Gyroscopic Roller Alignment Tool

Design Document

DEC13-05

Ted Beem
Ellen Laird
Aaron Peterson

Table of Contents

Executive Summary

This document is a composition consisting of the many steps involved in the design, development and final implementation of the Gyroscopic Roller Alignment Tool, which will be used in order to more accurately calibrate the orientation in space of the various components of roller-based assembly machinery, thereby preventing compounded error and allowing for more efficient production. The tree major elements which work together to form this system are the Code Design, the PCB Design, and the User Interface Design.

Code Design

As the alignment tool is designed for use both as an independent embedded system and in conjunction with a computer-based client program, the code for this project will need to be modular in nature, with clearly-defined overall organization based on certain components' dependencies on one another.

Circuit Design

The hardware of this tool will consist of three gyroscopes connected to a microcontroller. Each gyroscope will be placed at a different position in the tool in order to provide better detection of variations in position. The output of each scope will input to the microcontroller which will determine misalignment based on a previously stored value for pitch and yaw. These readings will be displayed on an LCD directly on the tool and sent through USB to a computer user interface. All components will be supplied with power via a battery directly on the tool. There will be a power switch which allows current to flow to the components. There will be two buttons next to the screen to be programmed for a 'capture' function and 'zero' function. The necessary components will be added to the circuit to drop input voltage to needed levels. The PCB will be designed using MultiSim and a gerber file will be generated to allow for manufacture of a two layer PCB.

User Interface Design

The User Interface will be used as a way for the user to receive and store all information for a current system of rollers, so that the user can access all information collected by the tool over a recent period. The user interface system will use this information to provide graphs of all rollers' offset compared to the master roller and update these graphs in real time.

This interface will be based on a laptop or desktop computer running a Windows environment and will communicate with the tool via a USB connection.

Physical Design

The physical part of the tool will be 12 inches long and 4 inches wide. It will be in the shape of a chevron, an upside-down V, and will have little legs on the end to balance on rollers with diameters to fit inside the chevron. The tool will be made out of a metal, either steel or aluminum depending on further testing, and the tool will be strapped on to the roller by bungee cords. The tool will be designed in AutoCAD and will be manufactured in house by Powerfilm Inc.

Definitions

Master Roller – The roller that the alignment tool is calibrated to.

Zero – Set the gyroscope reference position to the current orientation.

Roll – Rotation of a system about the X axis

Pitch – Rotation of a system about the Y axis

Yaw – Rotation of a system about the Z axis

PROPOSED SOLUTION

The tool will work such that it will be placed on a master roller and zeroed to that alignment. It will then be subsequently moved to each additional roller in the line and will display how the orientation of the gyroscopes has changed due to the alignment differences between the master roller and the current roller.

It will display a live feed on an LCD screen and also have a hookup to a computer through USB. There will be buttons on the tool so that it can be used independently of the computer.

Goals

In order to accomplish the completion of the alignment tool, the team will construct the physical design of the system and its associated software in tandem. This will be done through a succession of stages as follows:

Stage 1: Finalize hardware and software designs
- a. Obtain circuit components and define interfaces
- b. Determine component connections and design layout

Stage 2: Develop a mock-up product
- a. Implement connection from hardware to software
- b. Create a basic computer interface to display output

Stage 3: Interpret readings from environment
- a. Implement capture of gyroscope information
- b. Display live, processed measurements with calculations
- c. Create graphic system for displaying graph of input

Stage 4: Enable tool autonomy
- a. Implement input/output to and from LCD and hardware input
- b. Manage internal memory usage

Stage 5: Refine tool
- a. Design and execute testing methods for software and real-world implementation
- b. Design interface to better suit user needs

For the purposes of this project, the team will be sub-divided into three, with each sub-team focusing on one of the major components discussed in the executive summary.

Deliverable Product

The final projected product will be an alignment tool specifically designed for use with machine rollers, based on a battery-powered microcontroller. The device will perform all measurements with the guidance of multiple on-board gyroscopes which will be calibrated to a single roller for comparison. The alignment tool will be able to output its reading to a client program on a separate computer system via a USB connection, which will in turn be able to capture the device output and graph this saved information.

SYSTEM DESIGN

Requirements

As specified in the project plan, the device will need to fit within certain size constraints (twelve inches long, four inches tall and four inches wide) in order to most effectively fit within its operating environment. The device will need to be able to attach itself to each roller in a secure and stable position so that the tool can be said to be reliably aligned with the roller's axis of rotation, which will be accomplished through the use of a triangular base and multiple straps to fit various sizes of rollers.

The system will detect its current orientation through the use of three gyroscopes in conjunction with a central microcontroller. All circuit components will be mounted on a flat surface and protected by an outer shell, with these components connected to the client computer through a physical interface to provide more reliable communication. This system will also need to cost less than $500 to construct and cannot be reliant upon a line of sight with the nearest roller. The system will need to be accurate within 0.8 degrees over a distance of 30ft. and must be able to provide reliable calculations regardless of its current pitch.

Functional Decomposition

The system must be able to collect a stream of real-time information about its current orientation and compare it with a single saved measurement, to which the system will compare all other information. The microcontroller will be able to gather and process this data and output it to an LCD screen as well as receive physical user input so that the tool may operate independently of a computer program. The client program will be able to handle memory of multiple captured device outputs simultaneously and use these to form a graph in real time consisting of a visual representation of each individual roller's offset relative to the master roller.

System Analysis

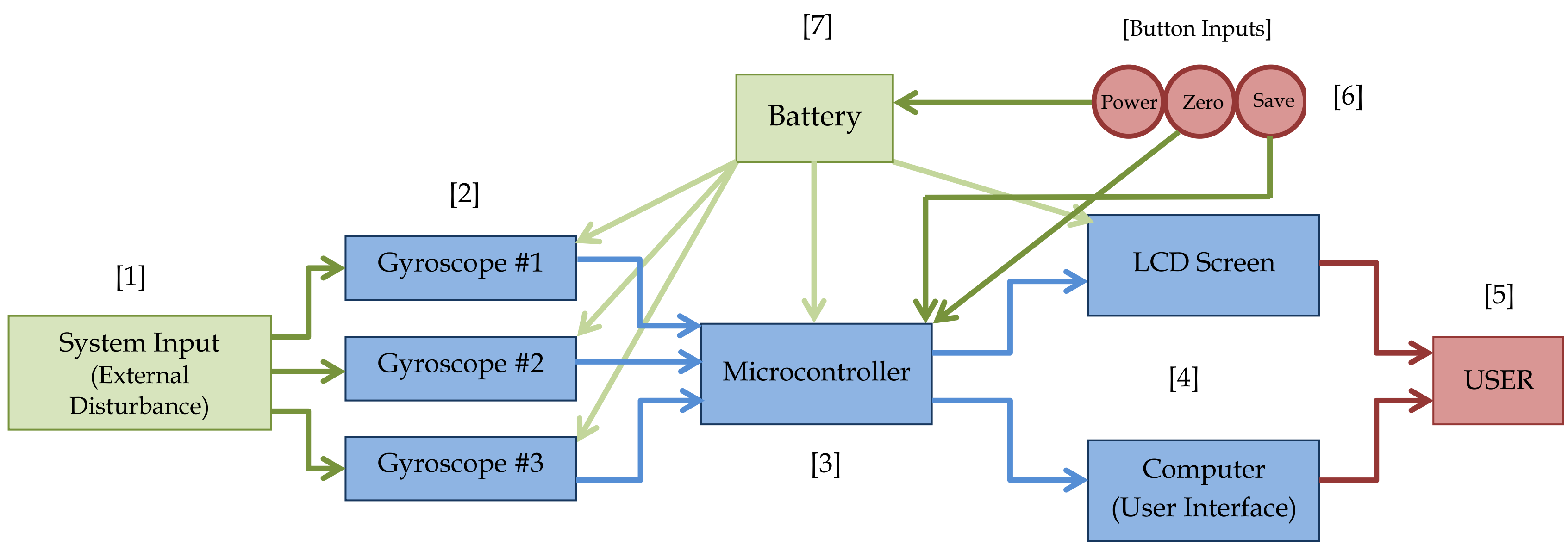


Figure 1: System Design

[1] System Input The tool will be first placed on a master roller with the axis of the tool aligned with the axis of the roller. The user will press the 'Zero' button and the tool will take its current position and refer to that measurement as the 'zero' position.
Once this has been done the tool will be moved to subsequent rollers. The difference in orientation between rollers will be the external disturbance for the system input.

[2] Gyroscopes There will be 3 gyroscopes in the system. Their function is to take measurements of external disturbance, created by the tool being moved from one roller to the next, and send these readings on to the microcontroller.

[3] Microcontroller The microcontroller will be the heart of the system. It will take readings from the gyroscopes, the button inputs, and the computer. It will calculate an average value for the pitch and yaw readings from each gyroscope so that instead of having six different readings the user will receive two.
From the gyroscopes it will take the values they measure and display how far from the last zeroed position the tool is currently.
The microcontroller will receive input from the button inputs, 'Zero' and 'Save'. When the 'Zero' button is pressed the microcontroller will store the current readings from the gyroscopes as the default position and will take all future readings as relative to that position until the 'Zero' button is pressed again.
If the 'Save' button is pressed the microcontroller will store the current gyroscope readings as a vector. It will NOT use these values as a default position. The purpose of the 'Save' button is to store a current value, move to the next roller, store another value (etc…) and then plug into the computer and access the saved vectors. This will allow the user to take measurements with the tool and generate a table of data if needed.
The microcontroller will control an LCD screen on which it will display current values for disturbance in pitch and yaw.
The microcontroller will communicate with the computer through a USB interface. Through this interface it will be able to receive 'Zero' and 'Save' commands to perform exactly as described above. When the microcontroller is connected to the computer the user will be given an option to access saved vectors in the microcontroller memory.

[4] System Displays The LCD and computer will be two different methods of displaying the readings from the gyroscopes. On the LCD the microcontroller will display the calculated averages of the readings it receives from all three gyroscopes. There will be three buttons available next to the LCD that allow the user to give the tool basic commands.
The computer will have a user interface that allows the user to access the on-chip memory of the microcontroller and thus view saved vectors of previous readings. The

interface will also allow the user to send the same commands that can be sent via the buttons by the LCD.

[5] USER The USER will be the person using the tool and sending commands via the buttons or the computer. They will also access data stored in the on-chip memory of the microcontroller through the user interface on the computer.

[6] Button Inputs The main purpose of the three buttons being directly on the tool is so the tool can be used independently of the computer. The user need not have the computer connected to the tool in order to send commands and save data. This will be useful if the tool is aligning a roller that has no nearby surfaces on which to set a laptop. On a similar note, the computer interface will be useful when the tool has to align a roller that is in an enclosed space and the LCD will not be readily visible.

[7] Battery Pack The tool will have an onboard battery pack which will supply power to the microcontroller, gyroscopes and LCD. When the 'Power' button is pressed the battery will begin supplying power to the components on the tool and will continue to do so until the 'Power' button is again pressed.
It has not been determined whether this power source will be a rechargeable battery pack or replaceable batteries, such as AA.

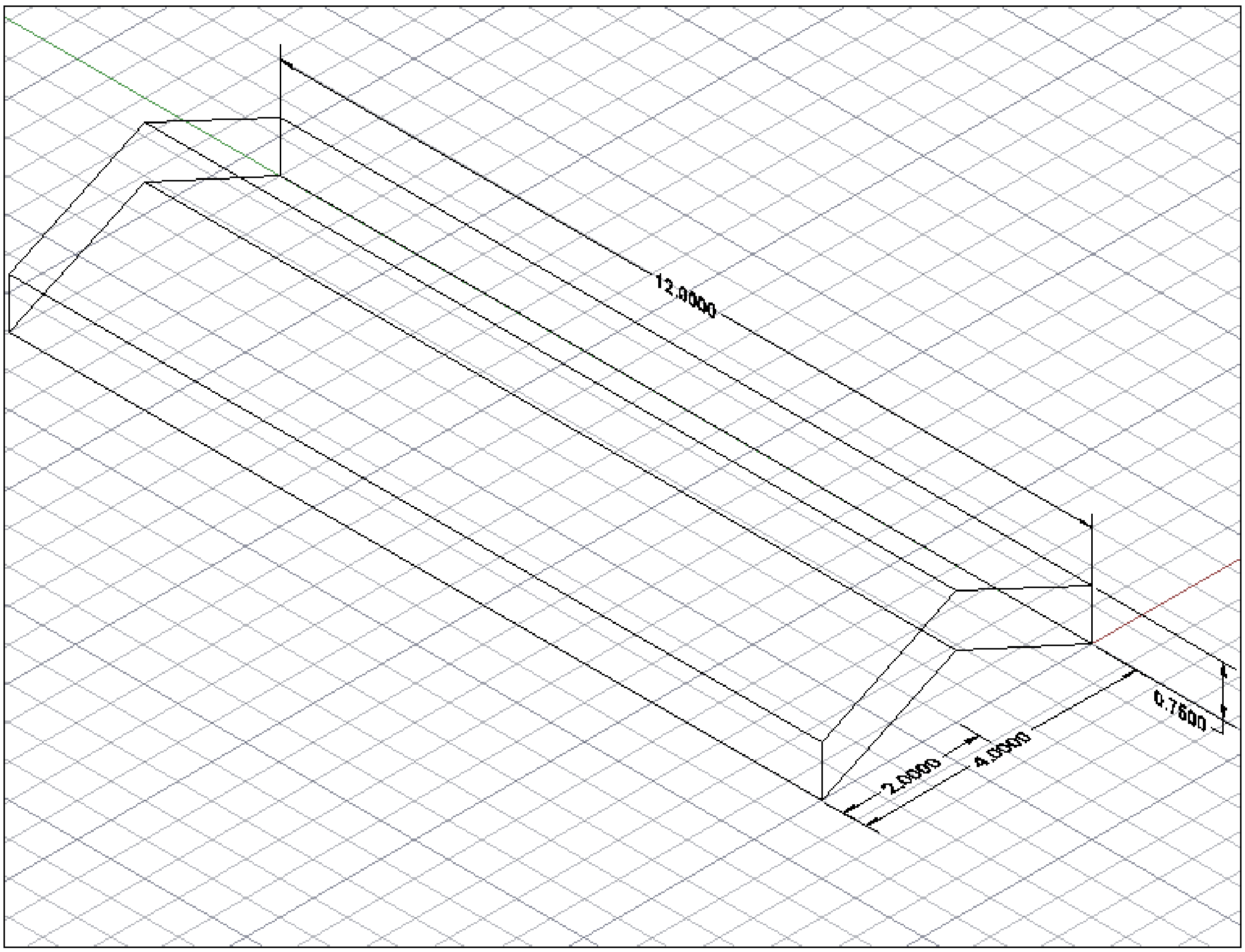
Materials/Components Used

Component	Supplier and Part Number	Quantity	Cost
Microcontroller	Texas Instruments: MSP430F2274	1	Sample
Gyroscope	STMicroelectronics: L3G4200D	3	$6.94 (each)
Battery		1	
LCD	Newhaven Display: NHD-0224BZ1-FSW-FBW	1	$15.00
Control Button		2	
Power Switch		1	
PCB	PCBexpress	1	$109.00-$139.00
FTDI Cable	FTDI	1	$20.00-$30.00

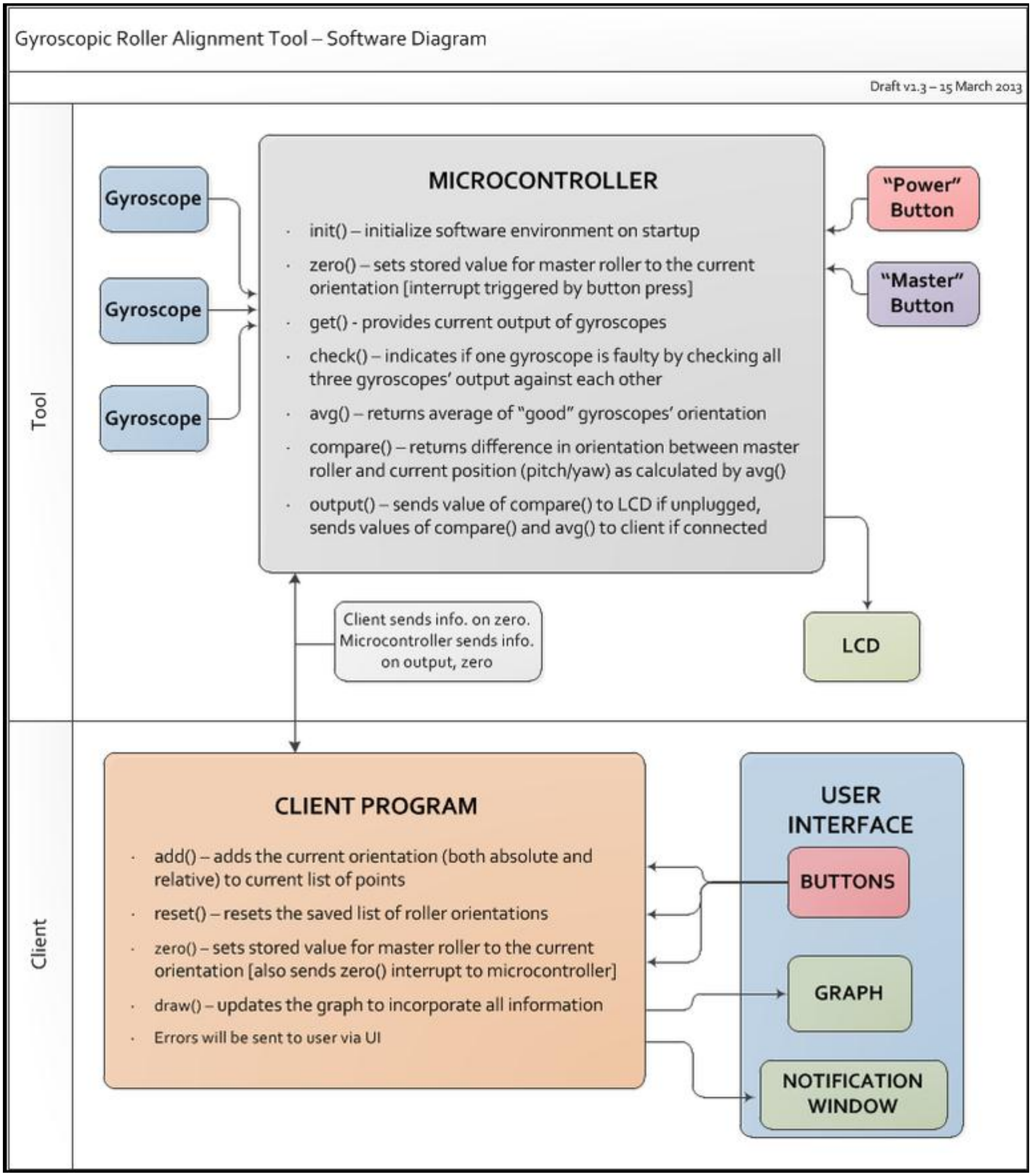
Figure 2: Materials/Components

Physical Specifications

The tool will be in the shape of a chevron. It will be 12 inches long and 4 inches wide. It will be made out of aluminum or steel, depending on consultation of the design with Powerfilm's machinist. The chevron will be ¾ inch thick and will have the PCB rest on top of one side and the LCD screen rest on the other to reduce height. The PCB will have a protective casing on it and the LCD will have a protective cover. The tool will be strapped on to the roller by bungee cords, unless Velcro straps prove sufficient restraint.



Block Diagrams



DETAILED DESCTIPTION

I/O Specification

This system will utilize SPI standards in order to facilitate inter-device communication in a C programming environment.

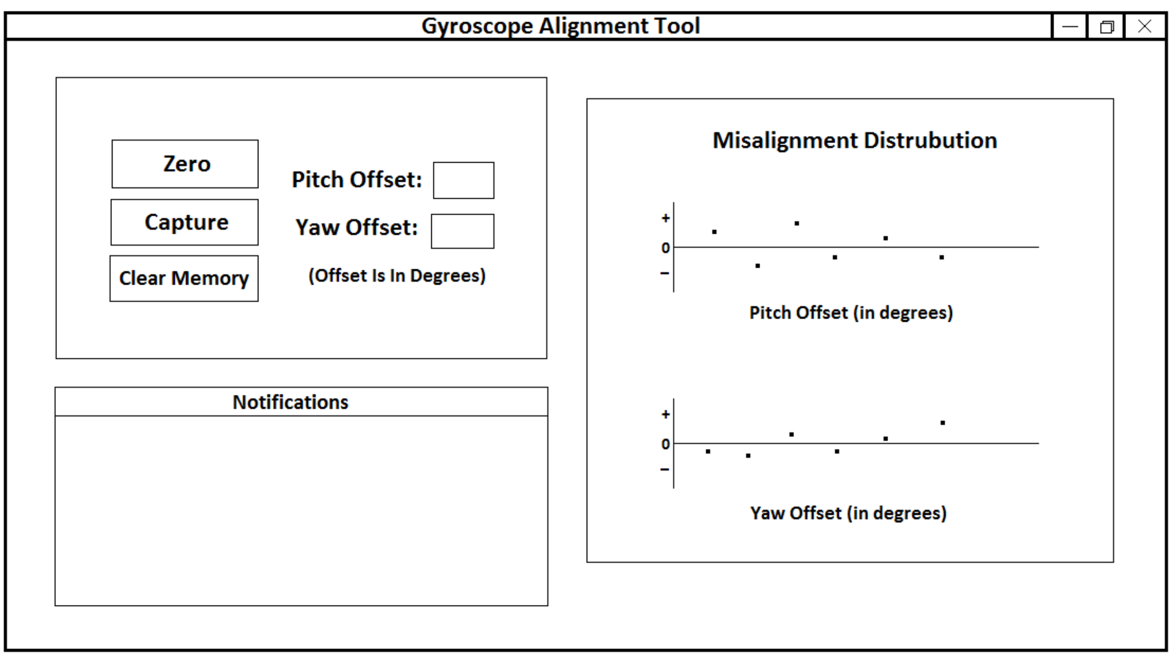
Hardware Interface Task List

- Uses an LCD screen to display the offset in pitch and yaw in positive or negative degrees.
- Includes a switch to power the tool on or off.
- Includes a button to zero the alignment tool to the roller.
- Includes a button to store the pitch and yaw offset values in memory.

Interface Specification

GUI Task List

- Displays the difference between in pitch and yaw in the master roller and current roller, in terms of positive or negative degrees.
- Includes buttons to zero the alignment tool, record the current alignment offsets, and reset the stored offset values.
- Ability to display notification and error messages.
- Graphs of the difference in pitch and yaw between different rollers.
- Updates in real time.



Hardware Specification

Microcontroller

MSP430F22x4 Device Pinout, DA Package

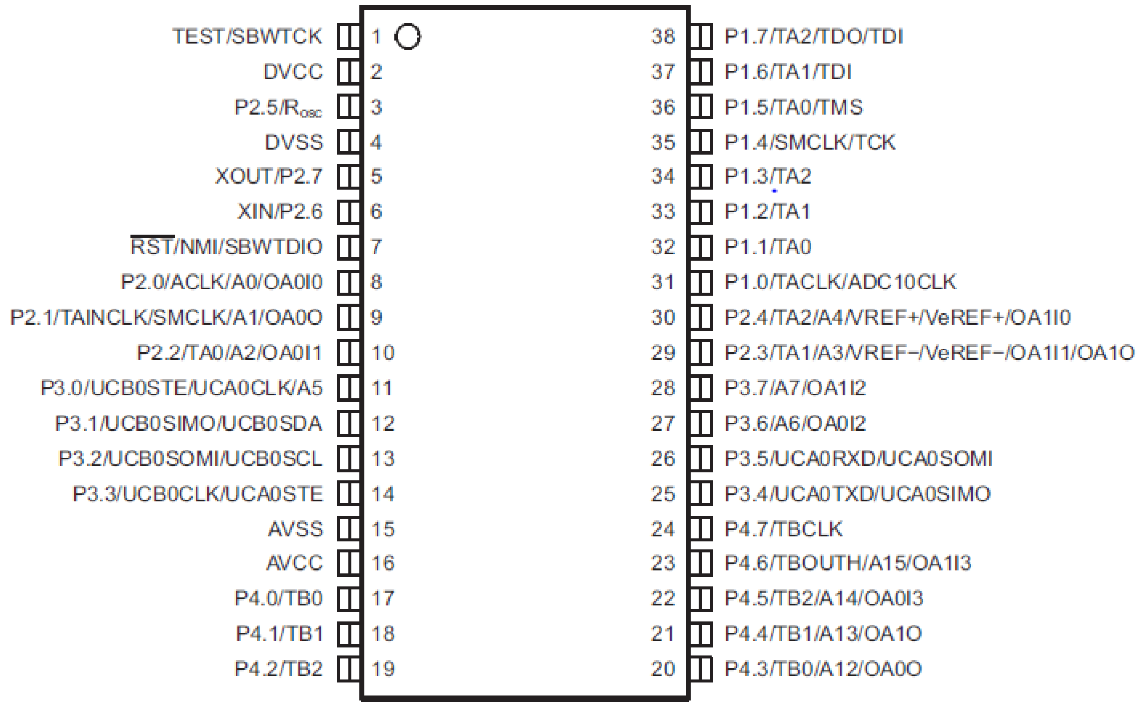


Figure 3: Microcontroller Pinout

Pinout of MSP430F2274 (courtesy of http://www.ti.com/lit/ds/slas504g/slas504g.pdf)

Pin 2 (DV_{cc}): Digital supply voltage, positive terminal
Pin 4 (DV_{ss}): Digital supply voltage, negative terminal
Pin 11 (USCI_B0) Slave transmit enable
Pin 12 (USCI_B0) SPI Mode: Slave in/master out
Pin 13 (USCI_B0) SPI Mode: Slave out/master in
Pin 14 (USCI_B0) Clock input/output
Pin 25 (USCI_A0) UART Mode: transmit data output
Pin 26 (USCI_A0) UART Mode: receive data input
Pins 17-24 (Port 4) General-purpose digital I/O

Gyroscope

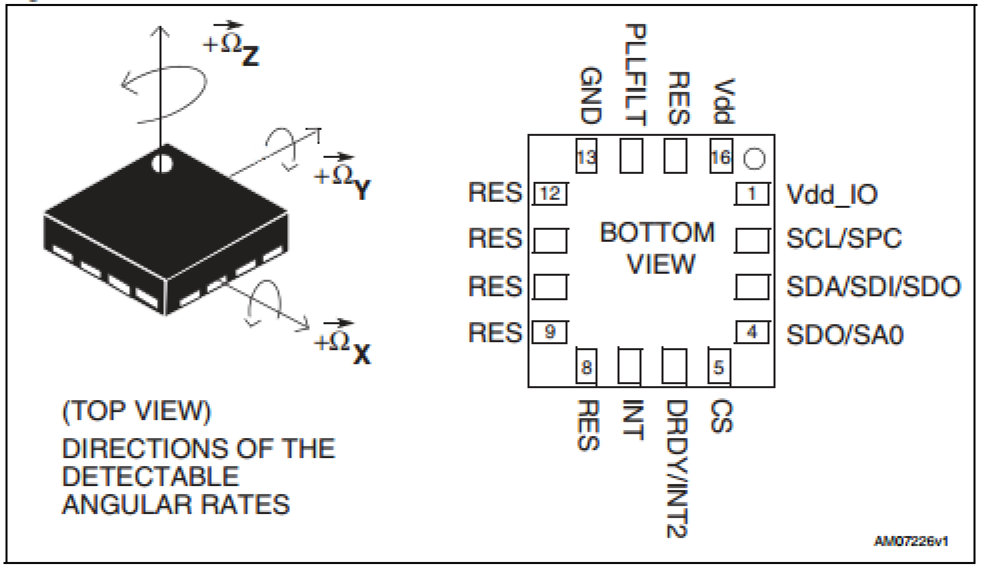
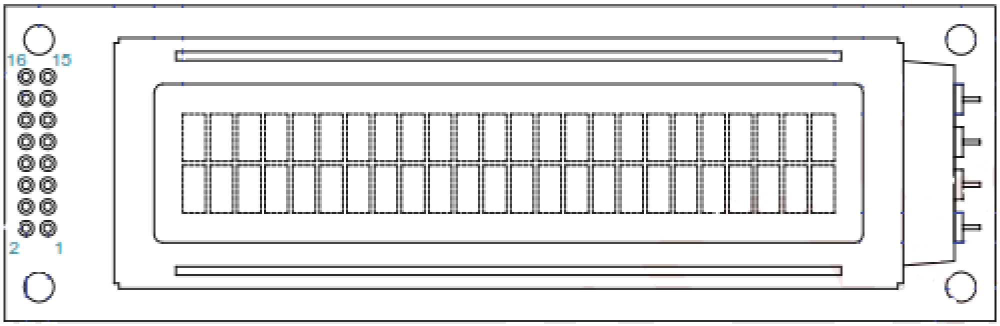


Figure 4: Gyroscope Pinout

Pinout of L3G4200D (courtesy of download.siliconexpert.com/pdfs/2011/1/10/2/27/32/108/st_/manual/17116.pdf)

Pin#	Name	Function
1	Vdd_IO	Power supply for I/O pins
2	SCL SPC	I^2C serial clock (SCL) SPI serial port clock (SPC)
3	SDA SDI SDO	I^2C serial data (SDA) SPI serial data input (SDI) 3-wire interface serial data output (SDO)
4	SDO SA0	SPI serial data output (SDO) I^2C least significant bit of the device address (SA0)
5	CS	SPI enable I^2C/SPI mode selection (1:SPI idle mode / I^2C communication enabled; 0: SPI communication mode / I^2C disabled)
6	DRDY/INT2	Data ready/FIFO interrupt
7	INT1	Programmable interrupt
8	Reserved	Connect to GND
9	Reserved	Connect to GND
10	Reserved	Connect to GND
11	Reserved	Connect to GND
12	Reserved	Connect to GND
13	GND	0 V supply
14	PLLFILT	Phase-locked loop filter (see *Figure 3*)
15	Reserved	Connect to Vdd
16	Vdd	Power supply

LCD Screen



Pin No.	Symbol	External Connection	Function Description
1	VSS	Power Supply	Ground
2	VDD	Power Supply	Supply voltage for logic (+5.0V)
3	V0	Power Supply	Power supply for contrast (approx. 0.5V)
4	RS	MPU	Register select signal. RS=0: Command, RS=1: Data
5	R/W	MPU	Read/Write select signal, R/W=1: Read R/W:=0: Write
6	E	MPU	Operation enable signal. Falling edge triggered.
7-10	DB0-DB3	MPU	Four low order bi-directional three-state data bus lines. These four are not used during 4-bit operation.
11-14	DB4-DB7	MPU	Four high order bi-directional three-state data bus lines.
15	LED+	Power Supply	Power supply for LED Backlight (+5.0V via on-board resistor)
16	LED-	Power Supply	Ground for backlight

Figure 5: LCD diagram and pinout

Courtesy of http://www.newhavendisplay.com/nhd0224bz1fswfbw-p-389.html

Software Specification

The user of this tool will be able to receive information in two ways. The primary and most detailed method will be via a computer-based client program. This program will be able to display the gyroscopes' output in real-time as well as capture and graph the current device output in order to compare the position of multiple rollers within a single machine. The other method is through a simple 16-digit LCD which will only output the device's current reading of pitch and yaw, for portable use without dependency on the client program.

Simulations/Modeling

*PCB layout and schematic will be placed here when designs are finalized.

Software Model

Embedded System Model: Current simulations of Microprocessor behavior are being handled using the eZ430-RF2500 Wireless Development Tool by TI through version 5 of their own Code Composer Studio IDE.

Computer Connection Model: Here we will have a model showing how the device connects to the computer software.

GUI Model: Here we will have a model showing how the GUI connects to the computer software.

Simulations: We will have an electrical circuit simulation using Simulink with MATLAB.

Implementation Challenges

Various components of this project, such as the PCB and the implementation of a GUI, will utilize interfaces and systems with which the team has not previously worked, creating a learning curve which will need to be overcome before any implantation may take place. In addition, this software will require a familiarity with classical physics and advanced mathematics in addition to electrical and computer engineering in order correctly handle the processing of all information received from the gyroscopes. Finally, the components used in this project are highly compact, requiring very delicate position in the construction phase of the project.

Testing Procedures

Set up a physical test area using wooden dowels (or some similar analogue) which are of a known displacement from each other. The readings of the tool should be the same no matter where on the roller the tool is place and since the misalignment between 'rollers' in this system is known we will be able to determining when the tool is working correctly.

We will set up automated tests for the embedded software and the computer interface. It will set up unit tests for both the code and the GUI.

We will likely be testing the final stage of the device using a system of dowel rods and supports to check different angles and elevations and any other arrangements. As we have access to the final tool's intended operating environment, on-site testing will also be executed in the final stages of the project.

PROJECT TEAM INFOMATION

Project Team Information

Faculty Advisor

Degang Chen

Department of Electrical and Computer Engineering

djchen@iastate.edu

Team Members

Ted Beem

Webmaster / Free Agent

Computer Engineering

tedbeem@iastate.edu

Ellen Laird

Hardware Stuff

Electrical Engineering

ellen.laird279@gmail.com

Aaron Peterson

Team Leader

Computer Engineering

apeter0807@gmail.com