ROB 310 Final Project Summary

Team “Ballers”

Matthew Greenbaum, Matthew Pince, Donovan Cece, Adrian Helmerci

Summary

The project implemented functions as a tracking method for ping pong balls bouncing on a 2D plane. The features of this project may be applicable in methods of tracking legged robots, tracking ballistics, and tabletop ball games. Photos, software, demonstration, and circuit design/simulation (Multisim) are available in the attached zip file.

In terms of implementation, the project utilizes an array of 4 piezoelectric elements, which are filtered at high speeds into logical level signals. These logical signals are directed into a high speed microcontroller which utilizes the time difference in between piezo events (piezo detects impact) and the distances between each piezo in order to create an estimate as to the position of impact of the ping pong ball. LEDs are mounted to the apparatus underneath each octant to display the estimated impact position of the ping pong ball.

Materials / Considerations

Given that the project requires accuracy at high speeds in order to facilitate the location tracking of impact points, the physical materials of the impact plane were selected such that they must have as slowest of a speed of sound possible while also not dampening vibrations. For this reason, polycarbonate was selected as the material for the impact plate given it conducts sound at 2270 meters per second. A 12” by 12” by 3/16” sheet of polycarbonate was selected such that our microcontroller may keep up with the speed of the signals (0.08937 inches / microsecond * 12 inches gives the microcontroller an approximate maximum of 1.0724 microseconds delay from impact).

The selected microcontroller was a Teensy V4.1 due to its high clock speed (600 MHz), which will allow for faster processing of signals from piezo events.

Four different piezoelectric elements were tested in a custom apparatus on the polycarbonate sheet in order to determine which element has the highest and most differentiable peaks at impact. 4.6 KHz piezo disk elements were selected given their clear distinct peaks during the tests. These parameters were selected since clear and distinct peaks are more viable for identifying a piezo event than peaks which might be convoluted with noise by our filtering circuit.

Given that the Teensy V4.1, like other microcontrollers, utilizes a SAR ADC to convert analog signals into digital signals which causes delays due to multiple clock periods being required for conversion, therefore a circuit is required on each piezo element in order to convert the peaks at impact into usable signals at high speed.

Circuit Design

Two stages of signal processing were utilized in order to turn the raw signals from the piezoelectric elements into usable logical signals by the microcontroller; a full-wave precision rectifier and a comparator circuit. The full-wave precision rectifier circuit functions to rectify the piezo signals, which is helpful for comparing both positive and negative peaks. The comparator circuit allows for a logical high signal to be sent to the microcontroller past a given voltage threshold which was tuned in design. Four of these two stage processing circuits were created with one being used for each piezoelectric element.

Software Iterations

Initially, the rationale for the software involved utilizing the time delay between piezo events post impact in a trilateration algorithm to estimate an impact point, however this method was proven to be ineffective as the time delays between piezo events were inconsistent after being measured constant parameters (impact point, height of ball dropped).

To create a functional project, the software design was streamlined into one which instead tracks the order of piezo events instead of the times between them. The four digital pins were constantly checked by the software, with the first two events used to estimate a position. This design approach allows for position to be estimated in terms of octants, with the first detected event giving information about which quadrant the impact occurred and the second detected event the octant within the estimated quadrant. The software then uses the detected octant to light an LED underneath the octant to display its estimation. A ninth LED was added for estimations of an impact in the center of the sheet, with its detection implemented as an edge case in which piezo events were detected on opposite corners of the sheet. A timing feature was also added to constantly reset the detected impacts such that consecutive impacts can be tracked.

Considerations for Future Revisions

To better improve this project, a PCB should be created so as to simplify wiring, assembly, and remove vibration related issues. Additionally, more testing on the times between impacts on the sheet might reveal a pattern in the inconsistent timings of the piezo events, which might be useful if a model were to be created to create more precise tracking of the impacts of the ball.