Automotive Wheel Alignment Sensor System

Project Proposal

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Table of Contents

1.0 Introduction

1.1 Statement of Purpose

The efficiency of automobiles is a very prevalent topic in today's society. With the push for green technology and the constant need to optimize every existing system, a system that can identify when a car is out of alignment is necessary. Vehicles out of alignment experience reduced performance; by being out of alignment, a vehicle can have up to ten percent lower fuel efficiency. In addition, the wear on the tire tread is a resource cost, since rubber is a finite resource and also leaves a carbon footprint.

1.2 Objectives

Goals

- Create a system that can detect static alignment issues.
- Create a system that can measure dynamic fluctuations in alignment.

Functions and Features

- Simulated infotainment system to view collected alignment data.
- Can prompt user when car is out of alignment by a significant enough margin.

2.0 Design

2.1 Block Diagram

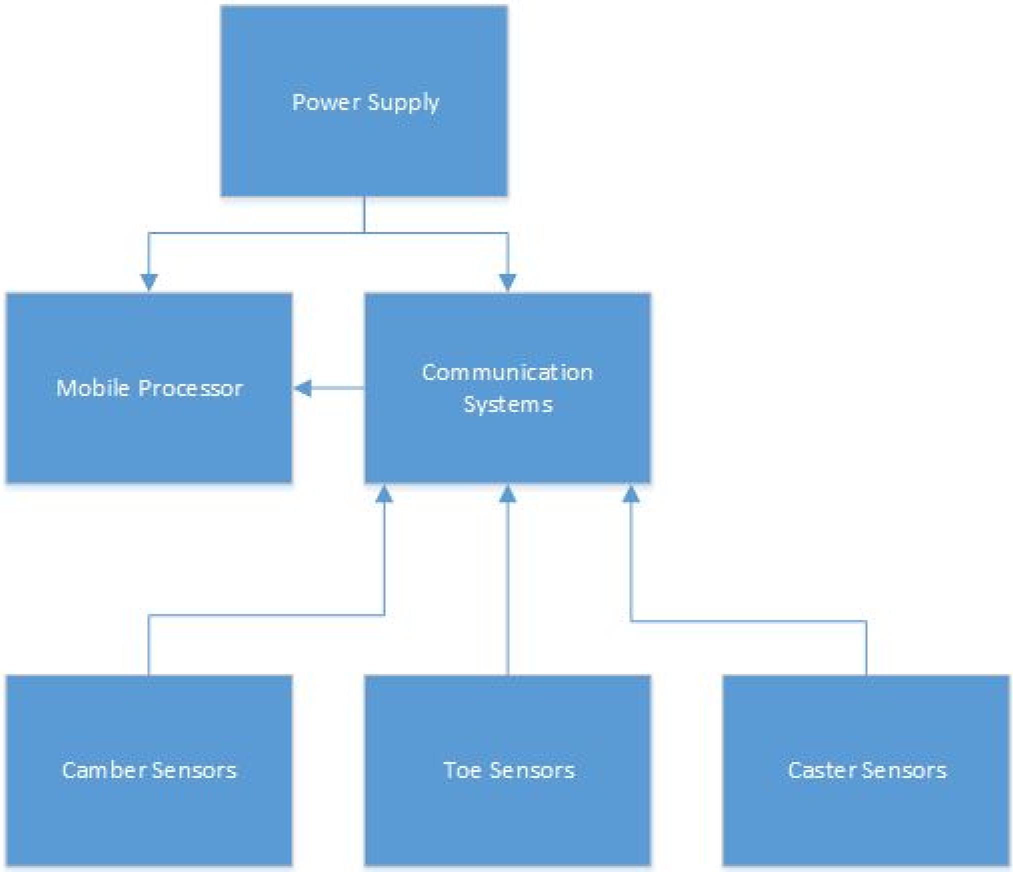

Figure 1: Hardware Block Diagram

2.2 Block Descriptions

2.2.1 Power Supply

This module will supply the voltage to the entire system. It consists of a 12V car battery that will be regulated by a linear regulator to step the voltage down to a 5V stable value. Power will only be supplied to the devices when the car is on or in accessory mode.

2.2.2 Mobile Processor

This module will consist of an ARM processor that will run all of the code in order to collect and calculate the results of the sensor measurements. This block will be implemented on a smartphone in order to simulate how the system would look from the viewpoint of an infotainment system. The Mobile system will make use of its onboard ADC to convert any incoming signal into usable digital data.

2.2.3 Communication Systems

The communication system will consist of a transmitter that will convert the digital signals from the sensors to an analog signal that will be transmitted to the Mobile Processor for conversion back to a digital signal and handled.

2.2.3-Tx Transmitter

The communication system will be a custom transmitter that will take the signals and transmit them at different carrier frequencies as to not overlap the signal. The transmitter will send the information at 4-ary bit pulse amplitudes at 1 Mhz.

2.2.3-Rx Receiver

The receiver system will consist of an antenna that is matched to the transmitter in order to take in all of the carrier frequencies that are transmitted. This receiver will then pass the information through to the Mobile Processor for further analysis and analog to digital conversion.

2.2.4 Camber Sensors

Each sensor will consist of a 3-axis accelerometer to measure the angle of inclination of the wheel in order to provide data about when the car is static and when the car is in motion. By differencing the acceleration of the tire and the acceleration of the wheel hub the camber can be calculated. A resulting difference of near zero will correspond to an aligned camber. Each sensor will be connected to a transmitter.

2.2.5 Caster Sensors

Each sensor will consist of a 3-axis accelerometer to measure the orientation of each individual strut. By comparing the orientation of the accelerometer to the orientation of a chassis-mounted accelerometer, caster can be determined. Each sensor will be connected to a transmitter.

2.2.6 Toe Sensors

Each sensor will consist of a 3-axis accelerometer that will measure the angle at which the tires point inwards towards the frame of the car. By comparing the orientation of the accelerometers to the orientation of a chassis-mounted accelerometer, static toe can be determined. When the car is in motion, the sensors will work by calculating the difference between wheel and chassis acceleration. Each sensor will be connected to a transmitter.

3.0 Requirements and Verification

System Component and Requirements	Verification
Power Supply 1) Transforms car battery voltage to 5V +/- 5% for sensor and mobile processor power.	1) Verification process for Item 1: (a) Check power supply output with multimeter with (i) car engine off & accessory power on and (ii) car engine on & accessory power on to verify voltage level meets requirement.
Mobile Processor 1) Executes alignment system software.	1) Verification process for Item 1: (a) Turn car accessory power on. (b) Start software. (c) Check that software runs without critical errors.
Communication Systems 1) Central receiving antenna receives sensor data from all transmitting antennas up to 10 feet away.	1) Verification process for Item 1: (a) Place sensor transmitting antennas 10 feet away from central receiving antenna. (b) Turn car accessory power on. (c) Start software. (d) Check that software runs without data transmission errors.
Camber Sensors 1) Sensors measure camber to +/- .005° from actual value.	1) Verification process for Item 1: (a) Turn car accessory power on. (b) Start software. (c) Note camber values. (d) Measure camber values manually or at an alignment shop. (e) Compare values.
Caster Sensors 1) Sensors accurately measure caster to +/- .005° from actual value.	1) Verification process for Item 1: (a) Turn car accessory power on. (b) Start software. (c) Note caster values. (d) Measure caster values manually or at an alignment shop. (e) Compare values.

Toe Sensors 1) Sensors accurately measure camber to +/- .005° from actual value.	1) Verification process for Item 1: (a) Turn car accessory power on. (b) Start software. (c) Note toe values. (d) Measure toe values manually or at an alignment shop. (e) Compare values.

4.0 Tolerance Analysis

The most important block of the design is the camber sensors. In order to have a robust system, the sensors must be able to withstand 260g of force. This calculation allows for 1% of error tolerance in calculations an extraneous forces acting upon the car. It must also be noted that 6g of random force acting upon the car is a tremendous amount of force and in addition the margins chosen for the calculation were on the generous side. This is calculated by defining the sensor to be placed 2.5 inches away from the center of a 16 inch wheel and for the car to be traveling at 90 mph. This calculation is a follows:

2.5 in = .0635 m
90 mph = 40.23 m/s
16 in = .4064
Circumference = $\pi(.4064)$ = 1.28 m
Angular Velocity = $\frac{40.23\ m/s}{1.27\ m}$ = 31.51 rad/s
Force on Sensor = $\frac{2\pi(31.51)^2(.635)}{9.8}$ = 254g
Error Tolerance = $\frac{254}{260}$ = 1%

5.0 Cost and Schedule

5.1 Cost Analysis

5.1.1 Labor

Name	Hourly Wage	Hours Worked	Subtotal	2.5 X Subtotal
Isaac Kousari	$31.85	250	$7962.50	$19,906.25
Michael Danek	$31.85	250	$7962.50	19,906.25
Total		500	$15,925.00	$39,812.50

5.1.2 Parts

Item	Quantity	Cost
3-axis accelerometer	13	$104
Mobile Processor	1	(user supplied Android device)
TE Connectivity Antennas	13	$9
Misc. Mounting Hardware	1	$15
Misc. Passive Electronics	1	$5
Total		$133

5.1.3 Grand Total

Labor	$39,812.50
Parts	$113
Total	$39,945.50

5.2 Schedule

Week	Task	Delegate
9/19	Finalize Design Requirements	Isaac Kousari
	Finalize Design Requirements	Michael Danek
9/26	Sensor placement and angle optimization	Isaac Kousari
	RF antenna communications and optimization	Michael Danek
10/3	Design sensor network for each block	Isaac Kousari
	Design Power Regulator for 12VDC to 5VDC conversion	Michael Danek
10/10	Create diagnostic software for running background systems	Isaac Kousari
	Signal Processing analysis and ADC/DAC programming	Michael Danek
10/17	Initial implementation and testing	Isaac Kousari
	Initial implementation and testing	Michael Danek
10/24	System redesign if necessary/ physics modeling & programming	Isaac Kousari
	System redesign if necessary/ finalize Tx/Rx design	Michael Danek
10/31	Preliminary Assembling and Testing	Isaac Kousari
	Preliminary Assembling and Testing	Michael Danek
11/7	Port software to Android	Isaac Kousari
	Data Statistics and Normalization	Michael Danek
11/14	Testing and Debugging	Isaac Kousari
	Testing and Debugging	Michael Danek
11/21	Optimization and Finalization	Isaac Kousari
	Optimization and Finalization	Michael Danek
11/28	Final Demonstration	Isaac Kousari
	Final Demonstration	Michael Danek
12/5	Final Presentation	Both