Machine Design

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1 Introduction

This document describes the process of designing the sorting machine for the project 2IO70 DBL Embedded Systems. It includes motivation of certain design choices and the description of the machine layout, but also the sub-documents "System Level Requirements" and "Machine Interface".

2 Machine Layout. Motivating the Design Choices

For the system to be easy to use and for us to be able to easily fix emerging problems we decided to design the machine on multiple levels. The first component of the machine is the loading tube and the dispenser — the mechanism to push one disc at a time onto the conveyor belt. It also includes the black/white detector, presence detector and a button located next to dispenser that is used to reliably determine its current position. This component is located on top of the machine so that the user can easily load the discs into the loading tube. The second component of the machine includes the conveyor belt, two trays for the discs and two side presence detectors that are used to determine whether a certain disc has indeed reached the tray and no exceptional situations have occurred.

To keep the machine as fast as possible we decided to identify the color of the disc before it is loaded onto the conveyor belt. This way we can ensure the disc keeps moving when it has left the loading tube and thus no time is wasted during the sorting process. Since identifying the color of a disc using the sensors included in the kit is nearly instant we were able to integrate the black/white detector into the component which pushes the disc on the conveyor belt.

After a disc has passed the black/white detector it will be pushed on the conveyor belt. As the conveyor belt itself is located on a lower level and is parallel to the dispenser mechanism, the disc will simply drop down onto the belt. This means that the component which pushes a disc from the loading tube to the conveyor belt can run on a higher speed without the risk of the disc falling sideways.

The conveyor belt itself is powered by a single engine which is able to turn both ways using the PP2 processor to change the polarity. Based on the input from the black/white detector the conveyor belt will either turn left or right to deliver the disc to its appropriate storage box. We decided to implement presence detectors on both ends of the conveyor belt which will detect if a disc has actually been delivered to its storage box. If the wrong detector or none of the detectors detect a disc it can send feedback to the machine, and the machine will then abort the execution of further processes.

3 System Level Requirements

This part of the document describes the possible use cases, user constraints and safety properties.

3.1 Use Cases

General description of sorting process:

- **Pre-condition**
  The PP2 processor is connected to all the engines, lights and sensors used in the machine according to the input/output map described in further documents. It is also connected to a computer, and the required program code is properly loaded. There are no discs in the loading tube or on the conveyor belt. No discs or other parts are blocking the moving parts of the machine.
- **Trigger**
  The user powers up and initialises the sorting machine by pressing the Start/Stop button and loads all the discs into the loading tube. After that the Start/Stop button is pressed again to start the sorting process.
- **Guarantee**
  The machine will start correctly sorting the black and white discs which were inserted into the loading tube.

Sorting under Normal Conditions

1. Pressing the Start/Stop button on the machine puts all mechanical parts in their appropriate resting states. The conveyor belt is stopped and all lights and detectors are turned on. The part which pushes the single discs from the loading tube onto the conveyor belt turns to its most retracted state.
2. The discs are inserted via the loading tube on top of the machine. When all discs are inserted, the user is allowed to press the Start/Stop button again.
3. Pressing the Start/Stop button starts the sorting process.
4. First the machine detects if there are discs left to sort by means of the presence detector.
5. If a disc has been detected it is pushed to the black/white detector which decides which way the conveyor belt should turn.
6. After the color of the disc has been determined the disc is pushed onto the conveyor belt.
7. The conveyor belt transports the disc to one of the two storage boxes depending on the color of the disc.
8. At the end of each side of the conveyor belt a light detector determines if the disc has indeed been delivered to the appropriate storage box in given time limit.

Sorting under Deviated Circumstances

- A disc fell off (is stuck on) the conveyor belt

  8-a Disc has not been detected by the corresponding side detector in the appropriate time. Abort all operations and go to the halting state. User intervention is needed to recover the lost disc(s).

  8-b Continue at the first state.

- The disc dispenser does not work properly

  5-a User detects malfunctioning of the machine which pushes the discs to the conveyor belt. The user has to press the Abort button.

  5-b The machine halts immediately, the user has to remove all discs from the system and fix the malfunctioning part.

  5-c Continue at the first state.

  Alternative

  8-a Disc has not been detected by the corresponding side detector in the appropriate time. Abort all operations and go to halting state. User intervention is needed to remove all discs from the system and fix the malfunctioning part of the machine.

  8-b Continue at the first state.

- The conveyor belt engine is malfunctioning

  7-a User detects malfunctioning of the engine which powers the conveyor belt. The user has to press the Abort button.

  7-b The machine halts immediately, the user has to remove all discs from the system and fix the malfunctioning engine.

  7-c Continue at the first state.

  Alternative

  8-a Disc has not been detected by the corresponding side detector at one of the trays in time. Abort all operations and go to halting state. User intervention is needed to remove all discs from the system and fix the malfunctioning engine.

  8-b Continue at the first state.

3.2 User Constraints

1. The user is only allowed to load the discs into the loading tube when the machine is in its resting state, after initialisation (the Start/Stop button has been pressed once, all lights are on, engines are off). The discs should be loaded with the flat part pointing to the top to avoid possible jamming that might happen due to configuration of loading tube and discs otherwise.

2. When the machine is running the user is not allowed to touch or move the discs.
3. When the user has pressed the Start/Stop button while the machine is running it will finish its current cycle and then go to its resting state. Pressing the Start/Stop button multiple times while it is running will have no effect.
4. When the user has pressed the Abort button the machine will stop immediately (within 15 ms). All discs which have left the loading tube have to be removed and reinserted into the loading tube (see 1. for loading constraints).
5. While the machine is running the user is not allowed to touch any of the components of the machine and should make sure none of the lights and sensors are blocked.

3.3 Safety Properties

Inputs (in order of use in a cycle)

- Dispenser button
- Presence detector
- Black/white detector
- Side presence detector white
- Side presence detector black

Outputs (in order of use in a cycle)

- Power engine dispenser
- Power light presence detector
- Power light black/white detector
- Power engine conveyor belt
- Power light presence detector white
- Power light presence detector black

Input and output relations

- None of the detectors can detect a disc at the same time.
- The engine for the belt can never run in both directions at the same time.
- When the Start/Stop button is pressed during a cycle the machine will only stop if the cycle has finished.
- When the Abort button is pressed all operations have to stop and the machine will go to its halting state. Even when the machine is mid cycle, so for example a disc is on the conveyor belt, the machine has to stop. When the user wants to start the machine again user intervention is necessary to remove any discs from the machine. The halting should take no more than 15 ms.
- When the presence detector has given a low signal either the black tray or white tray side presence detector should give a low signal before the dispenser finishes its rotation.

4 Machine Interface

The sorting machine is connected to the PP2 board, which plays a role of a microcontroller in this assignment, through a so-called machine interface. In this document every connection between the actual machine and the microcontroller is described briefly.

- **Motors**
  Two electrical motors are used in the machine. Let them be denoted as motor A and motor B for convenience. Motor A is responsible for the work of the disc supply mechanism, whereas motor B brings the conveyor belt in motion in one of the directions.

  Motor A is connected by a wire of type A to digital output 0 of the PP2, and motor B is connected by a similar wire to the H-bridge between outputs 6 and 7. That enables us to turn motor B in both directions so that we can bring the conveyor in motion in the correct direction and the disc can be deposited in the corresponding tray. When output 6 is high, the conveyor belt turns right; when output 7 is high, it turns left. These two outputs are not allowed to be high simultaneously. However, it does not matter in which direction motor A turns, so it is only connected to 1 output. Polarity in case of motor A does not matter as well.
- **Lamps**
  Every lamp is connected to a digital output on the PP2. They need to be turned on for the detectors to work (high output on corresponding digital output of the PP2). Polarity does not matter for the lamps. Lamp for the black/white detector is connected to PP2 board (output 2) using a wire of type B to limit the voltage. All the other lamps are connected in series to avoid taking too much current from the PP2 to output 3 by means of a wire of type A.
- **Phototransistors**
  Phototransistors are used as detectors of (reflected) light from the lamps. In order for them to produce results, both lamps and photo transistors should be connected to the PP2 and the lamps should be on. They are connected via wires of type A to digital inputs of the PP2. However, the photo transistor which is part of the black-white detector is connected to the analogue input of the PP2 by means of wire of type C. That allows for more precise detection of black and white discs (lower 8 bits of ADCONVS register on the PP2 get set). When the light is perceived, the value is high. When something blocks the light, the value is low. In particular, there are two detectors which determine if a disc has reached the tray (input gets low then high again), one detector checking if there are any discs left to sort (input is high if there are no discs left) and the black-white detector (input is lower for white discs). Photo transistor for the presence detector is connected to input 1; for the left tray side detector — to input 0; for the right tray side detector — to input 2.

- **Control buttons**
  There are two control buttons — Start/Stop and Abort — connected to the digital inputs of the PP2 via wires of type A. When the button is pressed, the corresponding input value is set to 1 (the value is high). Start/Stop button is connected to input 7, Abort button — to input 6. There also is an internally used button that is located underneath the dispenser motor and is used to safely determine the current position of the dispensing mechanism. It is connected to input 3 of the PP2 board by means of a wire of type A.