

**Load Stability Alarm for Non-Commercial Towing Applications
719005122010**

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Work performed at USC

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Abstract

This report explores the improvement of towing technology through the use of a load stability alarm. An accelerometer is used to detect the acceleration of a trailer in three different planes under various driving conditions. By analyzing this data thresholds will be created of acceptable acceleration values in all three planes of motion. If accelerometer reads data that is outside the acceptable limit for a long enough period of time an alarm will notify the driver to change driving behavior to prevent an accident. Currently there is no active load monitoring product such as the Load Stability Alarm for non-commercial purposes on the market. The device will be sold as a part of a trailer lighting and brake package and not as a standalone product. Selling the product through an existing distribution system and as part of products with which consumers are familiar with makes gaining access to the market easier and at a lower cost for the company. The market is large, as there are millions of towers in America alone, and the potential for profit is great.

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Summary

The Load Stability Alarm was designed to provide drivers with an active way of monitoring their tow load stability. The alarm works in a similar way to systems used in large commercial trucks (big rigs). Unlike commercial truck systems the Load Stability Alarm is a simple device requiring only a micro-controller and an accelerometer.

Current towing safety technologies and the consumer market were studied to determine if such a device could penetrate the trailer/towing market. Studies have discovered that accidents involving trailers have gone up in recent years and are caused by a general lack of towing safety knowledge, safety equipment failures, and tow vehicle driver error. The Load Stability Alarm aims to greatly reduce the number of traffic accidents involving trailers by providing towers with an advance warning system that will let them know there is something wrong with their load. The extra time provided by the early warning alarm allows the driver to take steps to prevent a dangerous towing situation from turning into a fatal accident.

Different driving maneuvers were performed during the test to expose the accelerometer to driving situations that may arise in real life. The data was collected along three different axis of motion and filtered to remove the 'noise' in the signal received by the accelerometer. The Fourier Transform of the data was also taken to determine the frequency of the motion exhibited by the trailer.

After analyzing the data from the one trial run performed it was clear that a device such as the Load Stability Alarm can actually work to prevent accidents. By plotting the data in MatLab it was easy to see parts of the graph that correspond to certain driving behaviors. Viewing these graphs allowed for a set of thresholds to be set; as long as the motion of the load/trailer is within the allowed thresholds the alarm does not go off. When excessive movement is detected the sensor goes through a process of determining when the alarm should sound. If the situation is deemed dangerous the alarm will go off and warn the driver.

Overall more tests need to be done to fine tune the calculated thresholds. The limited test runs and inability to perform certain driving maneuvers (ex. not able to tip trailer) prevented the sensor from experiencing everything it could encounter in a real world driving situation. More test runs where different driving scenarios are test will help reduce false positives (unwarranted alarms) and increase the effectiveness of the device.

The improved towing safety and ease of use are the two big marketing points that will ensure the profitability of the Load Stability Alarm. The relative low manufacturing cost, low overhead and large consumer market numbering in the millions will provide a high return on investment. Steps can also be taken to mandate the use of a Load Stability Alarm when towing due to improved highway safety which can ensure the success of the device.

1. Introduction

1.1 Concept

The basic concept of the Load Stability Alarm is to use an accelerometer to actively monitor load movement in towing applications. The accelerometer will be placed on the floor of the trailer and the movement of the entire load will be monitored along three axis. Data will be collected and simultaneously run through algorithms that will analyze the motion and determine whether or not it falls within certain, pre-programmed safe thresholds. In order to pinpoint these thresholds numerous test runs must be performed in which safe driving, and thus safe load motion, is exhibited. This will allow for a control to be developed against which all other data is compared to determine whether the motion in the load is safe or dangerous. After testing is complete thresholds will be set that will be used to alert the driver when movement of the load has become dangerous. The main purpose of this device is to provide the driver ample to time to change their driving behavior or perform maneuvers that may prevent an accident from occurring.

1.2 Target Consumer

Active towers are people who own a trailer hitch and tow various types of trailers (horse trailers, tool trailers, boat trailers, etc.). Currently, there is no data available on to how many people in the United States use their vehicles for towing purposes or actually own a trailer hitch. However there are over 8 million recreational vehicle owners in the United States alone. Many of those recreational vehicle owners use tow hitches to tow their day vehicles with them when they go on trips so they can use them once they reach their destination. There are also millions of camper owners in the United States. Campers are smaller than recreational vehicle and are towed by pick-up trucks or sports utility vehicles. These recreational users and the active towers are the main target consumers of the Load Stability Alarm.

The target consumers are **not** professional truck drivers. Their vehicles are already equipped with active load monitoring devices that are more advanced than the Load Stability Alarm. Users of the Load Stability Alarm are the average consumer and device pricing will follow as such.

Using the available data on recreational vehicle owners as well as estimates on the number of people who own trailer hitches based on earning reports from several trailer hitch manufacturers there are between 8 and 13 million target consumers in the United States alone.

2. Towing Technologies

2.1 Background Information

There are three major types of tow hitches which are used for towing loads for non-commercial purposes. Weight carrying hitches, weight distributing hitches and fifth wheel hitches are all available for consumers to buy and use to tow trailers and recreational vehicles. All three types of hitches can work with light and brake systems which provide hook up between the tow vehicle and the brakes and lights on the trailer. This can either be done manually on older vehicles or through a special pin connector on newer vehicles. This allows for the brakes and lights on the trailer to be controlled by systems in the tow vehicle. It is also important to note that the load is allowed to move independently of the steering, meaning that the load follows the tow vehicles and its wheels take no part in the actual steering of the vehicles. This leads to load behavior that is different from the tow vehicle and is a major contributing factor to accidents caused by load instability.

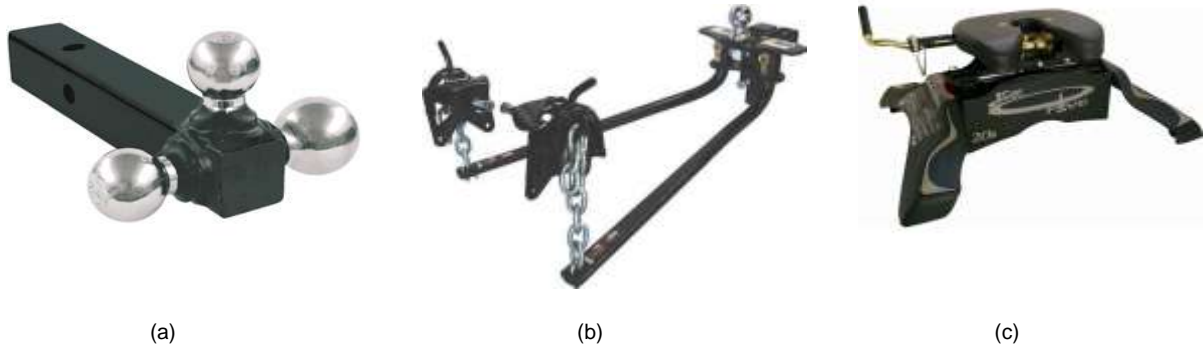


Figure 1: (a) Weight carrying hitch. (b) Weight distributing hitch. (c) Fifth wheel hitch.

2.1 Weight Carrying Hitches

Figure 1(a) is a photograph of a weight carrying hitch involve a trailer hitch receiver with a draw bar or ball mount on the tow vehicle that fits in to a coupler on the trailer. The ball mount part of the hitch is attached with a locking pin. The size of the ball on the ball mount determines the weight of the load that can be towed with this type of hitch. The junction of the ball mount and the coupler from the trailer creates a tongue. This tongue places the entire weight of the load on the axle of the trailer.

2.2 Weight Distributing Hitches

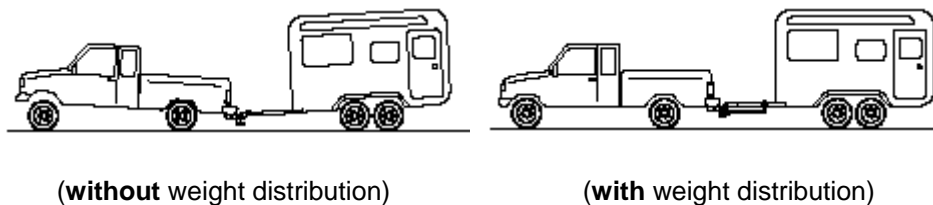


Figure 2: Diagram illustrating an unlevel load when towing without weight distribution versus a level load when towing with weight distribution.

Figure 1(b) is a photograph of a weight distributing hitch. The concept behind this hitch is basically the same as in weight carrying hitches with the main difference being in the weight distribution. The arms of the weight distributing hitch takes the weight pressing down on the tongue and distributes it to the axles of the tow vehicle as well as the trailer. The benefits of using a weight distributing hitch over a weight carrying hitch is that it stabilizes the load and prevents excess weight on the tongue which can lead to an unlevel load. This is illustrated in Figure 2. Other benefits of weight distribution hitches include better braking and handling as well as less strain on the tow vehicle and a greater tow capacity for the tow vehicle.

2.3 Fifth Wheel Hitches



Figure 3: Photograph of a pick-up truck towing a trailer using a fifth wheel hitch.

Figure 1(c) is a photograph of a fifth wheel hitch which is completely different than the other types of hitches. This is a special connector that is placed in the bed of a pick-up truck. In this application there is no tongue and most of the load weight is placed on the rear axle of the towing vehicle. This provides for more stable loads and a better overall weight distribution. Figure 3 is a photograph of a fifth wheel hitch application.

3. Hardware Architecture

Figure 4 is a photograph of the multi-sensor dongle device used to perform tests on the load stability in towing applications. The dimensions are 7.5 cm x 2.9 cm x 2.9 cm (length, width, and depth). The entire device is a combination of 5 sensors which measure different things. A 3-axis accelerometer MMA7260QT with sensitivity settings of 1.5 or 6 g, a pressure sensor MPXA4250A6U that uses a piezoresistive transducer, a light sensor TPS852, and a humidity and temperature sensor HTM1735 are all connected to a micro-controller PIC8F2410. Through the use of the micro-controller and USB connection to a computer data from the sensor can be acquired. For the purpose of the Load Stability Alarm only data collected by the accelerometer will be analyzed.

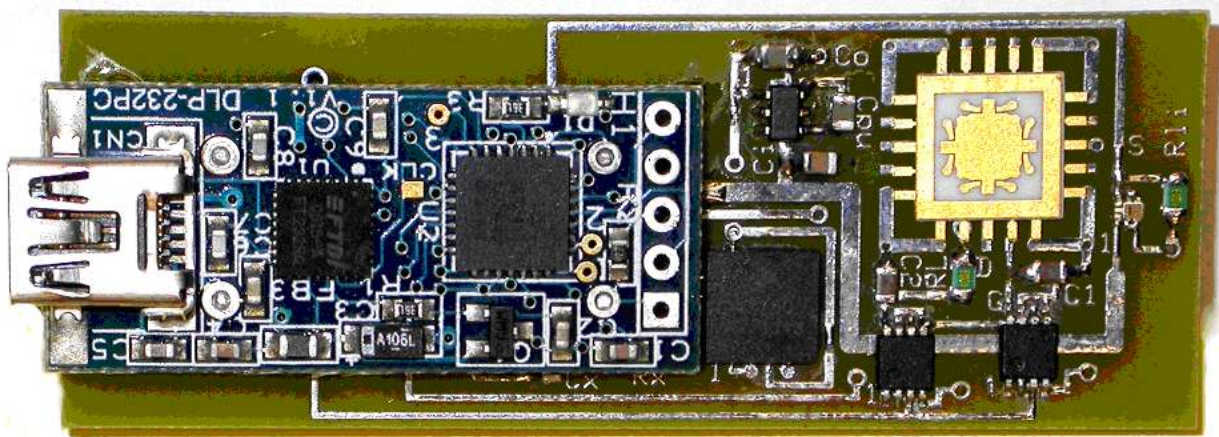


Figure 4: Photograph of multi sensor device used in testing. All sensors retrieved data during testing however for the purpose of this project only the accelerometer data was required and analyzed as outlined in the following sections. Note: The device is enclosed in a box to protect the circuitry from damage.

4. Software

The software required to run the dongle device is Matlab R2009b. The required Matlab code was provided and allowed for the collection of accelerometer data with the aid of a laptop. Once data was collected a .txt file containing the necessary data was created which was imported into Matlab for analysis. Data will be graphed and will show acceleration versus time along three different axis of movement. Various data manipulation calculations to be done using Matlab such as taking the Fourier Transform of the data or developing filters that reduce noise and enhance the data that is useful for the experiment. This allows for cleaner data that is mostly a result of the behavior of the load and not outside influences on the accelerometer. All calculations and graph renderings will be done using Matlab.

5. Testing Procedure

5.1 Testing Protocols

For the purpose of gathering data for this test the dongle device with the accelerometer was placed on the floor of the trailer and secured with tape. While it is known that the back of the trailer experiences a 'bumpier' ride (much like the last car in a roller coaster) the accelerometer was placed in the middle of the trailer in order to gain better data of how a balanced load would behave when put under certain stresses. These stresses amounted to performing various driving maneuvers with the tow vehicle that would simulate real world driving and the most extreme cases a driver would find himself in to see how the load would behave.

Data was collected the entire time the load was being towed. This may seem like an obvious point but it is crucial that the data from a complete run be gathered so the behavior of the load can be analyzed under all the driving conditions which are being tested. This means that if something went wrong during a run, such as the computer freezing where it could no longer gather data, the entire run was completed again. This is to protect the integrity of the findings which are justified by this data. For example if the computer broke down in the middle of a test run it would be difficult to determine whether or not the data is compromised. For this reason the entire run was repeated.

The movement of the trailer was analyzed in 3 separate planes of movement as outlined below. By analyzing the data it is possible to determine acceleration values which indicate unsafe load behavior that could be used to alert the driver before an accident can occur. Figure 5 is a photograph of the trailer used in this test. The trailer was empty when this test was conducted.



Figure 5: (a) Photograph of trailer used in this test.

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5.2 X-Plane

For this test the X-plane represents movement to the left and the right. This type of movement can lead to sway and eventual tipping. Hard swerves were taken in the tow vehicle to determine how it would affect the trailer and the overall stability of the load. While tipping could not be simulated sway can and this makes it possible to determine a threshold of acceptable sway that is still within the safe zone of movement in the X-direction. The X-plane is represented by the red plane in Figure 6.

5.3 Y-Plane

For this test the Y-plane represents movement backward and forward. Excess movement on this axis can lead to the tow vehicle being overtaken by the trailer. Also movement in the Y-Plane can be indicative of the load coming unhitched which can be very dangerous. This could not be simulated in this test. The Y-plane is represented by the green plane in Figure 6.

5.4 Z-Plane

For this test the Z-plane represents up and down movement. Trailer movement up and down indicates that the trailer is bouncing. If the load is not tied securely in the trailer this can lead to shifting of the load which can affect the stability of the entire load. If load becomes too unbalanced it could lead to tipping of the entire trailer. In order for the accelerometer to register a lot of movement up and down the trailer was driven over potholes and a curb during the test. The Z-plane is represented by the blue plane in Figure 6.

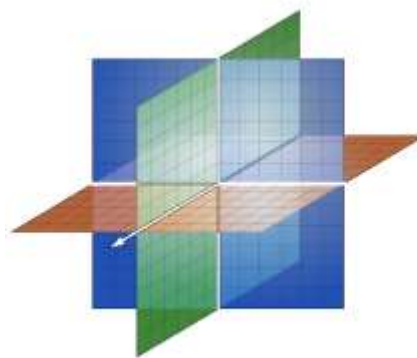


Figure 6: Diagram showing the X, Y and Z planes of movement.

It is important to note that movement in all three planes occurs at the same time and a combination of movement along all axis results in possible dangerous load stability problems.

6. Results

6.1 Raw Data

6.1.1 Raw Data Composite Graph

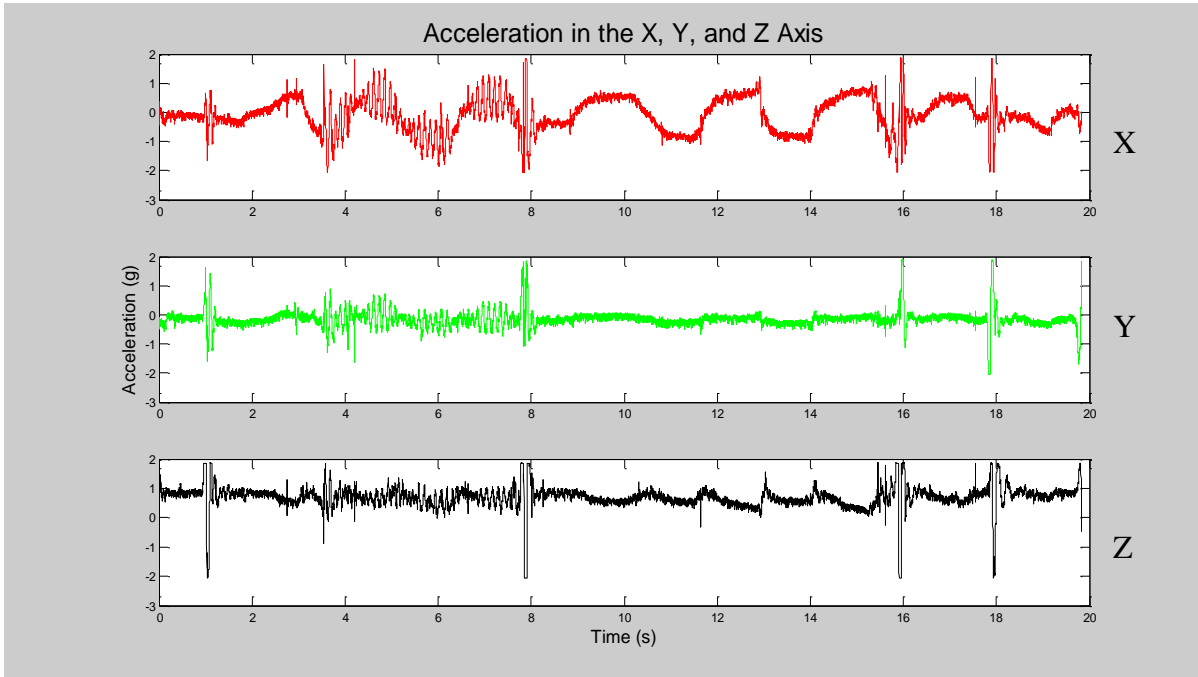


Figure 7: Graph showing a test run of the Load Stability Device. The raw data collected by the accelerometer is presented in all three axis (X on top, Y in the middle, Z on the bottom).

6.1.2 Raw Data Explanation

Figure 7 is a Matlab graph of the data collected by the accelerometer during the test run of the Load Stability Alarm that returned usable data. As can be seen there is a lot of motion along all three axis picked up by the accelerometer that was caused by the various driving maneuvers performed during the test. The large spikes in the graphs are times when the trailer was driven over large potholes. This was the most violent driving maneuver performed which cause the most motion in all three axis. The flat line in these spikes, or 'clipping', is due to the fact that the accelerometer was set to a sensitivity level of 1.5 g instead of the maximum 6 g that it is capable of. This was done because such large accelerations were not expected and other test runs with the higher sensitivity level could not be performed.

The rest of the 'Results' section is divided into subsections that analyze the motion in each separate axis. The data graphs presented are of filtered data. A moving average filter was created in Matlab and the data was run through it to remove some of the noise in the signal. Analysis was done on the filtered signal because using the filtered data will reduce the number of false positives and the alarm will only go off when the stability of the load is compromised.

The filtered data graphs also have the thresholds set to show how the micro controller on the device would determine whether or not to sound the alarm. Since only one test run was done these thresholds are not final and more testing needs to be done to determine their correct positions.

A graph of the Fast Fourier Transform is also provided and an explanation is provided as to why the data provided by the FFT is not needed in this application.

6.2 X-Axis

6.2.1 X-Axis Graph with Thresholds

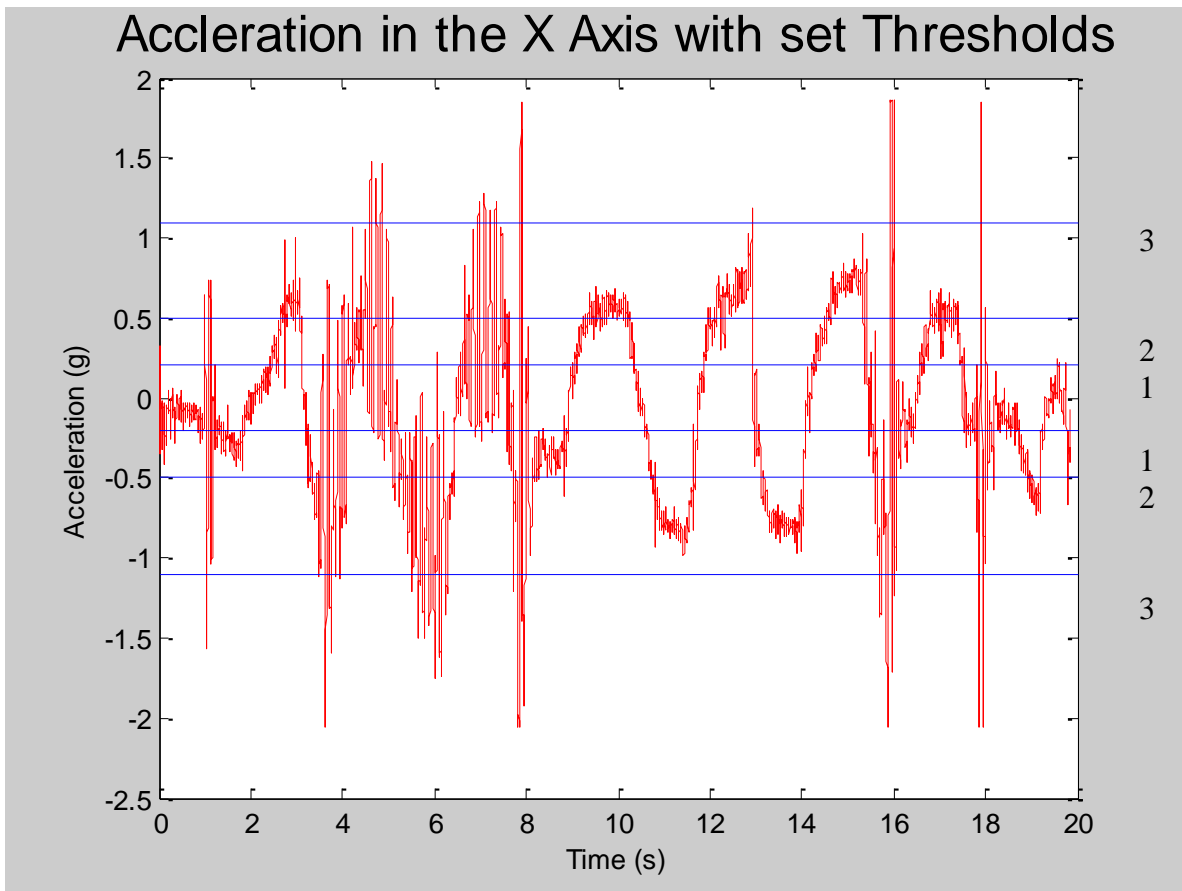


Figure 8: Graph showing the moving average filtered X-axis data with set thresholds. More testing needs to be done in order to determine proper thresholds.

6.2.2 X-Axis Motion Analysis

The X-axis represents motion from the left to the right. As seen by looking at the graph in Figure 8 there was a lot of motion in the trailer in this plane. For nearly the entire duration of the test run the tow vehicle was swerving from left to right in a violent manner to simulate dangerous driving behavior. This type of behavior is represented in the graph by the periodic up and down movement that is clearest between 9 and 15 seconds. From 4 seconds to 8 seconds the graph shows the trailer shaking from left to right in the hitch while it is also swerving with respect to the tow vehicle. This type of behavior can be attributed to driving through a 'rumble strip' (areas of the on the side of the road that are dimpled) while violently swerving. The large spikes in the graph correspond to times when the trailer was driven over large potholes. Seeing such large spikes in the side to side movement was initially unexpected but upon inspection it made sense that the up and down motion of driving over a pothole would propagate to the side to side movement when swerving while driving.

The thresholds set in Figure 8 are represented by the horizontal blue lines. There are three different thresholds that are set. The first is at ± 0.2 (labeled 1), the second at ± 0.5 (labeled 2), and the third is set at ± 1.1 (labeled 3). These thresholds dictate when the Load Stability Alarm indicating an unstable load. Threshold 1 is the first threshold of motion from the normal, which is a complete stop; no motion in the trailer. If the movement of the trailer causes an acceleration in the load that is greater than this threshold a timer begins keeping track of how long this time of motion is exhibited. If the motion goes

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back under this threshold or remains in between threshold 1 and 2 infinitely the alarm will not go off as this indicates a bumpy ride that is not necessarily dangerous in itself. If the acceleration is above threshold 1 for longer than 4 seconds and then moves up above threshold 2 that alarm will sound. This is called the 'primer' stage; the alarm is 'primed' to sound if the motion gets worse in. Setting this timer helps prevent the alarm from going off whenever the trailer is driven over a rumble strip; it creates a lot of motion in the trailer but it does not indicate a dangerous driving or load stability situation.

If the motion of the trailer causes a spike that passes threshold 1 and is in between thresholds 2 and 3 a timer is set again. This time if the acceleration values do not fall under threshold 2 in 2 seconds the alarm will sound. A shorter timer is used here because threshold 2 is more than double threshold 1 and can indicate rather dangerous load stability conditions. Whenever the acceleration of the trailer crosses threshold 3 the alarm will sound immediately. Large spikes above threshold 3 indicate a serious problem in load stability and immediate action by the driver is required. This can be caused by large potholes or a load that is not tied down and allowed to shift.

It is important to note that the values for the thresholds related here are not necessarily the proper values for a device that will be sold to consumers. The values here correspond to one test run and more tests are need in order to fine tune exactly what these thresholds should be to make the device more effective and allow it to actually work as a safety device.

6.3 Y-Axis

6.3.1 Y-Axis Graph with Thresholds

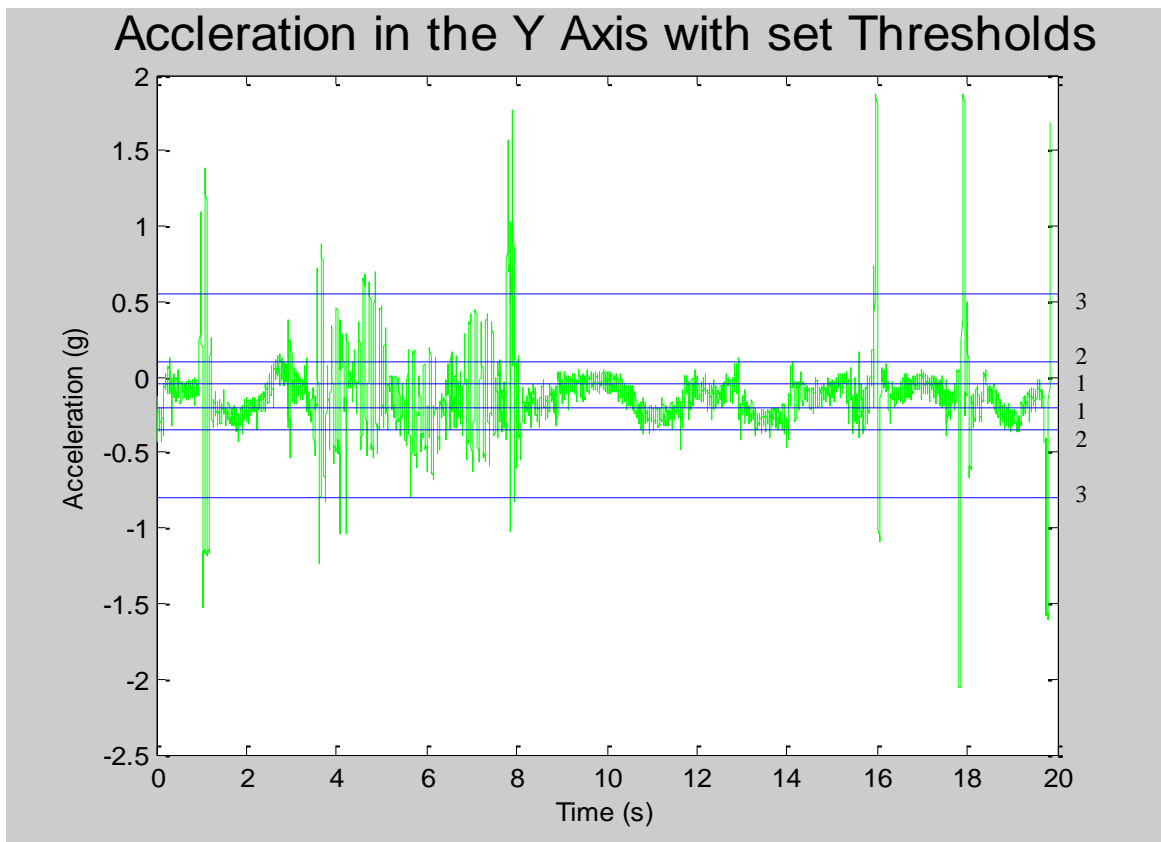


Figure 9: Graph showing the moving average filtered Y-axis data with set thresholds. More testing needs to be done in order to determine proper thresholds.

6.3.2 Y-Axis Motion Analysis

The Y-axis represents motion forward and backward. As seen by looking at the graph in Figure 9 a lot of the motion along the X-axis translated in to motion in the Y-axis. While the patterns in the motion are the same it is important to notice that overall the acceleration measured in the Y-axis is much less than the acceleration measured in the X-axis. Nearly all of the peaks are considerably lower than in the X-axis graph with just the large spikes measuring nearly identical. This is because motion backwards and forward in the trailer is very hard. There is no play in the hitch meaning that the coupling between the trailer and the hitch on the tow vehicle is very tight. This is expected because the trailer is not supposed to be able to overtake the tow vehicle while towing. Brake kits and tow weight ratings are meant to prevent this from happening. If this were to happen an accident is almost certain to occur.

Since overall the acceleration is condensed the threshold levels are lower than X-axis levels. The first is at -0.05 and 0.2 (labeled 1), the second at -0.35 and 0.1 (labeled 2), and the third is set at -0.8 and 0.55 (labeled 3). The average of the data collected in the Y-axis was not at 0 so the thresholds were set for the normalized 0 of -0.125 . The three thresholds are symmetric around this -0.125 and follow a pattern similar to the thresholds set for the X-axis. The alarm aspect of the Load Stability Alarm will work the same way in the Y-axis as it does in the X-axis.

6.4 Z-Axis

6.4.1 Z-Axis Graph with Thresholds

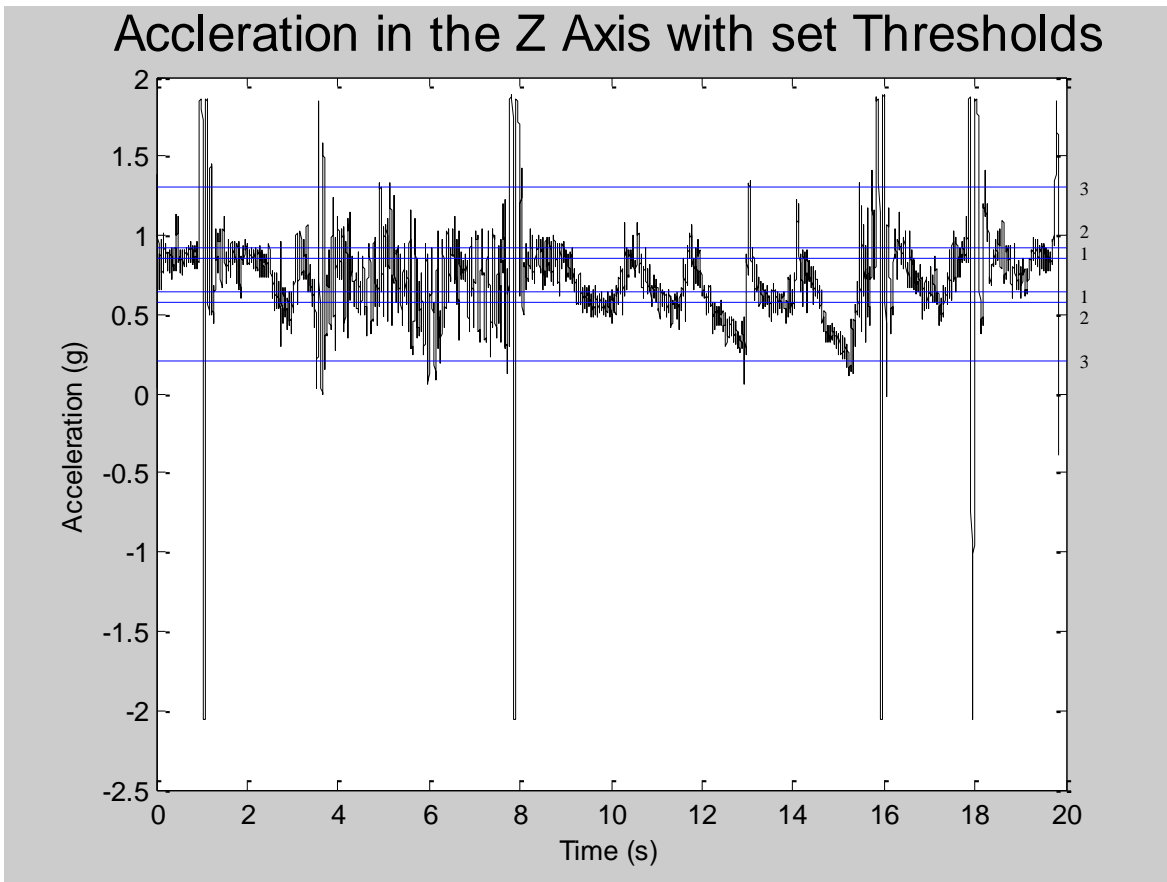


Figure 10: Graph showing the moving average filtered Y-axis data with set thresholds. More testing needs to be done in order to determine proper thresholds.

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6.4.2 Z-Axis Motion Analysis

The Z-axis represents motion upward and downward. Again it is possible to see that overall the acceleration followed the same general pattern as in the X and Y-axis. There was more acceleration along the Z-axis than along the Y-axis which was expected as much of the test involved driving over rumble strips and potholes. All of the imperfections in the road clearly translated in to the data provided by the accelerometer. The potholes clearly had an effect on the load stability as all of the spikes in the graph are large and have hit the point of clipping. This was expected as more up and down motion is generated when driving over a pothole.

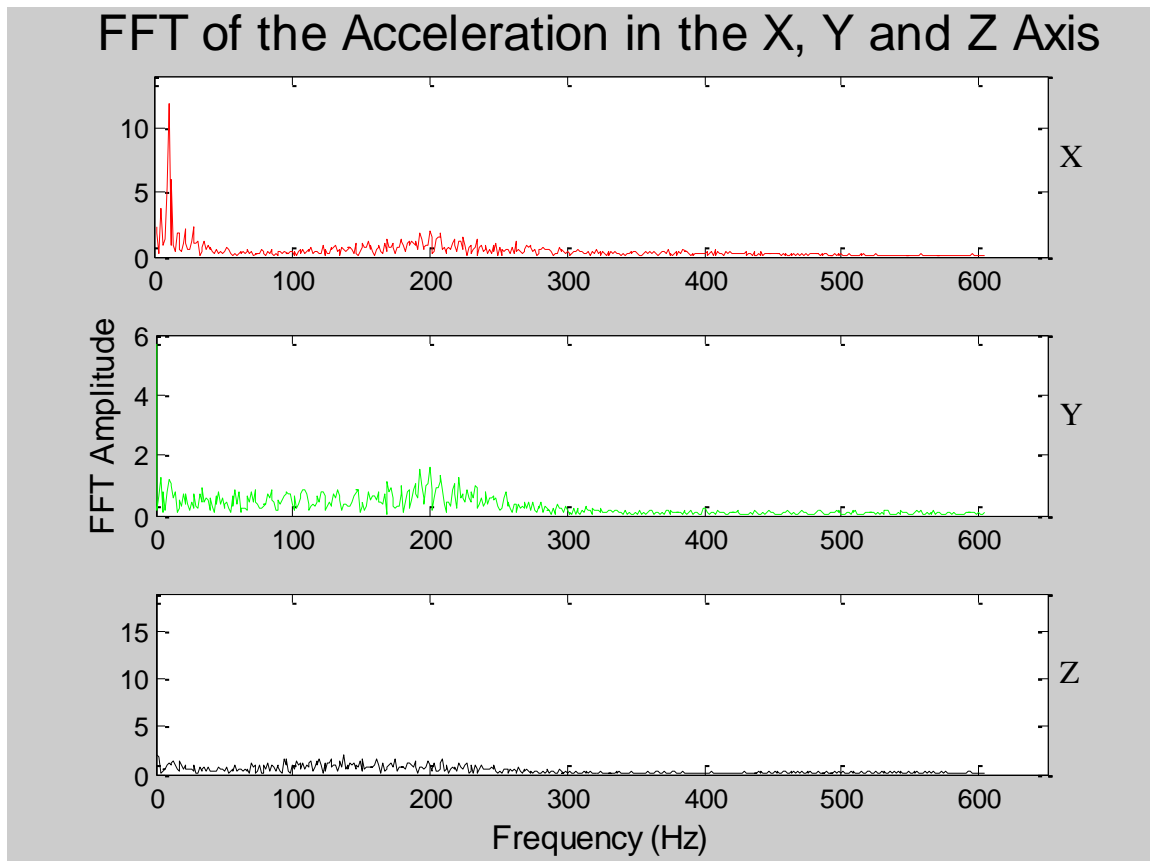
As with motion in the X-axis, motion in the Z-axis is most dangerous. Going over potholes causes shifts in the load and the bouncing of the trailer can cause it to come unhitched if it is not secured properly. This can create a dangerous driving scenario where motion in the Z-axis lifts the trailer from the hitch at which point the trailer's momentum in the Y-axis cause it to become unhitched and an accident in the making. These types of scenarios are what the Load Stability Alarm strives to prevent.

Again, the acceleration values are more condensed than in the X-axis so the threshold levels are different in the Z-axis however they still follow the same pattern as the ones in the X and Y-axis.

Since overall the acceleration is condensed the threshold levels are lower than X-axis levels. The first is at .85 and .65 (labeled 1), the second at .92 and .58 (labeled 2), and the third is set at .2 and 1.3 (labeled 3). The normalized 0 for the Z-axis is at .75. The Load Stability Alarm will work the same as at the previous two axis.

6.5 Fourier Transform

6.5.1 FFT Composite Graph



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Figure 11: Graph showing the FFT of the raw accelerometer data. The FFT is presented in all three axis (X on top, Y in the middle, Z on the bottom).

6.5.2 FFT Analysis

The Fast Fourier Transform of the accelerometer data is presented in Figure 11. The graph shows the different frequencies at which the trailer vibrated during the test run. Besides the large initial spike, indicating a low frequency vibration, there are no real patterns that transcend all three axis. This is of no concern as the frequency at which that trailer vibrates does not matter in the design of the Load Stability Alarm. The alarm is set off by acceleration readings. We are concerned about any motion in the load not at what frequency this motion occurs.

7. Design/Experiment Limitations

The main experiment limitation is the fact that there is only data from one run that can be analyzed. During the initial test day two runs were performed however halfway through the first run Matlab froze and the data could not be used. The second run was a complete 20 second run and that analysis was performed on this data set. Since access to the trailer was limited no more trials could be performed to see if the data can be duplicated. However from this one trial it is possible to see that the data is viable as there are no anomaly spikes and the behavior of the graph coincides exactly with what was physically done with the trailer and tow vehicle.

Another limitation of the experiment was that the trailer was empty except for the accelerometer and a laptop computer. To see the true effectiveness of the Load Stability Alarm the accelerometer must be placed in a loaded trailer because an empty trailer behaves differently than one that is carrying a load. A trailer that is loaded has a different center of gravity and would tip easier. Because of this more sway should be noticed by the accelerometer as well as more up and down movement attributed to a higher overall total weight of the trailer. Trials should also be performed to distinguish the difference between loads that are securely tied down and loads that are allowed to move inside the trailer (ex: a vehicle that is tied down to a trailer versus a trailer filled with unsecured boxes).

The test was also done on only one type of trailer hitch, the weight carrying trailer hitch. The data collected from the test run shows that active load stability monitoring is possible and that it would be beneficial to implement in towing applications. In order to justify the use of the Load Stability Alarm on all types of hitches tests should be done on trailers that are pulled by weight distributing hitches and fifth wheel hitches. That being said it is unlikely that different behavior patterns will arise; the change from hitch to hitch will be the thresholds of acceptable load behavior.

The last major limitation of this design is that it provides for a way to measure the angle of the trailer with respect to a vertically skyward point vector. The accelerator is capable of measuring this however when the test was performed the Matlab code that is used to calculate the angle of the accelerometer with respect to the vertical vector was not working. As a result the angle at which the trailer departs from the vertical could not be measured. Testing with this "Joystick" code will allow for setting a threshold angle at which the trailer can tip before the alarm goes off. This will provide another monitoring system that will benefit the driver as well as help prevent false positives from occurring by increasing the number of thresholds that must be crossed before the alarm goes off. Finding this threshold, which requires finding the true tip point of the trailer, is past the scope of this experiment as the resources required to actually tip a trailer are unattainable at this level.

8. Marketability



Figure 12: Photograph of utility trailers. Consumers who purchase these types of trailers are target consumers of the Load Stability Alarm.

As stated in the introduction the sensor will be packaged and sold for non-commercial towing applications. Figure 12 is a photograph of a trailer for which the Load Stability Alarm is intended to be used. The reasoning behind only marketing the Load Stability Alarm to the average tower/consumer is that commercial trucks (big rigs) already have active load monitoring capabilities that are much more advanced than what the Load Stability Alarm offers as it employs both sensors in the truck and on the road to verify load stability. The potential market for this device is large as there are millions of Americans who actively tow and who could benefit from such a device. The potential for profit is also large as the device is relatively inexpensive to manufacture while it provides a service which can prove to be invaluable to users.

8.1 Load Stability Alarm – Prevention of Accidents

As depicted in Figure 13 accidents involving trailers can be dangerous and cause damage that amounts to millions of dollars of property. While accidents that only involve property damage are the most common type of accident involving trailers there are also accidents that lead to injuries and fatalities. According to a 2006 study by the MasterLock company in 2004 there were more than 65,000 crashes on America's roads involving non-commercial towing vehicles. As a result 422 deaths and 27,232 injuries were reported in 2004 alone. There were also 46,737 accidents where only property damage occurred. The data for 2004 represents an increase of 20% of towing vehicle accidents when compared to the data from 2003. Out of all the accidents involving trailers in 2004 27% resulted in injury while 72% resulted in property damage only.¹

The high accident numbers can be attributed to consumer error. According to the same MasterLock report one in five trailer owners experienced a safety incident in 2004 ranging from fishtailing to loss of cargo. This is due to poor driving technique and behavior while towing and a general lack of knowledge when it comes to towing applications. The report also found that 71% of owners did not know what proper towing procedures are while 75% of owners said their knowledge of towing procedures was based on past towing experience which boils down to trial and error.¹ One startling fact uncovered was that only 13% of received towing information when purchasing a new trailer. This amounts to millions of unknowledgeable people on America's roads towing trailers in unsafe and dangerous ways. With the popularity of trailers growing the number of accidents is more than likely to go up if the public is left uneducated.

¹ MasterLock. *2006 Towing Troubles: Danger on America's Road*. MasterLock, 26 June 2006. Web. 25 Apr. 2010. <http://www.masterlock.com/automotive/pdf/Towing_Troubles_2006_B.pdf> 2.

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The biggest selling point of the Load Stability Alarm is that it can be used prevent accidents. Since in recent years accidents have been on the rise the device can be used to curb this pattern. The device would allow for advance notice to be given to the driver about the stability of the load allowing for corrective driving maneuvers (or even stopping the car to check the load, whichever is applicable to the situation) if a problem presents itself. This will drastically reduce the number of accidents on America's roads. Take in to consideration the fact that most towers are uneducated about safety procedures this device is a failsafe safety measure which cannot be over looked. The loud alarm will not go off until the device registers that the load is again behaving within the acceptable limits or the driver stops and adjusts the load. The Load Stability Alarm will become an invaluable device to towers and will become the most important safety device for towing applications.



Figure 13: Photograph showing an overturned trailer. Thousands of trailer accidents each year cause millions of dollars worth of property damage.

8.2 Load Stability Alarm – Ease of Use

The second selling point of the Load Stability Alarm is that zero calibration is required by the consumer. The device will be tested on all three types of commonly used trailer hitches (weight carrying, weight distributing, and fifth wheel hitches) and all of the calibration (such as setting the allowed motion thresholds) will be built in to the device. This does two things; it makes the device easy to use and install and it makes it more effective. By providing an enclosed device which does not require the consumer to do anything to make it work makes it extremely easy to use. The public cannot be expected to know how to calibrate the device by themselves. Allowing the consumer to do that would result in accidents from user error and greatly reduce the effectiveness of the device as a stability alarm. Not allowing the consumer to calibrate the device will also prevent lawsuits from being leveraged against the company when consumers experience accidents which they wish to blame on a faulty Load Stability Device. Tampering with the device in way would invalidate the warranty and the company will not be held responsible for damages occurring as a result of using a non authorized device.

Having the software preloaded on the device and the thresholds already set for each type of hitch makes the device more effective as countless hours of research went in to testing and determining what the thresholds are. If the consumer was required to set their own thresholds none of them would spend enough time to do this. Testing procedures that were performed by engineers could not be replicated by consumers and it would be impossible for the consumer to determine acceptable motion thresholds as

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precise as the engineers. Allowing the consumer to program their own device would defeat the purpose of the Load Stability Alarm and would not help reduce the number of accidents involving trailers.

8.3 Load Stability Alarm – Other Marketing Points



Figure 14: Photograph showing a trailer brake and light kit. The Load Stability Alarm will be incorporated into such kits and sold as a total package.

A major benefit of manufacturing the Load Stability Alarm is that a distribution system is already in place. Figure 14 is a photograph of a trailer and brake light kit. The device will be manufactured as an added component of kits like this and sold as complete units. The Load Stability Alarm will not be sold as a standalone product. This is because the lack of a distribution system and the difficulty this will present to consumers to add to their trailer and tow vehicle would not generate enough profit to make this a feasible option.

Working with insurance companies to lower the insurance rates for consumers who use the Load Stability Device is another important marketing point. This will make purchasing the device attractive to consumers as it will save them money in the long run. It should not prove difficult to establish partnerships with insurance companies. Showing the insurance companies data on how the Load Stability Alarm can increase driver awareness of load behavior and how this can be used to prevent accidents it will become clear that it would save them money by reducing the number of accidents and insurance claims filed each year. The savings they would experience would be passed down to their customers and would result in a partnership where everyone will benefit.

9. Conclusions

The test run performed during this experiment proved that an accelerometer and micro-controller can be used as an active load monitoring system. The Load Stability Alarm concept device was able to recognize motion in all three axis and clearly relate the physical motion of the trailer to acceleration in the three axis. Analysis of the data provided by the accelerometer showed that the trailer is experiencing tremendous force and accelerations in all directions caused by driving behavior as well as the environment (ex. road surface, type of hitch, etc.). This can lead to load shifting or even tipping of the entire trailer. The magnitude of the accelerations showed that this was possible and this proves that a device such as the Load Stability Alarm would be beneficial to towers.

While this test proved to be an effective demonstration of the concept more experiments must be done in order to determine the proper thresholds. There are driving behaviors that were not tested during the test run that should be in order to have an effective device. Before the device can be sold testing must be done on all three types of hitches. Since weight is distributed differently by each hitch and this affects the movement of the load and trailer the thresholds for each type of hitch will be different. It would be irresponsible and unethical to either test on only one type of hitch or to average out the data from the different types and sell one product. Three different products must be sold for each different hitch.

Overall the Load Stability Alarm is a device that can be industry changing. It has the potential to change how people tow for the better. It will reduce the number of deaths on the road each year as well as save millions of dollars in property damage. The extra few seconds the alarm can provide is can prove to be essential in accident scenarios. While implementation of the device does not mean that the public will be more knowledgeable about towing safety or procedures it does add an early warning system that can tell the public when something is wrong. Instead of having an uneducated public blindly towing trailers in potentially dangerous ways the Load Stability Alarm will be the eye on the load the public needs to make towing safer.

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11. Distribution list

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