued).

Connector Pane

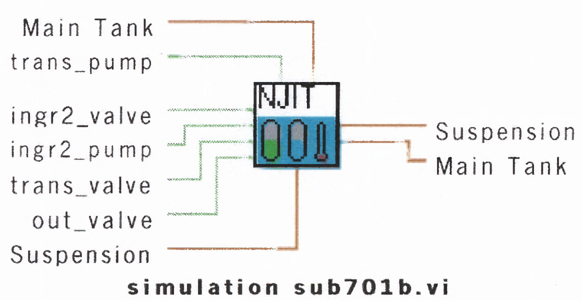


Figure 5.6 (b) Front Panel of Model Simulation.

Front Panel

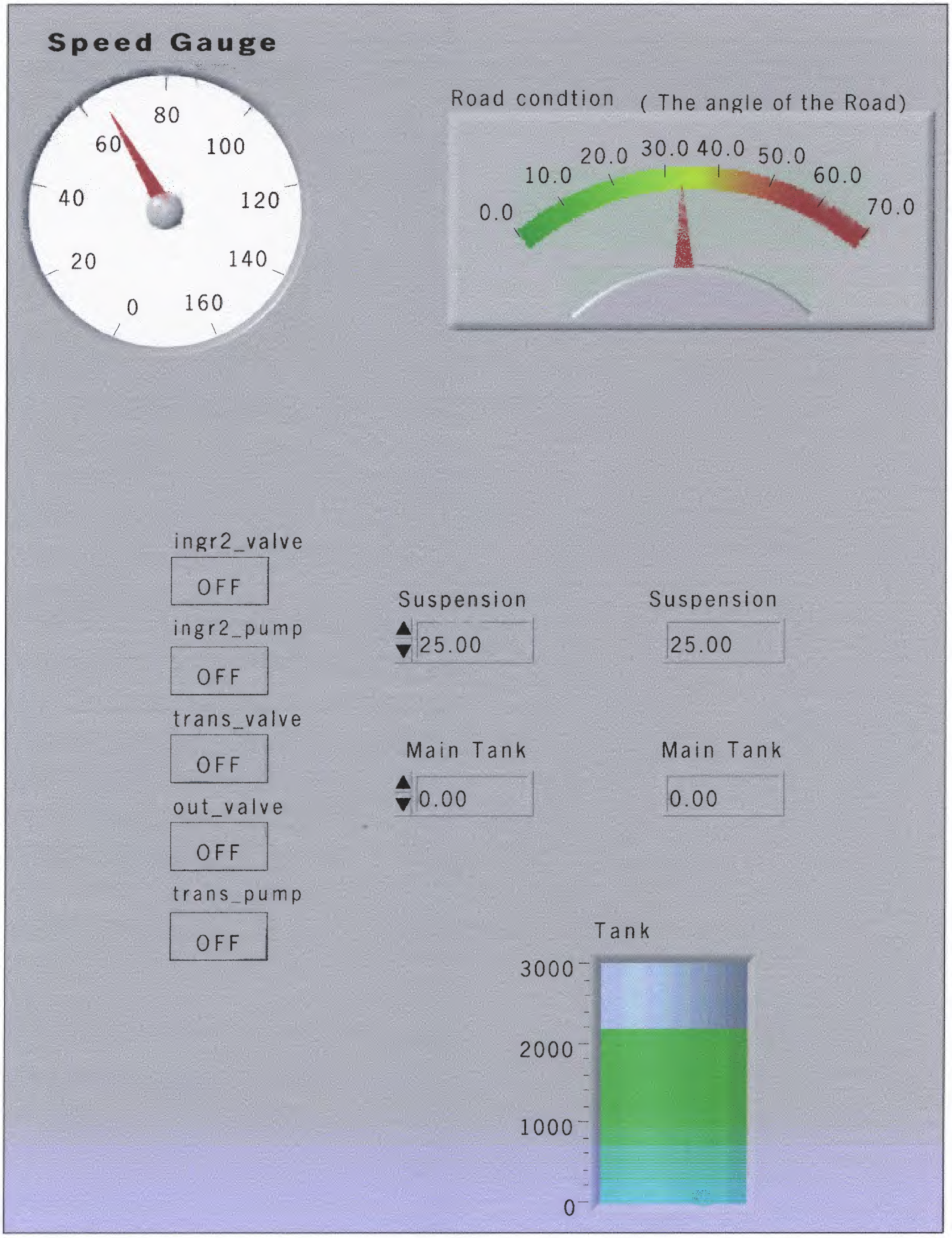


Figure 5.6 (c) The Relationship Between Vehicle and Road Conditions.

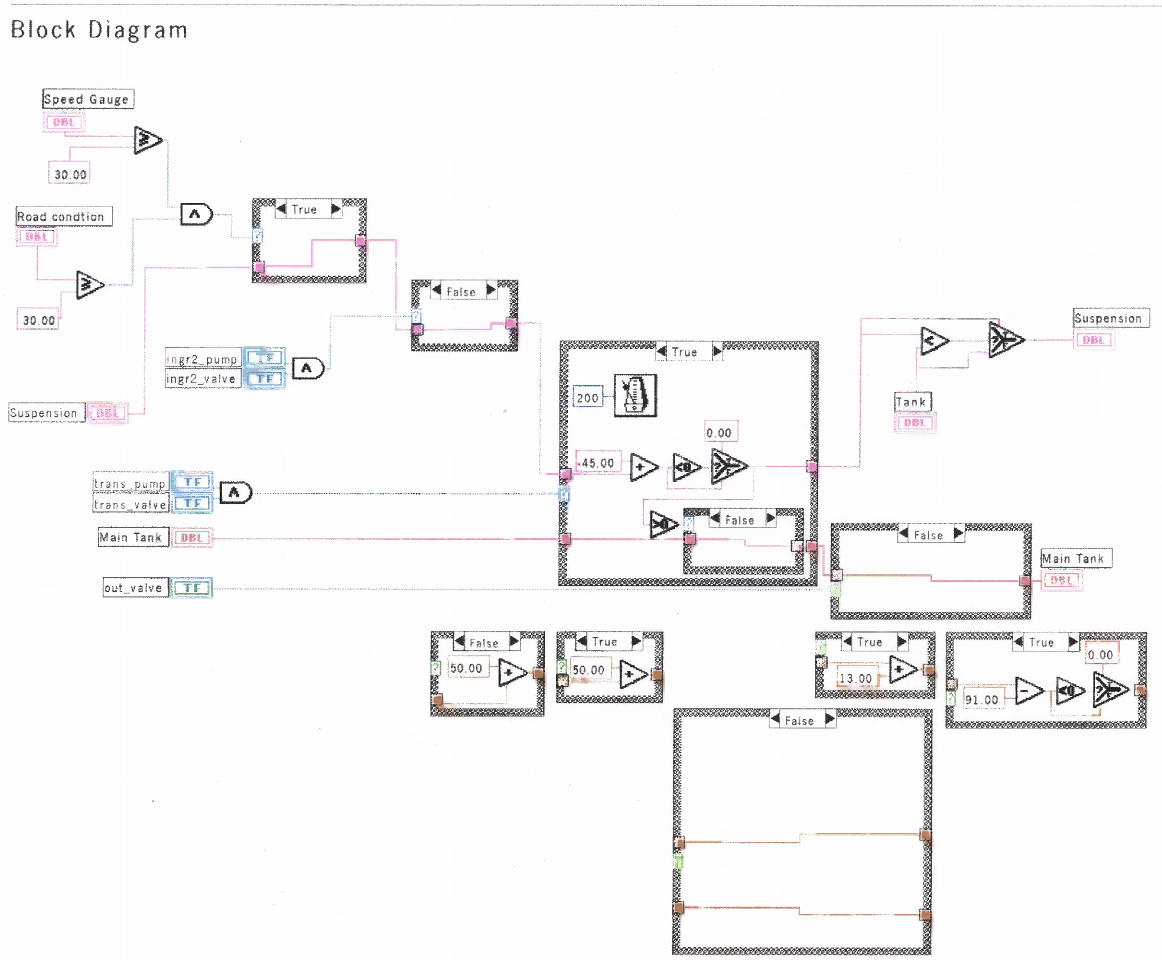


Figure 5.6 (d) Block Diagram of this Relationship.

5.6 Hydraulic Unit (HU)

HU consists of five major components, as shown in Figure 5.7.

1. Fluid tank.
2. Pump.
3. Reverse valves with solenoids to switch the fluid direction from tank/hydraulic suspension to recycle the fluid from/to tank. They receive signals from PLC (Programmable Logic Controller) to open/close the fluid tunnels also the valve body the only contact unit between fluid pump and shocks.
4. Hydraulic suspension: special shocks which able to extend according to valve body commands and go back to initial position under spring force. Two sets of shocks: one on the passenger side (right) and the other on the driver side (left). Only one set of shocks is active at a time.
5. Regular Valves and filters.

The HU can be divided in two categories, as shown in Figure 5.7

1. High-pressure region [red line].
2. Low-pressure region [blue line].

High-pressure region appears only when the HU system is activated or when the system is neutral; that is the vehicle is in normal situation. On the other hand, if the vehicle is stable, the hydraulic pump pushes the fluid, through reverse valve, to main tank. When electric signals are sent from EU to solenoid, the reverse valves switch the fluid direction to go to the shocks rather than to the tank. Hydraulic pump and vehicle engine are running and stopping simultaneously. Figures 5.7 a-f illustrates the HU parts and assembly drawing.

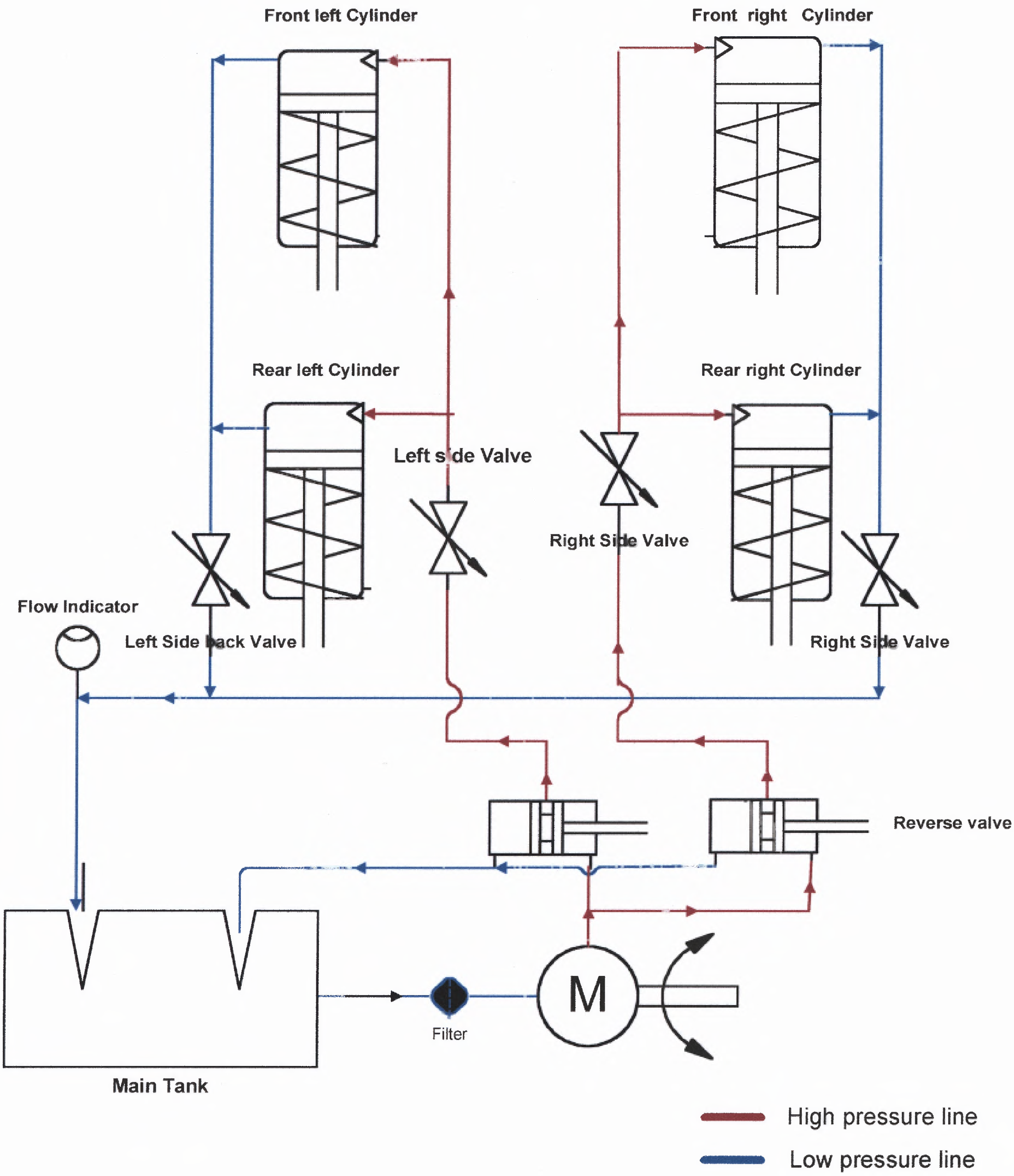


Figure 5.7 Shows the Hydraulic Unit with all Components.

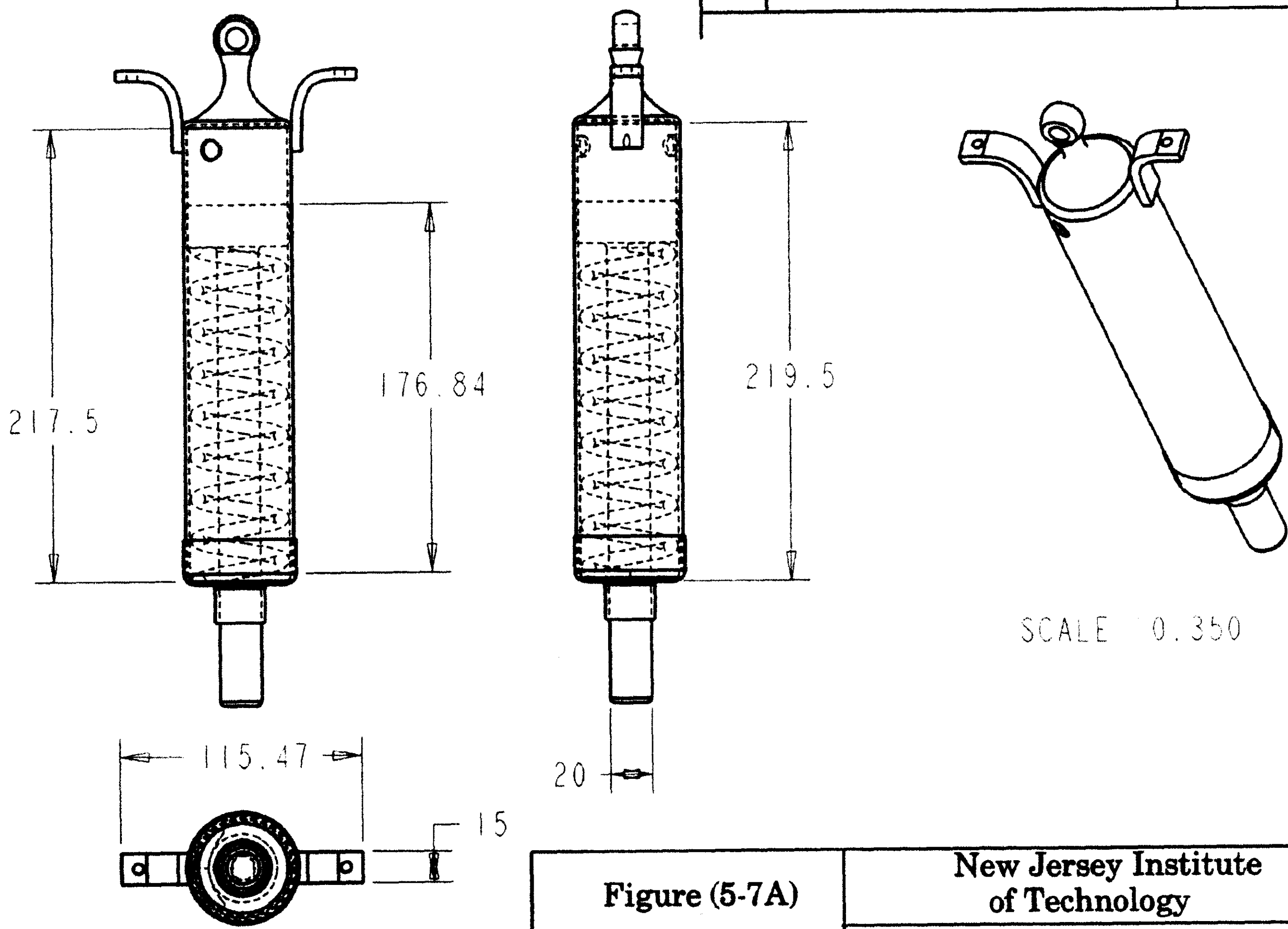
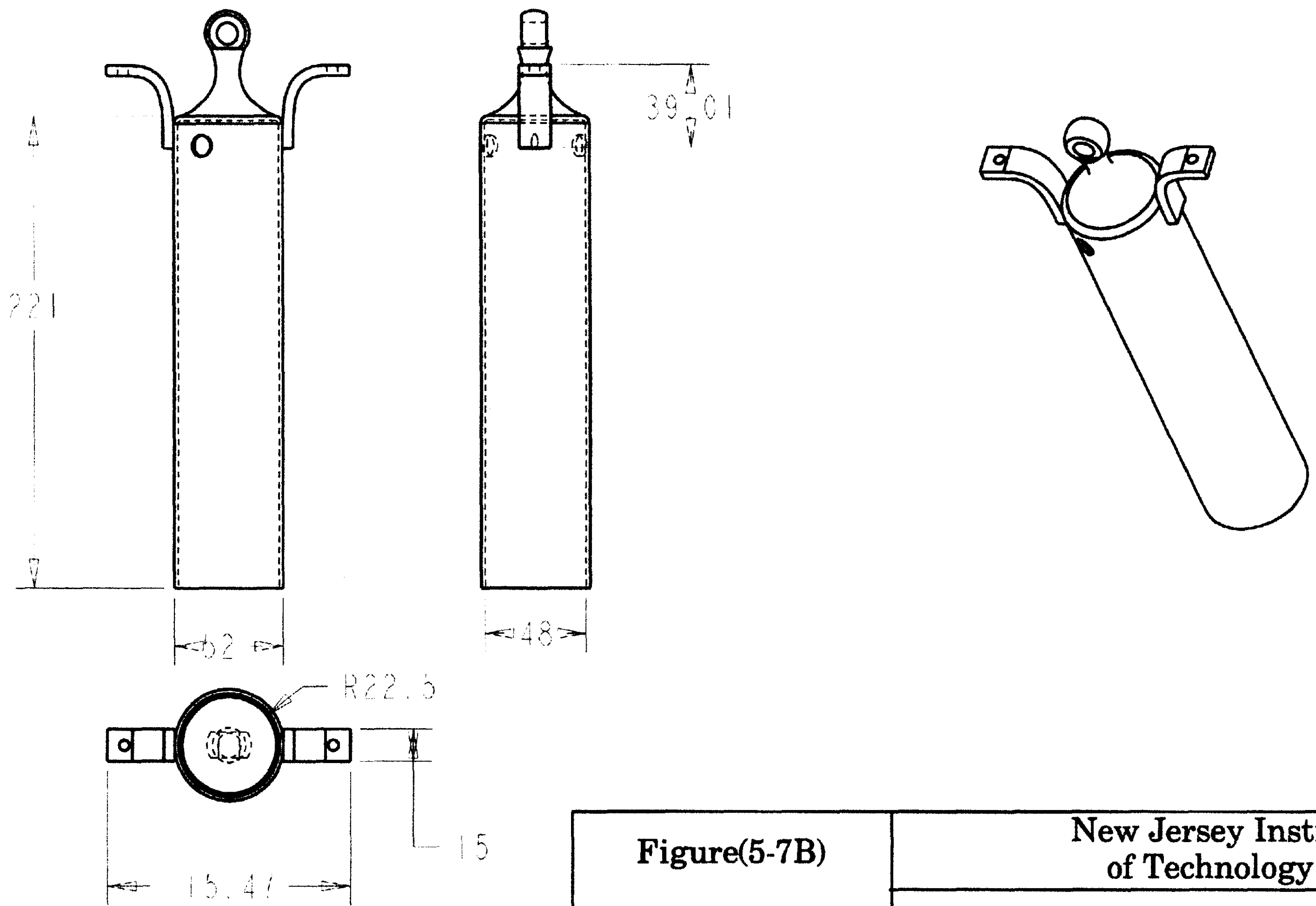


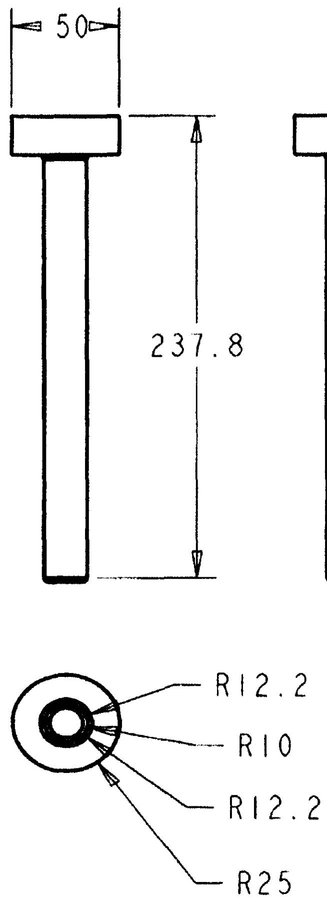
Figure (5-7A)	New Jersey Institute of Technology
	HU Assembly



Figure(5-7B)

New Jersey Institute of Technology

Hydralic Cylinder



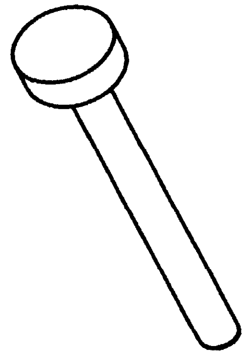
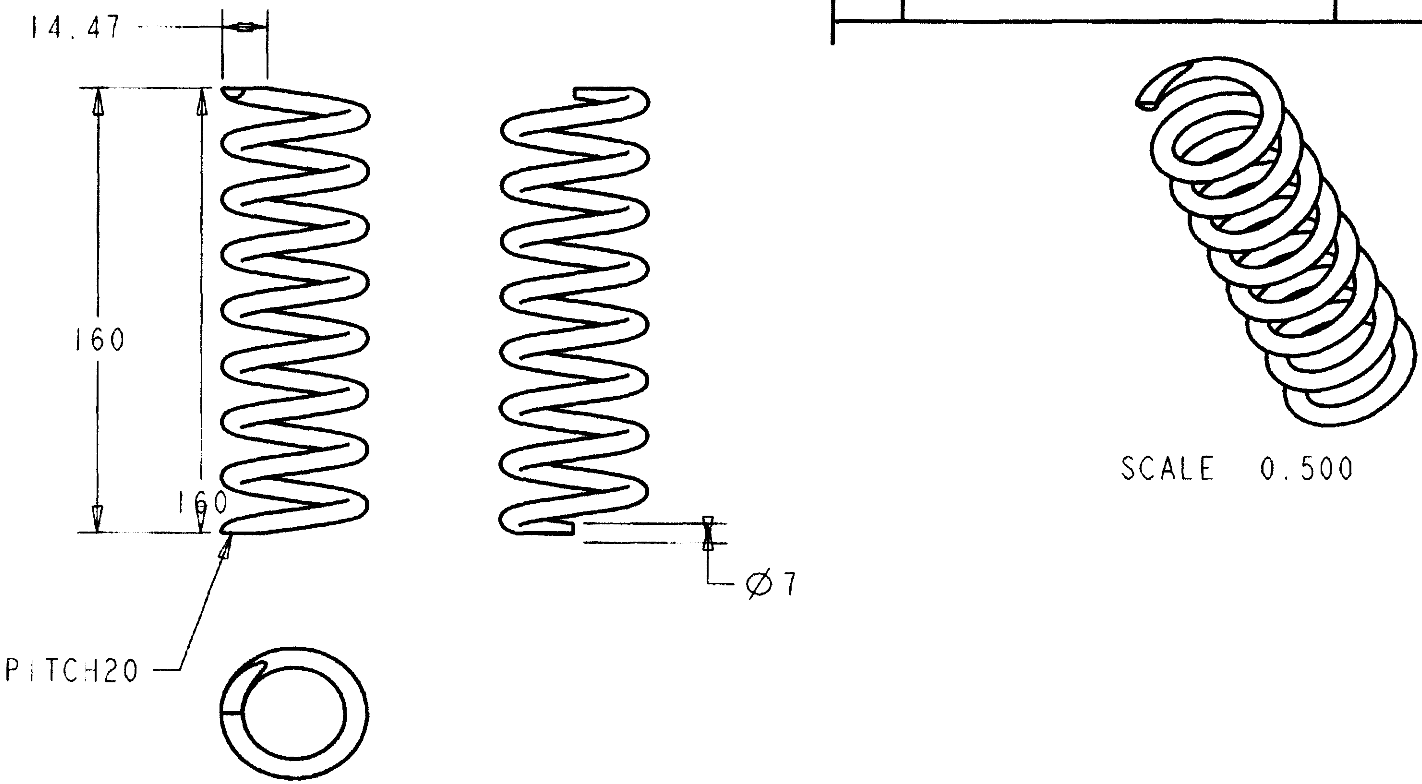


Figure (5-7C)

New Jersey Institute of Technology

Piston Part



Figure(5-7D)

New Jersey Institute of Technology

Spring Part

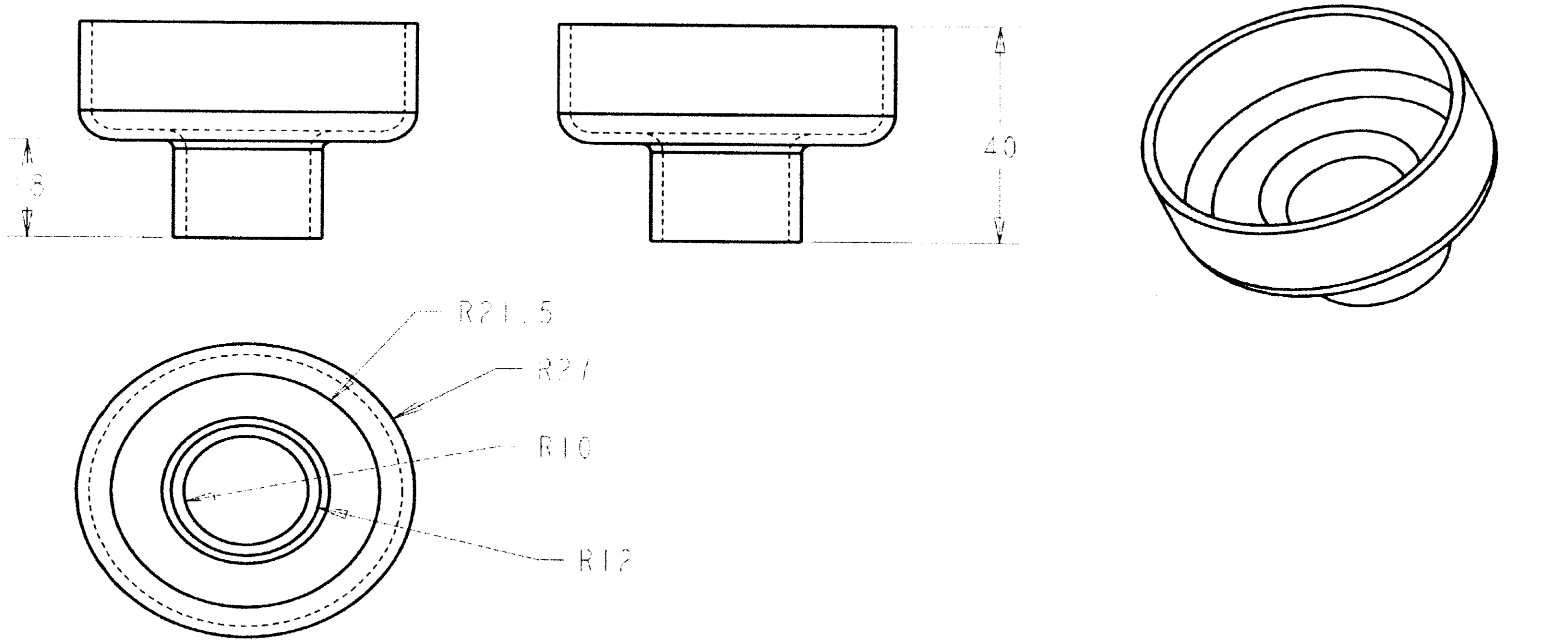
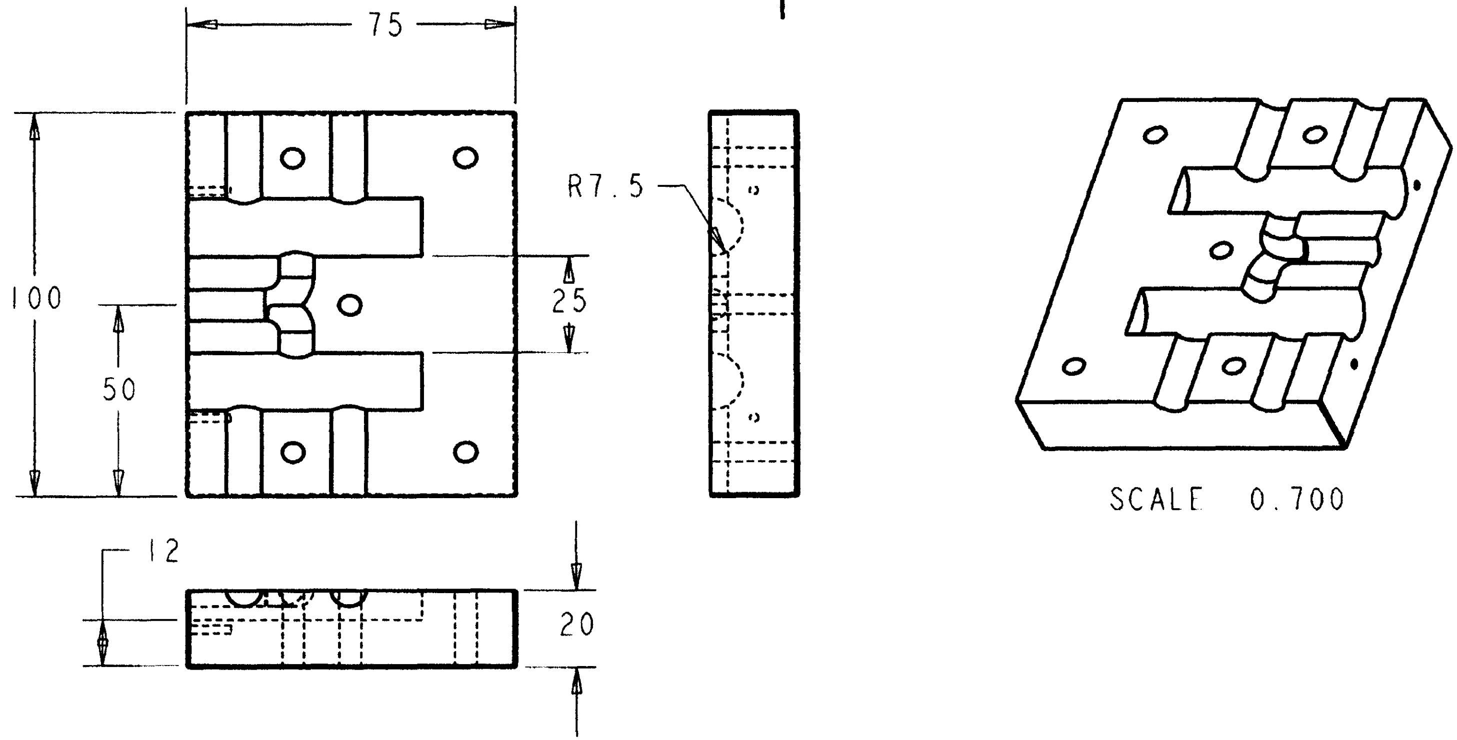


Figure (5-7 E)	New Jersey Institute of Technology
	Cover



Figure(5-7F)

New Jersey Institute of Technology

Valve Body

- **HU effect on the Overall Mechanisms.**

The hydraulic suspension in HU is an additional system to the existing system already built in the vehicle. The existing suspension, as normal vibration analysis, performs the function of vibration filter that reduces the amplitudes of vibrations excited by geometric variations in the road surface. This is the function of the spring damper arrangement that is an integral component of the suspension. The operation of the HU suspension is independent of the existing function and does not affect the existing suspension performance.

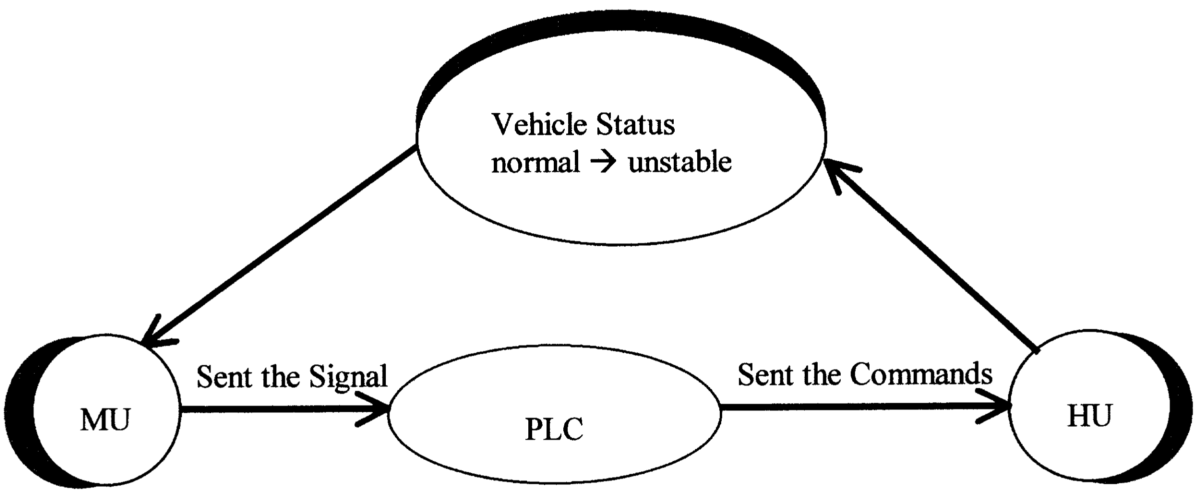


Figure 5.8 Relation Ship Between all Units.

5.8 The First Order Negative Feedback Loop.

The Structure to be found in feedback loop appears in Figure 4.7. Here a single decision (Electro Hydromantic System E.H.S) controls the input to one system level (Actual Vehicle Stabilized AVS) where there are no delay or accept any kind of delay or distortion in the information channel going from AVS to EHS and This loop is classified as first order because there is one level only variable (AVS). This diagram illustrates an elementary AVS.

The goal of the system is to maintain the Desired Vehicle Stabilized (DVS), which is shown on the diagram as a constant in the decision process

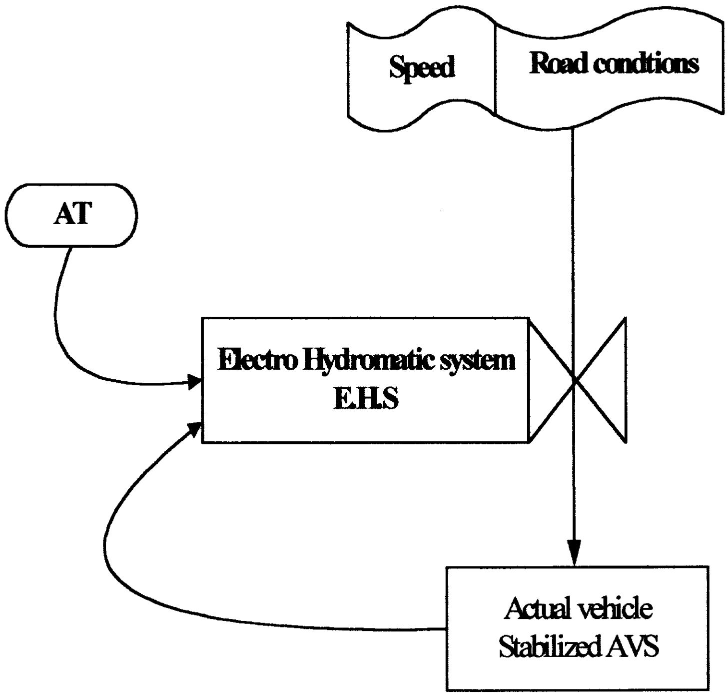


Figure 5.9 The First Order Negative Feedback Loop.

Where the AT adjustment time which is responsible for reaction the whole system (EHS) at abnormal condition happened make the vehicle loss it balance. An intrinsic relation between whole (EHS) and (AVS), that the relation belongs to the efficiency of (AT) the time of response.

5.9 Operation Theory

When the vehicle is driven over a curve above the speed limit or over an elevated hill or ramp, the whole vehicle turns in the opposite direction than of the center curve due to the generated centrifugal force, except the Ball Weight in MU which will remain vertically due to the gravity power as shown in Figure 5.10.

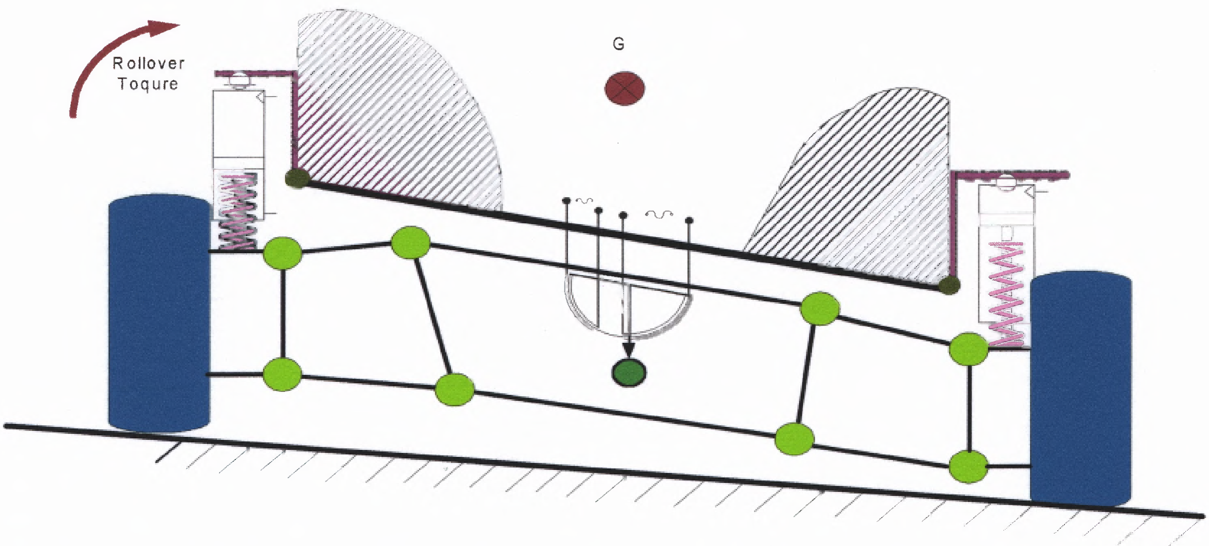


Figure 5.10 Ball Weight in Vertical Position.

The needle attached in the Ball Weight in case of vehicle turning, touches the electronic coil; thus it generates another outline for electric power known as electric coils resistance I. The transducer in EU senses that and generates volts (V) quantity as input from the following relationship;

V=I* R where I is Amber and is constant, V is Volt, R resistance

It is clear from the equation that V is linear and is increasing as R increases.

After the value of V is sensed, the EU sends signals to hydraulic unit to open up the solenoids of the high region valves in order to allow the fluid to reach the shocks. The solenoids, valves and shocks open only on the same side, which the vehicle turns on. Figure 5.11 shows the system when is activated according to the road conditions. The left side solenoids are activated so that pushes the vehicle from the opposite side to create enough moment that eliminates the rollover crash. They remain activated until vehicle stability, as shown in Figure 5.12, is reached as quickly as possible. However, the shocks returns to normal status slowly to keep provide comfort to passengers.

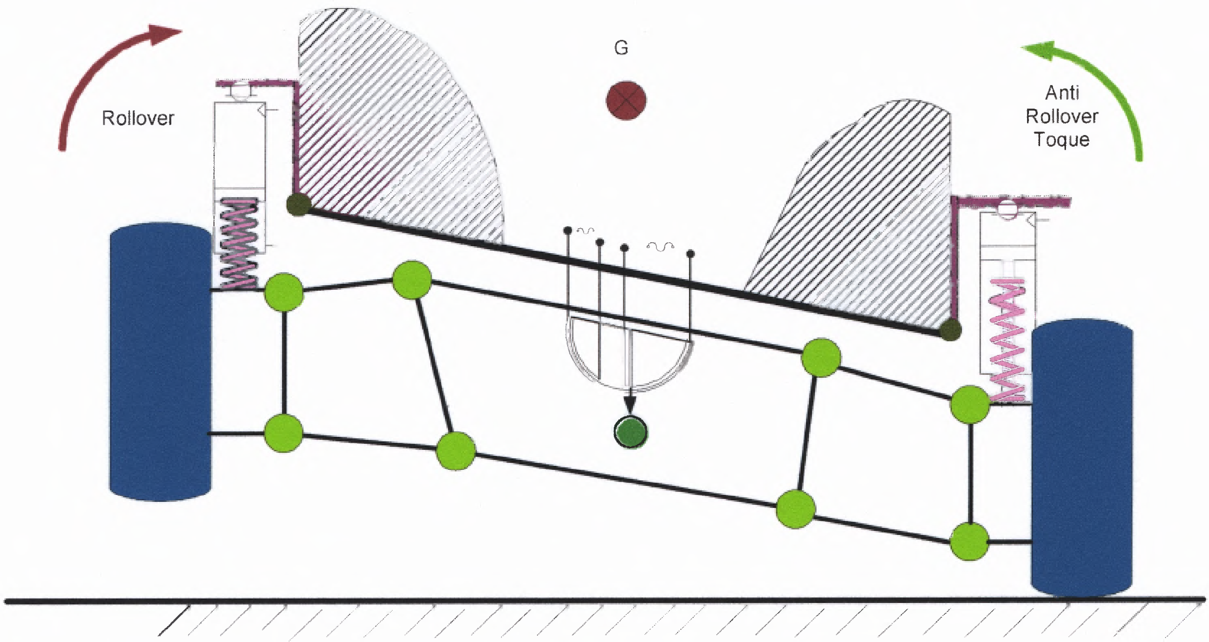


Figure 5.11 System Activated According the Road Requirements.

If the driver is making a quick left turn in case of vehicle instability, the vehicle will be turning to the right and stops at an equilibrium point, Figure 5-13. Although the vehicle will be leaning slightly to the right, an anti-rolling torque is immediately generated by the proposed suspension design. There are two conditions must be carefully observed, as follows:

1. The system remains sluggish, if the vehicle speed is less than the predetermined maximum critical speed of the curve turning.
2. The system is not activated until the vehicle-turning angle reaches the predetermined critical rollover angle.

The main system attributes, in addition to vehicle specifications:

1. Rollover angle. 2. Vehicle speed. 3. Road conditions.
4. Road curvature. 5. Road super-elevation.

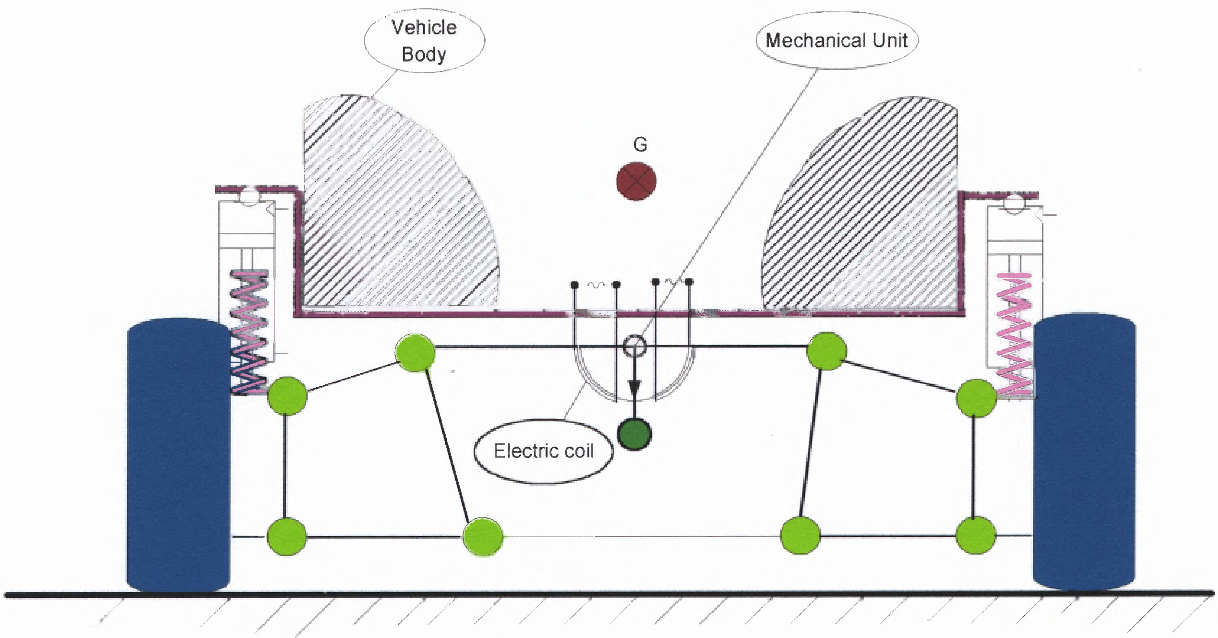


Figure 5.12 Normal Situation for the Vehicle.

The maximum effective results can be obtained from the road super-elevation angle, vehicle speed and road curvature. However, different road conditions, such as the case of raining or snowing, were not examined in the proposed model. Thus, there are other significant factors must be thoroughly examined to add more in order to refine the proposed system.

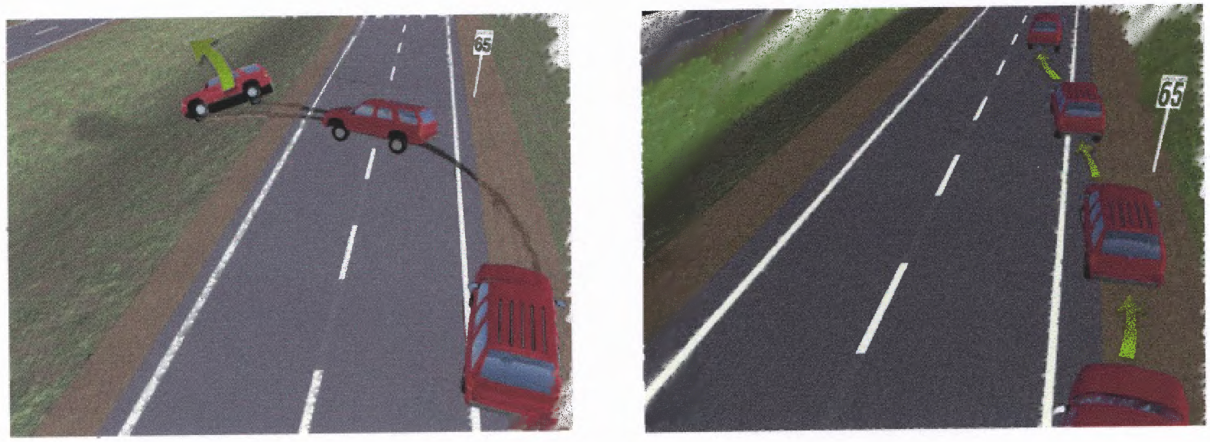


Figure 5.13 A Vehicle Without Stability Mechanism on the Left and Another Vehicle With it on the Right.

CHAPTER 6

CASE STUDY AND ANALYSIS

The Ford Explorer SUV was considered for the case study in order to highlight the advantages of applying the proposed system. The specific dimensions for the 2001 Ford Explorer XTL gasoline SUV are listed in Table 6.1.

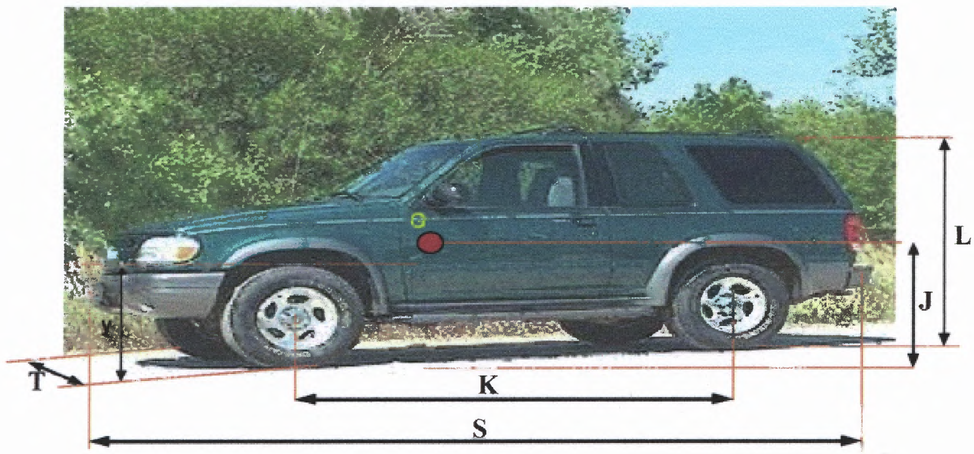


Figure 6.1 Ford Explorer XTL/2001.

Table 6.1 Ford Explorer Dimensions

Code	Description	Inches	Feet
L	cab Height (Empty) 4x2/4x4	67.7/67.5	5.625
J	Load Hight (Emptiy) 4x2/4x4	29.1/28.9	2.408333
K	Wheelbase	111.6	9.3
S	over all Length	190.7	15.89167
T	over all Width	70.2	5.85
y	the hight of suspension	14.3	1.191667

Curb Weight in lbs (standard equipment, fuel, water, & oil)

Model	Eng	Front	Rear	Total
4x2 4-Door	4.0L	2010	1835	3845
4x4 4-Door	4.0L	2200	1845	4045
4x2 4-Door	5.0L	2177	1873	4050
4x4 4-Door	5.0L	2367	1883	4250

Other Specifications:

Front Axle: W/ 4x2 Ford twin- I-beam IFS, rated capacity 2710 Lbs. Capacity, w/4 Ford twin- traction beam IFS drive axle, hypoid gear rated cap 5850 Lbs

Rear Axle Ford single reduction semi floating hypoid gear Hotchkiss drive rate capacity 3200 Lbs

The complete simulation model is in the Appendix CD under "Sim_Modle" folder. Assuming that the height of center of gravity from the ground, is a significant factor to balance of the vehicle. Lab View software was used to design and simulate the process control of the proposed mechanism. This simulation able to give the final status for any kind of vehicle when complete the table (1) and table (2) with any vehicle information to check if the vehicle stability or instability at different speed

From page (62) shows front panel and block diagram for the simulation and page (63) has results from the existing program.

- This simulation able to help engineering department in motor vehicle companies to determent the new vehicles dimensions before start production and optimize the dimensions.
- Also able to defined the maximum speed for each particular car in curve.

A vehicle is turning clockwise at 80 MPH on the perimeter of a circle, with a radius of 200 feet. Applying the specifications of the 4x4 4-Door Model and assuming the sliding coefficient of friction between tires and road is 0.75, the critical angle that the vehicle would be unbalanced and the anti-rollover torque required to keep the vehicle balanced, are determined as follows:

Vehicle speed converted to ft/sec: V= [80 (mi/hr) x 5280(ft/mi)]/3600 (sec/hr) = 117.3 ft/sec

From Chapter 4, the Torque P is equivalent to:

$$P = W^* t - f y - F_C \cos \Phi\, h + W \sin \Phi\, h = 0 \quad (6.1)$$

Where $F_C = m V^2 / R = 4045 (117.3)^2/200 = 2784.39$ N (6.2)

$$f = \eta W = 0.25 * 4045 = 1011.25 \text{ N} \quad (6.3)$$

by substituting W= m*g in the above equation;

$$m^*g^*t - f y - F_C \cos \Phi\, (j\text{-}y) + m g \sin \Phi\, (j\text{-}y) = 0 \quad (6.4)$$

Then, by dividing the above equation by g

$$m t - [f y - F_C \cos \Phi\, (j\text{-}y)]/g + m \sin \Phi\, (j\text{-}y) = 0 \quad (6.5)$$

$$4045*35.1 - [1011.25*2.4 - 177765.78 (\cos \Phi) (2.4-1.19)]/32 + 4045 (\sin \Phi) (2.4-1.19) = 0 \quad (6.6)$$

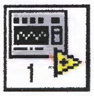
or,

$$139552.5 - 2762.05 (\cos \Phi) + 4894.45 (\sin \Phi) = 0 \quad (6.7)$$

Thus; the Critical Angle of turning **$\Phi = 58.919° \approx 59°$**

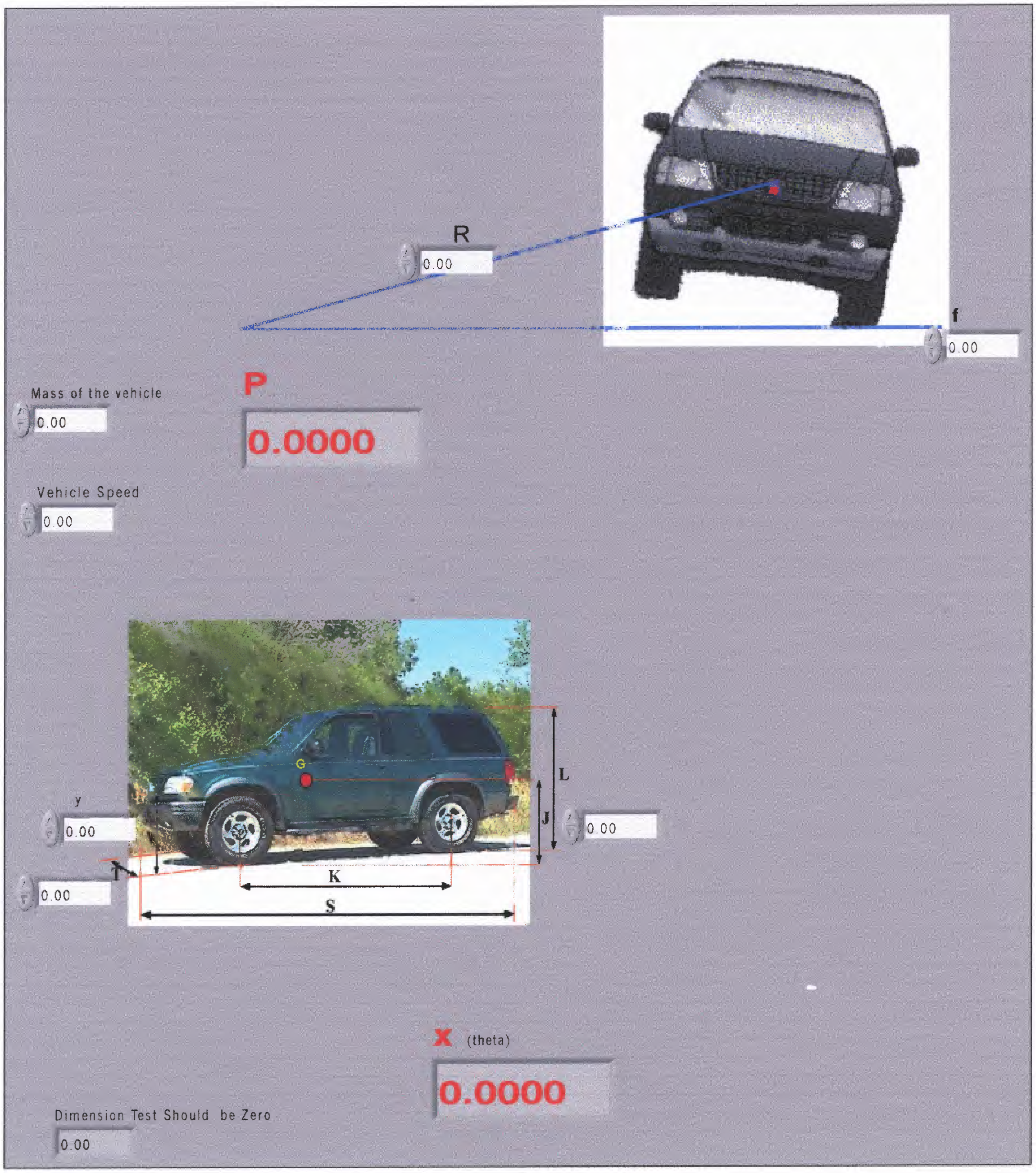
The second phase of the research is to conduct the simulation model for the process control of the proposed mechanism. Figures 6.2, 6.4 illustrate the input sub-model of the case study. The complete simulation of the case study is in the Appendix CD under "Sim_Cstudy" folder.

Connector Pane

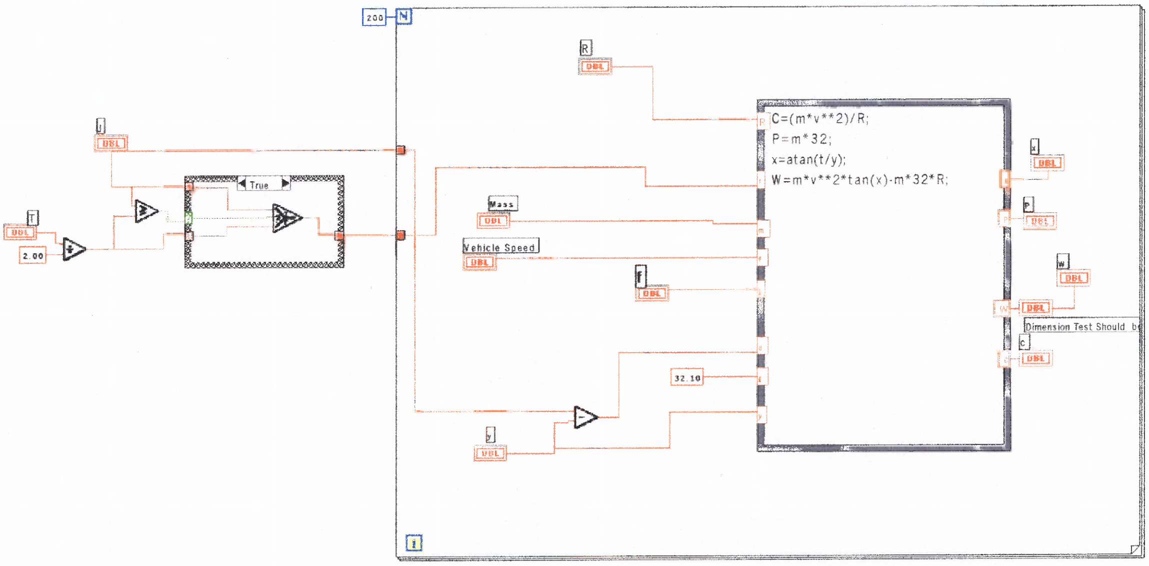


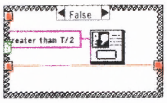
Sim_Cstudy.vi

Front Panel



Block Diagram





CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

As stated in the research objectives, the proposed mechanism and the simulation of its controller clearly have demonstrated the elimination of rollover crashes. The following conclusions can be drawn:

1. By following the analysis described in Chapter 5, one can easily design an Anti-Rollover unit (Electro Hydromatic), which creates anti- rolling torque for vehicle stability.
2. Although the physical model of the proposed mechanism was not produced, the Lab View simulation has clearly shown the precise results of the process control of the mechanism.
3. Anti-Rollover (Electro Hydromatic) can be fit in any vehicle in production, by determining the required dimensions to fit in the vehicle.
4. The proposed design with practical consideration could be physical produced and implemented.

For future work, there are multiple suggestions to increase the efficiency of the adjustment time for the control of the proposed mechanism, or on the other hand, reducing the response time. These are as follows:

- Minimize the number of curves in fluid lines as soon as possible; also maximize the diameters of fluid pipes.
- Reduce the number of valves and regulators or any kind of fluid resistance.

- Other practical factors must be considered to incorporate other road conditions, such as in case of raining and snowing.
- The step motors efficiency, according the system is required.
- Break fluid is recommended for the proposed mechanism.
- The movement part must be made of stainless steel to prevent rusting.
- Hydraulic system must have an additional fluid tank to help the system to back up in initial condition.

APPENDIX

SIMULATION MODEL "SIM_MODLE, SIM_CSTUDY"

This appendix included complete simulation model and design under "Sim_Modle" folder and the complete simulation of the case study under "Sim_Cstudy" folder.

CD Attached

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