Final Report

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2IO70

Version 1

This document will contain the documents of the preceding phases and give an introduction and conclusion to the project. "The Final Report presents the reader with a clear picture of the designed machine, the method of working followed, the specification, validation, and design of the software, and a motivation of the main design decisions." (Source: *Project Guide Design Based Learning "DBL 2IO70" "Sort It Out"*)

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# Introduction

In this document you will find the details on how we have designed and built, in the past eight weeks, a sorting machine and the software that runs it. This Final Report will contain the five “Product” documents previously handed in and approved by the tutor, and a “Process” document. The five Product documents explain how we arrived at our final design for both the hardware and the software. In order of when we made them, these are “Machine Design”, where we explain how the machine was designed and why we chose to do it that way. Subsequently comes “Software Specification”, where we made a finite state automaton that the software was going to be based on. Then came the “Software Design” and “Software Implementation and Integration” documents in which we first designed the full program in pseudo-Java code and then subsequently translated this into working Assembly code. Throughout this document there are validation segments in which we explain how we validated our decisions. In the “Validation and Testing” document we look back at these segments and describe the measures we took to ensure that our final product would meet the initial requirements. The second part of the Final Report is the Process document, in this document we describe how we worked as a group over the course of this project, and how we decided to tackle any issues that arose. This Final Report is the final deliverable for the course.

We begin the document with our product and start with “Machine Design”. Next, we give a description of how the PP2 should behave in the “Software Specification” segment. Thereafter, “Software Design” will complement the Final Report. Then the designed program is translated into Assembly in “Software Implementation and Integration”. Last but not least, our product is to be validated. The validation is scattered throughout the document, which will be explained at the end in “System Validation and Testing”.

After the “Product”, we describe our process as a group in “Process”. Finally, we end this document with a conclusion. Included at the end as appendices are a model of the finite-state automaton, made in UPPAAL, a table of the display of states, the Java program, an explanation of the PHP to Assembly compiler and the functions of the compiler, the PHP program, and the Assembly code.

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# Product

## Machine Design

In this phase, we explain the design of our machine and how we decided on this design, and why we decided on this design. To do this we will take a look at our requirements and priorities. Afterwards we will look at the design and the decisions leading to that design.

## High level Specification

#### The specification as given in the Technical Guide

The goal of this project is to build a simple sorting machine that is able to separate small objects, plastic discs that may be either black or white, into two sets: the black discs and the white discs. (…) The machine must contain at least one **conveyor belt**.

(…)

The machine is to be operated by means of two push buttons, called **“START/STOP”** and **“ABORT”** (…) By pressing button **“START/STOP”** the machine is started. (…) If 4 seconds after (…) expected arrival time the presence detector has not signalled the arrival of a disc (…) the machine stops (…) If, during the sorting process. The push button **“START/STOP”** is pressed the machine (…) continues its normal operation until the current disc has been deposited into the correct tray. Then, the machine stops. (…) Push button **“ABORT”** (…) makes the machine halt immediately. (…) Pressing this button while the machine is in its resting state has no effect. (…) If subsequently, the push button **“START/STOP”** is pressed once, the machine returns to its resting state.

To be able to guarantee that the mechanism depositing discs onto the **conveyor belt** stops in a well-defined state, this mechanism must be equipped with (at least) one **switch** to signal that this mechanism has reached the correct state.

#### Our specification

We have to make a so-called sorting machine. This machine should be able to separate, by colour, small black and white plastic discs. The requirements are as follows, the machine should:

* Have at least one conveyor belt.
* Have two buttons called “START/STOP” and “ABORT”.
* Start when the machine is in a resting state and “START/STOP” is pressed.
* Stop when the machine is running and “START/STOP” is pressed, before stopping it should sort all discs that are on the belt.
* Abort when “ABORT” is pressed, this should halt the machine immediately unless it’s in the resting state.
* Go to a resting state when the machine is in a halting state and “START/STOP” is pressed.
* Have at least one switch to signal when the machine is in a resting state.

## Priorities

1. We define reliability as the ability of the machine to correctly sort all the inputted disks. We validate the reliability of the machine by checking the correctness of the code running the machine and also by conducting long-term test. Reliability is mainly reflected in our decision to encase the conveyer belt so that it is prevented any possibility of the discs, that are transported, to slip out. The goal of the project cannot be met with an unreliable design.

2. The speed of the machine is defined by the number of disks sorted in a unit of time. We search to select the design solution that improves this number. Speed is essential to offer a pleasant experience operating the machine. Speed is also the first thing that stands out when two machines of this sort are compared.

3. We define robustness as the fact that the machine does not break easily. The validation is if the machines state wouldn’t be changed, they wouldn’t break during: build phase, test phases, simulations, transportation and the end process, all during the period of the project cycle. Then we can consider the machine to be robust. Robustness can be observed from our design solution from the partial encasing used. Also the disc container was design to be robust do to its shape, size and simplicity. We do not meet our project goal if the machine isn’t capable of running during the final process.

4. We define user accessibility as the ease in which the user takes the actions required from the machine. Validation is done by checking the compatibility of the design and the user constrains. The disc container was built with user accessibility in mind, it is fairly easy and fast to load discs. The reason why this priority is important is that the machine requires a user to be operated and in consequence its operation must be possible.

5. We define amount of space by the amount of floor space that the machine occupies. Checking if there are useless components in the machine or other components that can be replaced with smaller counterparts without influencing the priorities above does validation of the low amount of space. From this perspective the current Feeder occupies a small amount a space, while the other feeder design would of forced us to add an extra floor extension because of its large dimensions. The reason of this priority is to ease the transportation and storage of the machine.

6. The Difficulty of Building is self-explanatory. We validate this be checking if there are any useless components. In our decision to have the conveyer belt larger, trying to fit on the platform size, we simplified the design and left more physical space to work on the other components connected to the machine. Opting for such a priority would make our solution easy to implement.

7. The Amount of Parts of the Machine is also self-explanatory. We also check if there are any useless parts. An example were we used very little parts by choice in our machine is the feeder component. Reasons why we picked this priority is that it might improve the overview of the machine and also the error-detection.

For the validation of these priorities see “Testing machine design to the priorities”.System Level requirements

The system level requirements consist of 3 parts. These 3 parts are the USE-cases, the safety properties and the user constraints.

## USE-cases

There are 6 USE-cases, which are described below.

### Starting the machine

|  |  |  |
| --- | --- | --- |
| Primary Actor | | Machine operator (student or teacher at TU/e) |
| Scope | | A sorting machine |
| Brief | | The machine operator starts the machine, machine parts go to their initial state and the machine starts sorting. |
| Postconditions | | The machine starts the sorting process. |
| Preconditions | | - |
| Trigger | | es user is requi discs that arethe machine has stopped running. The resting State is also the state from which you can start thBooting the machine / finished the abort or start/stop routine |
| Basic Flow: | 1. Machine puts devices in their initial state. 2. The user presses the START/STOP button | |

### Stop the **machine**

|  |  |  |
| --- | --- | --- |
| Primary Actor | | Machine operator (student or teacher at TU/e) |
| Scope | | A sorting machine |
| Brief | | The machine is waiting for the current process to end before it is send into an inactive state. |
| Postconditions | | The machine is sent into an inactive state with no process interrupted. |
| Preconditions | | The machine is running. |
| Trigger | | The START/STOP button is pressed. |
| Basic Flow: | 1. The machine finishes sorting the disks currently in the machine 2. The machine enters an inactive state and will not take any more disks form the storage\* unless the START/STOP button is pressed | |

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### Sort unsorted disks

|  |  |  |
| --- | --- | --- |
| Primary Actor | | Machine operator (student or teacher at TU/e) |
| Scope | | A sorting machine |
| Brief | | The machine sorts the unsorted disks provided into two separate containers based on colour. |
| Postconditions | | There are no unsorted disks left  All sorted disks are in a container based on their colour |
| Preconditions | | The machine is not already running. |
| Trigger | | The user provides unsorted disks and presses the “START” button. |
| Basic Flow: | 1. An unsorted disk is moved to the colour detector 2. The machine decides to which of the two containers the disk needs to be moved 3. The machine moves the disk to the designated container 4. The machine repeats step 2 through 4 until all disks have been sorted 5. The machine pauses within 4 seconds | |

### Abort the process

|  |  |  |
| --- | --- | --- |
| Primary Actor | | Machine operator (student or teacher at TU/e) |
| Scope | | A sorting machine |
| Brief | | The machine should immediately stop doing anything. |
| Postconditions | | The machine stopped running and is ready to start again. |
| Preconditions | | The machine is sorting discs. |
| Trigger | | The use wants to immediately stop the machine. |
| Basic Flow: | 1. The machine stops transporting the discs. And doesn’t put any more discs on the transporting mechanism. 2. The user is required to remove all discs that are neither in the container unit nor sorted. 3. When the user removed all unsorted discs that were not in the container unit he presses the START/STOP button. | |

### Booting of the machine

|  |  |  |
| --- | --- | --- |
| Primary Actor | | Machine operator (student or teacher at TU/e) |
| Scope | | A sorting machine |
| Brief | | The machine will prepare to start the program. And do the required actions. |
| Postconditions | | The machine is ready to get instructions of the user. |
| Preconditions | | The machine is off. |
| Trigger | | N/a |
| Basic Flow: | 1. Connect the PP2-board to the pc. 2. Plug the pp2-board in to the power socket. 3. Start the debugger 4. Connect the pp2-board using the debugger. 5. Load the program into the debugger. 6. Run the program. | |

### Shutting down the machine

|  |  |  |
| --- | --- | --- |
| Primary Actor | | Machine operator (student or teacher at TU/e) |
| Scope | | A sorting machine |
| Brief | | User unplugs the power supply and disconnects the processor from the PC and the machine. |
| Post conditions | | The PC can be used for other things and the processor and machine can be stored separately. |
| Preconditions | | Everything is in its initial state or the machine has stopped. |
| Trigger | | N/a |
| Basic Flow: | 1. Unplug the power supply of the machine. 2. Unplug the power supply of the processor. 3. Disconnect the processor from the machine. 4. Disconnect the PC from the processor. | |

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## User Constraints

* Before the start button is pressed, the user is required to place all discs to be sorted in the container unit
* While the machine is running the user is not allowed to move the machine or touch anything except the buttons.
* When the abort button is pressed or the machine has been shut down, the user is required to remove all discs that are neither in the container unit nor sorted.

## Safety Properties

1. After pressing an emergency button, within 50ms there should be no moving part in the machine
2. If all disks are sorted the machine should stop within 4 seconds.
3. After the start-up of the machine, the assembly program should not stop until the machine is shut down.
4. The outputs connected to the h-bridge may never be powered on at the same time.
5. The outputs connected to the motors should never output more than 9 volts

## Explanation of Safety Properties

1. When there is an emergency it is important that whatever is going wrong will not get worse. One of the ways this can happen is for instance that someone's finger gets stuck, to minimize damage to this finger the machine should stop quite fast. After discussion we decided 50ms would be a reasonable maximum stop time as it whatever is going wrong will not get worse in 50ms.
2. To minimize electricity usage we think that the machine should not keep running while there are no disks in it.
3. If the assembly program stops while the machine is still running, we can no longer control the machine. We can for instance no longer detect when the emergency button is pressed, meaning we cannot guarantee safety property #1.
4. The H-bridge should never have two inputs powered on at the same time. Because then you create a short circuit.
5. According to the project guide this is the maximum voltage the motors are certified to work with.

## Design Decisions

The way we approached the design of the machine is by separating the machine into multiple parts. Those parts exist out of: the feeder, the transportation mechanism, and the sorter.

### The Feeder

The feeder has as objective that it needs to somehow get the disks from the container onto the conveyor belt. This is needed for the use case “Sort unsorted disks”.

For the design of this feeder we had two competing designs. Both use the two hollow tubes stacked as a container. We chose to do this because they are completely reliable in containing the disks and because a new disk simply falls out if the bottom one is removed, they are very fast. Because the container is made off two big parts and some small parts to make them stack, the container is also very robust. It’s quite easy to put the disks into the big hole at the top, so user accessibility was very high. In short, the first solution that came to mind scored extremely high on all priorities and we looked no further.

The first design for the feeder consist of 3 important parts. First you have the container. The container drops a disk, which is then pushed onto the conveyor belt using a cam. A wall to the left of the container makes sure the disk is pushed up and not to the left.

Our second feeder design also consisted of a block that pushes the disk. To make this block move a lever attached to a wheel is used. Rotating the wheel makes the block move back and forth, pushing disks onto the conveyor belt.

Both designs correctly implemented the use cases. To test which one would be better we build both and tested them. They scored the same on almost all top priorities. They were both completely reliable for instance. There was also no difference in speed, both would push a disk onto the conveyor belt with every turn of their wheels. Both did not hinder the user, so the good user accessibility of the container was unchanged. When we came to the last three priorities there were some differences making us choose the first design: It was easier to build, used less parts and was a lot more compact.

### The Transportation and Scanning

When considering the transportation method we had a 3 main ideas. The first one was that we used a short conveyor belt. The second idea was about a long conveyor belt. And the last idea used a turning wheel and 2 conveyor belts. All these ideas included a conveyor belt because that was required.

The thought behind the short conveyor belt was that in the feeding mechanism would push the discs hard enough so that we could put the sensors on that part and to have a small but conveyor belt to transport the discs. The conveyor was short because nothing needed to happen on it. Thus it would only be there because it was a requirement. To us it seemed a bit useless to not do anything on the conveyors belts. So that was when the second arose.

The second idea had a long conveyor belt to put the sensors on. And also a part of the separating mechanism. The conveyor belt would limit how fast the machine can run but all the actions would happen on the conveyor belt so that time wouldn’t be wasted. It also isn’t that hard to create a long conveyor belt so we kept the idea in mind.

Our final idea was that there would be some sort of wheel with separate compartments for discs in the centre which would rotate and put discs on to two different conveyor belts. Each conveyor belt led to a storage unit of the sorted discs. The problem with this idea was that it would be hard to prevent the discs from spinning out of the compartments when they shouldn’t while still being able to let the discs go out when they had to. Because we couldn’t get it to work the idea was dropped and we went back to the idea about a long conveyor belt.



We were capable of realizing the of the long conveyor belt. But during the build of the conveyor belt we noticed that it would not be tight enough around the gears. Thus we tried to remove a small part of the belt. But this still didn’t have to effect we hoped for. So we added a third gear in the middle which tightened the belt to an acceptable state.

The conveyor belt was still far from perfect because it would tilt at certain points and the discs could fall off. So to prevent it we build 2 walls around the belt. On the first part they are low because the low walls were more robust than the high walls and for the user it is easier to access the discs on the conveyor belt. The high walls have been secured using 4 pillars because that made it robust enough to make sure they didn’t break. The walls had to be high because we needed to put a set of sensors on it.

Those sensor had to be above the conveyor belt. They also needed to be at an angle to work properly. That was required else the sensor wouldn’t be able to check if the disc was black or white.

The other set of sensors didn’t need to be place at an angle thus they were simply put on each side of the conveyor belt. This set of sensor would then be capable to scan if there was a disc on that spot of the conveyor belt. This sensor is need to time at which moment the other set of sensor had to check the colour of the disc. And it is also used to check if there are any more discs left to scan.

### The sorting mechanism

For the mechanism that does the actual sorting we chose between a couple of different designs. These designs are listed and explained below.

The first, and most simple design was to use just one conveyor belt that would move left or right based on the colour of the disks. This design is listed under the use of the conveyor belt above, this is why I will not describe it again.

The second design is a slight improvement on the first one where we would use a second, shorter, conveyor belt to do the sorting. This design would place the two conveyor belts in a T-shape with the colour check done on the first one, after which the second conveyor belt moves left or right. We considered this design an improvement on the first one because the second conveyor belt could be made much shorter. This means that the design can sort faster than the single conveyor belt one.

The second conveyor belt was faster than the first design with only one belt, however we soon realized that we could do this even faster. By removing the second belt and replacing it with a seesaw that could be angled to face one of the two sorted containers, we could increase the speed even more. Since the disk would essentially be sorted the moment it reached the end of the conveyor belt. This would be a great design, was it not for the fact that the seesaw required a lot of height. In fact, the entire machine looked like it was placed on stilts, requiring us to use lots of parts and having a lot of wasted space underneath. This design could do it faster at the cost of requiring more space than any of the others.

While the use of a seesaw sped up the sorting process, it also took a lot more space, so we went back to the drawing board and discarded this idea. Instead coming up with a wedge that would be slide onto the conveyor belt from the side whenever a disk of a certain colour is detected. This would then allow the conveyor belt to push the disk against the wedge making a roughly 45° angle thus pushing the disk of the side of the belt and into the collection box. The second colour could just continue while the wedge was pulled back and off the end of the belt. This means that the design cuts off part of the machine at the end and allowing us to make the machine lower than before.

We liked the idea of letting the conveyor belt doing the sorting by placing a wedge in the way, but after some thinking we realized that it could be done both faster and more compact. The trick was to change the direction in the wedge moves from horizontal to vertical. Doing so moves the entire mechanism, aside from the wedge itself, in an upright position pushing it very close to the machine. Aside from saving space, this also allowed the wedge to move much less, since it only has to move just over 1cm above the conveyor belt rather than move all the way over it to the side. This final design does not sacrifice any reliability from its predecessors while being the fastest. It also takes by far the lowest amount of floor space, characterized by the fact that this final design including this sorting mechanism is our only design that fits on only one of the two provided floor plates. For these reasons we believe this design for the sorting mechanism to be the best.

## Machine interface

### The feeder

The motor for the feeder turns a clam. With that motor turning clockwise the disc, which is on the surface in front of the clam, will be pushed off the surface and on to the conveyor belt. To make sure the engine runs clockwise the minus has to be connected to the connection closest to the spot where 6V is marked. We connect this engine to the 3rd output of the pp2-processor.

### The position sensor

The way a position sensor is set up us by using a lens lamp and a phototransistor. The lens lamp will be shining in the direction of the phototransistor. The light from the lens lamp makes the phototransistor send a signal to the pp2-processor. If a disc comes in between the lens lamp and the phototransistor then there won’t shine any light at the phototransistor and thus it won’t send a signal to the pp2-processor. The phototransistor is connected to the 8th input of the pp2-board. The phototransistor is polarized and thus it is important that it is connected correctly. The correct way to connect is with the ground to the connection closest to the white spot on the phototransistor. The lens lamp isn’t polarized and does not move in any direction and thus it doesn’t matter in which connection the ground is. The lens lamp is connected to the 2nd output of the pp2-processor.

### The black white detector

The black white detector uses the same components as the position sensor but they are implemented in a different way. The way in which the colour is detected is by the reflection of light on the disc. Because white discs reflect light very well the phototransistor does pick up some light and thus sends a signal. Black disc on the other hand do not reflect enough light to let the phototransistor pick it up. Thus a white disc can be detected if the sensors are placed in the correct way.

To make sure the phototransistor picks up only the reflected light a cap is placed over it with a hole in the middle. So only light from in front of it will influence the phototransistor. But to make sure that the reflected light can pass through that hole the sensor must be placed at an angle. The reflected light, which is detected by the phototransistor, is at its strongest when the lens lamp is also placed at an angle.

We connected the lens lamp in the same way as the lens lamp of the position sensor only now to the 6th output of the pp2-processor. The phototransistor is also connected as described in the position sensor only now to the 3rd inputs.

### The sorter

The divider uses a so-called “H-bridge” to move up and down. We use output 0 and output to control the H-bridge, which in turn controls the motor moving the divider. We connect the ground of the H bridge with the output 0 to the 6-side of the motor. Now when we power up output 0 the divider will move up. When we power up output 1 the divider will move down. Output 0 and output 1 are never allowed to be on at the same time, which is also stated in the safety properties. We want to move the divider as fast as possible so we always use the maximum allowed voltage of 9 volts. To detect when the divider is in its upmost position we use a push sensor. When the PP2 detects that this push sensor is pressed we immediately cut the power to output 0. We do not detect when the divider is at the bottom, because as soon as the push sensor is not pressed then there isn’t enough space for a disc to go underneath. Thus we simply power on the motor for a set amount of time. This time should be enough to make it move to the bottom but not low enough to interfere with the conveyor belt.

### The buttons

The button that is used to start/stop the machine will be button 0. The button to abort the machine will be button 1.

### The conveyer belt

The conveyer belt uses 5 gears of which only 3 touch the conveyer belt. 2 of those 3 gears are used to make sure the conveyer belt is horizontal and the third one is used to make the conveyer belt turn. The third gear is connected to a metal rod. On that metal rod another gear is connected and that gear will be turned using the gear which is connected to the engine. Because we have those gears in between the direction in which the engine turns has to be counter clockwise. Then the conveyer belt does turn clockwise and the discs will be moved in the right direction. To let the engine turn clockwise we have to connect the ground to the connection closest to the 9V. This engine is connected to the 3rd output.

## I/O tables

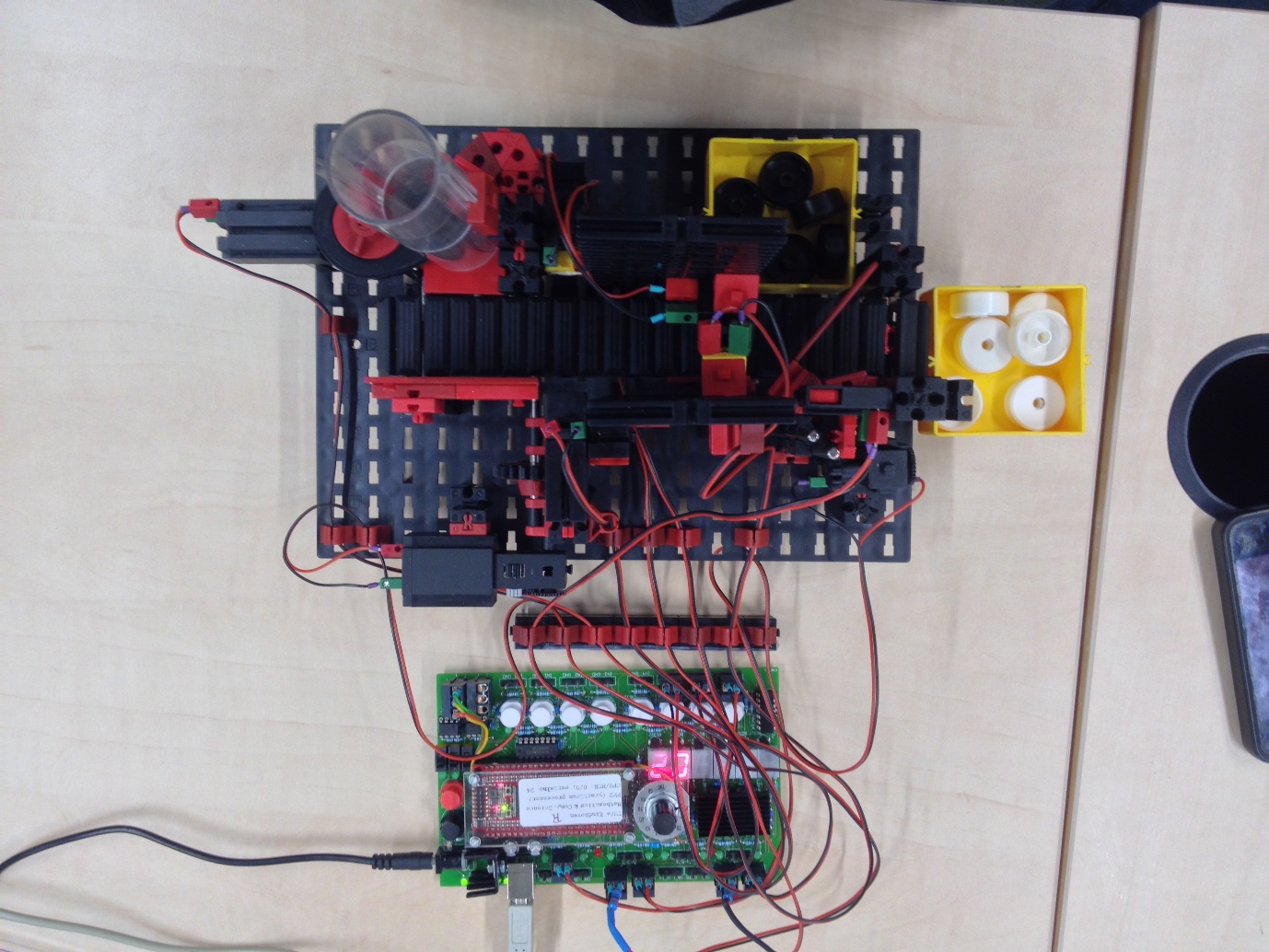
### Outputs

|  |  |
| --- | --- |
| Output | The range/type of the value |
| Start/Stop button | Boolean value |
| Abort button | Boolean value |
| Push button(sensor) | Boolean value |
| Colour detector | Boolean value |
| Position detector | Boolean value |
| Timer | Values range from seconds to clock ticks |

### Inputs

|  |  |
| --- | --- |
| Input | The range/type of the value |
| Lens lamp 1 | Boolean value |
| Lens lamp 2 | Boolean value |
| Conveyer engine | Between 6 and 9 V (Volts) while running 0 V when not running |
| Feeder engine | Between 3 and 7 V while running  0 V when not running |
| Sorter engine | Between 6 and 9 V while running  0 V when not running |
| Display | Integer value, positive |

## Picture



Out 0-1

Disp

Out 7

Out 0-1

Out 3

Out 7, 6, 3, 2

Out 2

Out 6

In

1 0

In 7, 6, 5

## System Validation and Testing

### Validate High level specifications

Our high level specifications are correct, because in the exercise it is said that a sorting machine for black and white discs should be made. And it also is said that we need at least one conveyer belt.

### Validation System Level Requirements

The high level specification defines the basic flow of the use-cases, user constraints and safety properties. At the same time, we validate the System Level Requirements through the high level specification. “Sort unsorted discs” is correct, because the high level specification mentions that the machine should sort discs. Aborting the process happens because in every machine something could go wrong and thus it needs to be able to be stopped at any point in time. “Starting the machine” and “Stopping the machine” are actions which are also needed for machines because else you couldn’t make them stop or start doing what they are supposed to do. “Booting up the machine” and “shutting down the machine” is required, because the disc sorter has to be turned on and off, in order for it to fulfil its purpose.

Before the start buttons is pressed the user is required to place all discs to be sorted in the container unit. The discs should be placed in the container, so that the machine is able to sort the discs.  
While the machine is running the user is not allowed to move the machine or touch anything except the buttons. If the user makes contact with either the conveyor belt or the discs while they’re on the conveyor belt, the machine might not be able to separate the discs correctly.  
When the abort button is pressed or the machine has to be shut down, the user is required to remove all discs that are neither in the container unit nor sorted. The user is supposed to do this, so that the machine will be able to restart the sorting process with a new disc.

After pressing an emergency button, within 50 ms there should be no moving parts in the machine. The machine should immediately abort its current process, according to the high level specification, although this is not realisable. Therefore, this is set to be within 50 ms.

According to the High level Specification the machine should stop sorting if there is no more disk signalled after 4s. We made this into a safety property, because a running machine with no use is only going to possibly harm people getting in contact or the machine itself.

According to what the high level specification offer, there is nothing that could stop the assembly program as long as the code is correctly written for this purpose, we don’t consider accidents and flaws, the only way for the program to end is by powering off the machine.

The outputs connected to the h-bridge may never be powered on at the same time. If this happens, the PP2 processor short circuit, and the machine won’t work anymore.

### Validation Priorities to SLRs

Reliability:

The use-cases describe how we want to sort multiple coloured disks, because we want the sorting to be done as accurately as possible we chose reliability as one of our priorities.

Accessibility:

The use-cases describe that the user has to remove all disks from the machine after the “ABORT” button is pressed. Because of this we want to make the machine somewhat open, so the user can remove the disks with relative ease.

Speed:

The use-cases describe how we want to sort multiple coloured disks, because we want the sorting to be done as fast as possible we chose speed as one of our priorities.

Robustness:

The use-cases describe that the user has to remove all disks from the machine after the “ABORT” button is pressed. For this reason we want the machine to be fairly durable so that the user does not easily damage it. Additionally, since the machine contains a number of engines and moving parts, it will be vibrating ever so slightly. These vibrations should also not cause any damage to the machine leading to our priority of robustness.

Amount of space:

This priority does not have a clear relation to our SLRs, however, we believe that a small machine capable of accomplishing the same task is generally better than a larger version. This is because the machine has to be stored or placed somewhere, leaving you with more space for other machines. This is why we chose for minimizing floor space as one of our priorities.

Difficulty of building:

This priority also does not have a clear relation to our SLRs, but this would make our job as builders easier. It would also allow for greater rates of production of the machine. For these reasons we chose difficulty of building as one of our priorities.

Amount of parts:

This priority also does not have a clear relation to our SLRs. A lot of parts, though, would make our machine more expensive and harsher on the environment, leading us to make the amount of parts one of our priorities.

Because the priorities “Amount of space”, “Difficulty of building” and “Amount of parts” have no clear relationship to the SLRs we chose to put them on the bottom of our priority list.

### Testing machine design to the priorities

1. Perform a test with alternating black and white discs to test the moving of the divider multiple times and check that the discs are sorted right and all discs were sorted.

2. Check if it sorts 10 discs within 30s with a load of white discs, black discs and alternating black and white discs

3. Let the machine perform a run without pushing buttons and with pushing the abort button while running and check if nothing breaks.

4. Look at points in the machine where a disc could get stuck and check if you can access the disc to remove it.

5. Check if the machine fits on 1 floorboard of the Fischer Technik.

6. Check if you can build the machine within 1.5 hours with 2 people.

7. Check if there are any parts without a function.

## Software Specification

In the Software Specification phase, we give an as accurately as possible description of the required behaviour of the PP2, without describing how this is achieved, and a UPPAAL model of this behaviour. In order to do this, we translate the system level requirements to a high level specification of what the software controlling the physical machine should do.

## Inputs and Outputs

### Inputs

|  |  |  |
| --- | --- | --- |
| Input | The range/type of the value | Abbreviation |
| Start/Stop button | Boolean value | In 0 |
| Abort button | Boolean value | In 1 |
| Push button(sensor) | Boolean value | In 5 |
| Colour detector | Boolean value | In 6 |
| Position detector | Boolean value | In 7 |
| Timer | Values range from seconds to clock ticks | Tim |

The **Start/Stop** and **Abort buttons** speak for themselves. They are either pressed or not pressed.

**Push button**(sensor): the sorter touches the push sensor or doesn’t touch it, to detect the sorter’s position.

The **position sensor** and **colour detector** are either on or off.

The **timer** is a count-down timer that is set to a certain value and runs at a frequency of 10 kHz. All given times were calculated by taking the average time of ten measurements, using 50 to 60% of the Potentiometer on the PP2 board. Thus, the sorting mechanisms are faster in reality. The input of a timer is set to a defined value or not set.

**TEnd** is the moment of termination of the timer, so when the timer reaches zero.

**Motor Down** is defined as the time it takes for the engine of the sorter to move the sorter from the lowest point to the highest point, until sorting mechanism touches the push sensor. This takes 0.30 seconds.

**Motor Up** is the state of the sorter moving from the highest point to the bottom of the engine sorter. Since the engine sorter for Motor Down and Motor Up have the same voltage, this will take 0.30 seconds as well.

**Sort** is the amount of time it takes for a disc to be transported from the black/white detector to the end of the conveyor belt, which is measured to be 0.85 seconds.

**Belt** is the period that a disc travels from the feeder to the end of the conveyor belt, until the disc reaches the tray for black discs. This action takes 2.0 seconds.

**Tic** is defined as one clock tick of the PP2. A clock tick is incredibly fast.

### Outputs

|  |  |  |
| --- | --- | --- |
| Output | The range/type of the value | Abbreviation |
| Lens lamp 1 | Boolean value | Out 2 |
| Lens lamp 2 | Boolean value | Out 6 |
| Conveyer engine | Between 6 and 9 V (Volts) while running 0 V when not running | Out 7 |
| Feeder engine | Between 3 and 7 V while running  0 V when not running | Out 3 |
| Sorter engine | Between 6 and 9 V while running  0 V when not running | Out 0-1 |
| Display | Integer value, positive | Disp |

**Lens lamp position** and **lens lamp sorter** are the lamps that make up part of the sensors and can be turned on or off.

The **conveyor and feeder engines** respectively move the conveyor belt and the feeder. They are either on or off.

**Hbridge0** indicates whether the sorter moves up or not. On the other hand, whereas **Hbridge1** shows that the sorter moves down or halts.

The **display** shows the state that the machine is currently in. Depending on the available time, we might or might not implement this.

The **Timer start** output is the same as the Timer input, except that the timer counts down.

## Relations

### Lens lamp of the black white detector

The lens lamp of the black white detector will be on when the machine is sorting. Thus the lens lamp will react to the input of the “START/STOP” button and the “ABORT” button. The lens lamp will go on when the machine is in resting state and the “START/STOP” button is pressed and it will go off when the “ABORT” button is pressed while the machine was running.

### Lens lamp of the position sensor

The lens lamp of the position sensor reacts only to the “START/STOP” button and the “ABORT” button. The lens lamp will be on after the “START/STOP” button is pressed and the machine is in its resting state. If at any other point in time the “ABORT” button is pressed it will go off. When the “START/STOP” button is pressed and the machine is running then the lens lamp also goes off.

### **Engine of the conveyor belt**

The engine of on the conveyer belt only reacts to the input of the “START/STOP” button and the “ABORT” button. The engine will start then the machine is in its resting state and the “START/STOP” button is pressed. If however the “START/STOP” button is pressed and the machine is not in its resting state then the machine will stop after it completed its current cycle. Whenever the “ABORT” button is pressed the engine stops within 50ms.

### **Engine of the feeder**

The engine for the feeder also only reacts to the input of the “START/STOP” button and the “ABORT” button. This engine also starts when the machine is in tis resting state and the “START/STOP” button is pressed. If however the machine is running then the engine will stop. When the “ABORT” button is pressed the engine stops within 50ms.

### Engine for the sorter

When the machine is running the engine of the sorter reacts to inputs of the colour detector, the push sensor and the timer. When a signal is received from the colour detector the engine pushes the sorter up, the engine then waits until the timer gives a signal to go down again after it let the discs through, it knows when it is in the correct “up” position from the push sensor . If the “START/STOP” button is pressed when the machine is in its resting state, then the sorter will wait for a signal from the timer that marks the end of the current cycle. If at any time the ““ABORT”” button is pressed, the sorting mechanism is to stop within 50ms.

### Display for the state

The display output depends on what state we are currently in. The corresponding state to a number can be found in appendix 2 .

## Design Decisions

### Feeder

The feeder in constantly on because of priority 2, speed, mentioned in the Machine Design document. Another reason is that there's a turning part that needs to spin through to get to its initial position to be able to deposit discs again.

### Lens lamp position

We chose to have the lens lamp for position sensor constantly on, because it's easier to code resulting in spending less time on it. The optimization is minimal if we would turn them off every time there's a gap between discs, because of the feeder being quite fast in depositing the next disc.

### Conveyor belt

The conveyor belt is constantly running, because the feeder is constantly pushing discs onto the conveyor belt. This goes hand in hand with our second priority, which is speed.

### Lens lamp colour

Like with the position sensor, it's easier to code that it is continuously on. The light being off if it's possible, would again be a minimal improvement, because the gaps between discs being pushed on the conveyor belt is the same as with the black white detector.

### Push button

We use the push button, because of priority 1, correctness, to know if the sorter arm is at its highest point. We need to know this, because we need to know when to stop the motor making the sorter arm going up.

## Description of States

### Initial\_state

In the initial state the machine starts calibrating the sorting mechanism by moving it up.

|  |  |
| --- | --- |
| Outputs | Value for output |
| Lens lamp position | 0 |
| Lens lamp sorter | 0 |
| Engine conveyor | 0 |
| Engine feeder | 0 |
| Hbridge0 | 0 |
| Hbridge1 | 0 |
| Display | 0 |
| Timer start | 0 |

### Calibrate\_Sorter

In the calibrate sorter state the sorting mechanism moves down until it is just above the conveyor belt.

|  |  |
| --- | --- |
| Outputs | Value for output |
| Lens lamp position | 0 |
| Lens lamp sorter | 0 |
| Engine conveyor | 0 |
| Engine feeder | 0 |
| Hbridge0 | 0 |
| Hbridge1 | 1 |
| Display | 1 |
| Timer start | 0 |

### 

### Resting\_state

In the resting state the sorting machine is at rest and waiting for the user to press the START/STOP button.

|  |  |
| --- | --- |
| Outputs | Value for output |
| Lens lamp | 0 |
| Lens lamp | 0 |
| Engine conveyor | 0 |
| Engine feeder | 0 |
| Hbridge0 | 0 |
| Hbridge1 | 0 |
| Display | 2 |
| Timer start | 0 |

### Running\_state

In the running state the sorting mechanism, the conveyor belt, the position detector, and the colour detector are turned on.

|  |  |
| --- | --- |
| Outputs | Value for output |
| Lens lamp position | 1 |
| Lens lamp sorter | 1 |
| Engine conveyor | 1 |
| Engine feeder | 1 |
| Hbridge0 | 0 |
| Hbridge1 | 0 |
| Display | 3 |
| Timer start | 2 s + Belt |

### Running\_Wait

In this state a disc has been detected and that disc is moving along the conveyor belt to the sorter.

|  |  |
| --- | --- |
| Outputs | Value for output |
| Lens lamp position | 1 |
| Lens lamp sorter | 1 |
| Engine conveyor | 1 |
| Engine feeder | 1 |
| Hbridge0 | 0 |
| Hbridge1 | 0 |
| Display | 4 |
| Timer start | 2 s + Belt |

### Running\_Timer\_Reset

In this state a new disc was detected and the timer has been reset.

|  |  |
| --- | --- |
| Outputs | Value for output |
| Lens lamp position | 1 |
| Lens lamp sorter | 1 |
| Engine conveyor | 1 |
| Engine feeder | 1 |
| Hbridge0 | 0 |
| Hbridge1 | 0 |
| Display | 5 |
| Timer start | 2 s + Belt |

### Motor\_Up

In this state the motor of the sorter is moving up until it hits the push button.

|  |  |
| --- | --- |
| Outputs | Value for output |
| Lens lamp position | 1 |
| Lens lamp sorter | 1 |
| Engine conveyor | 1 |
| Engine feeder | 1 |
| Hbridge0 | 1 |
| Hbridge1 | 0 |
| Display | 6 |
| Timer start | Sort |

### Motor\_Up\_Stop

In this state the motor of the sorter is moving up until it hits the push button. And the machine has to stop because the start stop button was pressed.

|  |  |
| --- | --- |
| Outputs | Value for output |
| Lens lamp position | 1 |
| Lens lamp sorter | 1 |
| Engine conveyor | 1 |
| Engine feeder | 1 |
| Hbridge0 | 1 |
| Hbridge1 | 0 |
| Display | 14 |
| Timer start | Sort |

### Motor\_Down

In the Motor\_Down state, the sorter is moved down.

|  |  |
| --- | --- |
| Outputs | Value for output |
| Lens lamp position | 1 |
| Lens lamp sorter | 1 |
| Engine conveyor | 1 |
| Engine feeder | 1 |
| Hbridge0 | 0 |
| Hbridge1 | 1 |
| Display | 8 |
| Timer start | 0 |

### Motor\_Down\_Stop

In Motor\_Down\_Stop, the sorter is moved down, after the start/stop button has been pressed.

|  |  |
| --- | --- |
| Outputs | Value for output |
| Lens lamp position | 1 |
| Lens lamp sorter | 1 |
| Engine conveyor | 1 |
| Engine feeder | 1 |
| Hbridge0 | 0 |
| Hbridge1 | 1 |
| Display | 16 |
| Timer start | 0 |

### White\_Wait

In this state the machine waits until the colour detector has detected a white disc.

|  |  |
| --- | --- |
| Outputs | Value for output |
| Lens lamp position | 1 |
| Lens lamp sorter | 1 |
| Engine conveyor | 1 |
| Engine feeder | 1 |
| Hbridge0 | 0 |
| Hbridge1 | 0 |
| Display | 7 |
| Timer start | Sort |

### White\_Wait\_Stop

In this state the machine waits until the colour detector has detected a white disc, after the START/STOP button has been pressed.

|  |  |
| --- | --- |
| Outputs | Value for output |
| Lens lamp position | 1 |
| Lens lamp sorter | 1 |
| Engine conveyor | 1 |
| Engine feeder | 1 |
| Hbridge0 | 0 |
| Hbridge1 | 0 |
| Display | 15 |
| Timer start | Sort |

### Running\_Timer

Running\_Timer is the state that sets the interrupt timer to make sure the machine stops after the current cycle.

|  |  |
| --- | --- |
| Outputs | Value for output |
| Lens lamp position | 1 |
| Lens lamp sorter | 1 |
| Engine conveyor | 1 |
| Engine feeder | 0 |
| Hbridge0 | 0 |
| Hbridge1 | 0 |
| Display | 9 |
| Timer start | Belt |

### Motor\_Up\_Timer

Motor\_Up\_Timer is the state that sets the interrupt timer to make sure the machine stops after the current cycle.

|  |  |
| --- | --- |
| Outputs | Value for output |
| Lens lamp position | 1 |
| Lens lamp sorter | 1 |
| Engine conveyor | 1 |
| Engine feeder | 0 |
| Hbridge0 | 0 |
| Hbridge1 | 0 |
| Display | 10 |
| Timer start | Belt |

### White\_Wait\_Timer

White\_Wait\_Timer is the state that sets the interrupt timer to make sure the machine stops after the current cycle.

|  |  |
| --- | --- |
| Outputs | Value for output |
| Lens lamp position | 1 |
| Lens lamp sorter | 1 |
| Engine conveyor | 1 |
| Engine feeder | 0 |
| Hbridge0 | 0 |
| Hbridge1 | 0 |
| Display | 11 |
| Timer start | Belt |

### Motor\_Down\_Timer

Motor\_Down\_Timer is the state that sets the interrupt timer to make sure the machine stops after the current cycle.

|  |  |
| --- | --- |
| Outputs | Value for output |
| Lens lamp position | 1 |
| Lens lamp sorter | 1 |
| Engine conveyor | 1 |
| Engine feeder | 0 |
| Hbridge0 | 0 |
| Hbridge1 | 0 |
| Display | 12 |
| Timer start | Belt |

### Aborted

Aborted is the state where the machines goes to if the abort button is pressed, the machine has come to a halt.

|  |  |
| --- | --- |
| Outputs | Value for output |
| Lens lamp position | 0 |
| Lens lamp sorter | 0 |
| Engine conveyor | 0 |
| Engine feeder | 0 |
| Hbridge0 | 0 |
| Hbridge1 | 0 |
| Display | 17 |
| Timer start | 0 |

### Running\_Stop

Running\_Stop gives the same outputs as the Running state, the only difference being a running timer in the stop process.

|  |  |
| --- | --- |
| Outputs | Value for output |
| Lens lamp position | 1 |
| Lens lamp sorter | 1 |
| Engine conveyor | 1 |
| Engine feeder | 0 |
| Hbridge0 | 0 |
| Hbridge1 | 0 |
| Engine sorter | 0 |
| Display | 13 |
| Timer start | Belt |

## State transitions

|  |  |  |  |
| --- | --- | --- | --- |
| Current state | Input | Input value | Next State |
| Initial | Push | 1 | Calibrate\_Sorter |
| Calibrate\_Sorter | Push | 0 | Resting |
| Resting | StartStop | 1 | Running |
| Running | Timer | TEnd | Initial |
| Running | PositionSensor | 0 | Running\_Wait |
| Running | Abort | 1 | Aborted |
| Running | StartStop | 1 | Running\_Timer |
| Running\_Wait | Timer | TEnd | Initial |
| Running\_Wait | PositionSensor | 0 | Running\_Timer\_Reset |
| Running\_Wait | ColorDetector | 1 | MotorUp |
| Running\_Wait | StartStop | 1 | Running\_Timer |
| Running\_Wait | Abort | 1 | Aborted |
| Running\_Timer\_Reset | Tick | 1 | Running\_Wait |
| Running\_Timer\_Reset | Abort | 1 | Aborted |
| MotorUp | PushButton | 1 | WhiteWait |
| MotorUp | StartStop | 1 | Motor\_Up\_Timer |
| MotorUp | Abort | 1 | Aborted |
| WhiteWait | StartStop | 1 | White\_Wait\_Timer |
| WhiteWait | Abort | 1 | Aborted |
| WhiteWait | Timer | SORT | MotorDown |
| MotorDown | StartStop | 1 | Motor\_Down\_Timer |
| MotorDown | Abort | 1 | Aborted |
| MotorDown | Timer | Motor Down | Running\_Wait |
| Running\_Timer | Timer | Tic | Running\_Stop |
| Running\_Timer | Abort | 1 | Aborted |
| Motor\_Up\_Timer | Timer | Tic | Motor\_Up\_Stop |
| Motor\_Up\_Timer | Abort | 1 | Aborted |
| White\_Wait\_Timer | Timer | Tic | White\_Wait\_Stop |
| White\_Wait\_Timer | Abort | 1 | Aborted |
| Motor\_Down\_Timer | Timer | Tic | Motor\_Down\_Stop |
| Motor\_Down\_Timer | Abort | 1 | Aborted |
| Motor\_Up\_Stop | PushButton | 1 | White\_Wait\_Stop |
| Motor\_Up\_Stop | Abort | 1 | Running\_Stop |
| Motor\_Up\_Stop | Timer | Timer Interrupt | Initial |
| Motor\_Up\_Stop | Abort | 1 | Aborted |
| White\_Wait\_Stop | Timer | SORT | Motor\_Down\_Stop |
| White\_Wait\_Stop | Abort | 1 | Aborted |
| White\_Wait\_Stop | Timer | Timer Interrupt | Initial |
| Motor\_Down\_Stop | Timer | Motor Down | Running\_Stop |
| Motor\_Down\_Stop | Abort | 1 | Aborted |
| Motor\_Down\_Stop | Timer | Timer Interrupt | Initial |
| Running\_Stop | ColorDetector | 1 | Motor\_Up\_Stop |
| Running\_Stop | Abort | 1 | Aborted |
| Running\_Stop | Timer | Timer Interrupt | Initial |
| Aborted | StartStop | 1 | Initial |

## Finite-state Automaton

Blue line means that the trigger for the transition is a clock tick.

## Tests done

On the next page is the UPPAAL model. This UPPAAL model has been tested for 2 safety properties. The first one is “ After the start-up of the machine, the assembly program should not stop until the machine is shut down.”. This has been tested using the following property “A[] not deadlock”, and we didn’t have a deadlock. The second safety property which was tested is: “The outputs connected to the h-bridge may never be powered on at the same time.”. This was tested using the following property “A<> !(hbridge0==1 && hbridge1=1)”. This one was also correct.

### Validation of “Inputs and Outputs”

We see that the inputs and outputs of Software Specification are correct. The inputs of Machine Design should be equal to the outputs of Software Specification, which they are.

### Validation of “Relations”

The relations between the inputs and outputs can be validated with the input/output tables. For all inputs, we have outputs. These outputs depend on one or more inputs, which is described in the Relations.

### Validation of “Description of States”

To validate the states we will look at the USE-cases again to see if every USE-case is implemented. To do this we look at the basic flow and trigger of every use case and see what states we use to realize this.

We also validate the states to the relations. For every USE-case we looked at what states would be necessary to achieve it.

### Starting the machine

**Preconditions:** -

**Trigger:** Booting the machine / finished the abort or start/stop routine

**Postconditions:** The machine starts the sorting process.

|  |  |  |
| --- | --- | --- |
| **Basic Flow** | **State** | **Explanation** |
| Before Trigger | Any State | It does not really matter which state the machine is in before the trigger |
| After Trigger | Initial State | Initial state is the first state, so after booting the machine we will be here.  Finishing the abort or start/stop routine will also end in the initial state |
| 1. Machine puts devices in their initial state. | Initial State + Calibrate Sorter + Resting State | The only thing that needs to be put into an initial state is the sorter mechanism. In initial state the machine moves the sorter up until it touches the push button. It then transitions to Calibrate Sorter where it starts moving down. After a set amount of time it will stop moving the sorter and transition to the resting state. This way we know exactly where the sorter is positioned |
| 1. The user presses the START/STOP button | Running State | From the Resting State the transition to the running state is pressing the START/STOP button |
| Postconditions | Running State | The running state is the start of the sorting process |

### Stopping the machine

**Preconditions:** The machine is running.

**Trigger:** The START/STOP button is pressed.

**Postconditions:** The machine is sent into an inactive state with no process interrupted.

|  |  |  |
| --- | --- | --- |
| **Basic Flow** | **State** | **Explanation** |
| Preconditions | Not initial state, Calibrate Sorter or aborted | When the machine is not in any of these states it is running. |
| After Trigger | One of the (greenblue) Timer statesaria the machine is not in any of these states it is running.s means they do not use states. This also means we can'sitioned. th | When the START/STOP is pressed the machine transitions to a timer start state, which starts a timer and stops the feeder mechanism. |
| 1. The machine finishes sorting the discs currently in the machine | One of the sorting states | While the timer is running the machine keeps sorting. The timer is the time it takes for the conveyor belt to make a complete rotation, guaranteeing there are no more discs on the belt. |
| 1. The machine enters an inactive state and will not take any more discs form the storage\* unless the START/STOP button is pressed. | Initial State + Calibrate Sorter + Resting State | After going through the initialize process we go back to the resting state, which waits on the START/STOP button. |
| Postconditions | Resting StateRstiresting state, which waits on the START/STOP button. timer is the time it takes for the conveyor belt to make a complete ro | Resting state in an inactive state and we finished the sorting process. |

### Sort unsorted discs

**Preconditions:** The machine is not already running.

**Trigger:** The user provides unsorted discs and presses the “START” button.

**Postconditions:** There are no unsorted discs left, all sorted discs are in a container based on their colour.

|  |  |  |
| --- | --- | --- |
| **Basic Flow** | **State** | **Explanation** |
| Preconditions | Resting State | The program first initializes and then waits for the user to press that start button. This waiting happens in the Resting State. In the resting state the machine is not running |
| After Trigger | Running State | Pressing START/STOP is the input to transition to the running state |
| 1. An unsorted disc is moved to the colour detector | Running Wait + Running Timer Rest | When moving to the colour detector it will have to pass the position Sensor which is the input to move to Running Wait, the disc is then still in front of the position sensor so the program moves to Running Timer Rest |
| 1. The machine decides to which of the two containers the disc needs to be moved | Running Wait + Running Timer Rest  OR  Motor Up  + White-Wait | Depending on whether the disc is white or black the sorter either needs to move down or keep its down position. If it keeps its down position it should just keep checking for an unsorted disc and when it detects one it will move to Running Timer Rest  If it needs to move up the colour detector will detect a white disc and therefore transition to Motor Up. Moving the sorter up will trigger the pushButton, which is the input to transition to White-Wait |
| 1. The machine moves the disc to the designated container | Running Wait + Running Timer Rest  OR  Motor Down + Running Wait | If the sorter did not detect a white disc we are still waiting like in basic flow 2.  If it did detect one then while the disc is moving to the designated container the sorttimer will count down making the machine transition to Motor Down |
| 1. The machine repeats step 2 through 4 until all discs have been sorted | - |  |
| 1. The machine pauses within 4 seconds | Initial State + Calibrate Sorter + Resting State | If there are no discs anymore the machine will stay in Running Wait waiting for the timer interrupt which will come within 4 seconds, making the machine transition to initial state.  There it will reset the sorter and transition to the resting state |
| Postconditions | Resting State | We repeated the sorting step until all discs where sorted, meaning all discs are now sorted |

### Abort the process

**Preconditions:** The machine is sorting discs

**Trigger:** The user wants to immediately stop the machine.

**Postconditions:** The machine stopped running and is ready to start again.

|  |  |  |
| --- | --- | --- |
| **Basic Flow** | **State** | **Explanation** |
| Preconditions | Every that is not initial state, Calibrate Sorter, resting state or Abortedcdlsls | All other states are states in which discs are being sorted |
| After Trigger | Aborted | Every state (apart from the one mentioned in before trigger) have a line to abort with Abort as input |
| 1. The machine stops transporting the discs. And doesn’t put any more discs on the transporting mechanism. | Aborted | Because the machine is now in the abort state, which has all outputs set to 0, nothing will be moving. |
| 1. The user is required to remove all discs that are neither in the container unit nor sorted. | Aborted | The machine will remain in Abort until the user presses START/STOP. This means everything is stopped and the user can safely remove all discs |
| 1. When the user removed all unsorted discs that were not in the container unit he presses the START/STOP button. | Initial State + Calibrate Sorter + Resting State | Pressing the START/STOP button is the input for the transition to Initial State  There it will reset the sorter and transition to the resting state |
| Postconditions | Resting State | We are in the resting state, so the machine has stopped running. The resting State is also the state from which you can start the machine again |

Booting of the machine and Shutting down the machine do nothing with our software. This means they do not use states. This also means we can’t validate those USE-Cases here.

### Validation of “State Transitions”

The description of our machine states is validated through its representation in the transition table. No state is excluded from being represented in the state transition table, all transitions will have the initial transition state differ from the end state.

### Validation of “Finite-state Automaton”

When we were making our finite-state automaton we looked at our state description and made sure that all states were represented, then we used our state transition table to make sure all transitions were correctly implemented.

### Validation of “UPPAAL model”

All transitions which exist in the UPPAAL model also occur in the Finite State Automaton. And the same action has to be performed to take that transition. Also all states of the Finite State Automaton occur in the UPPAAL model. The states of the UPPAAL model also have the outputs in them. The states of the Finite State Automaton do not have the outputs in them. Thus we validate the values of the outputs, which are in the states, to the description of the states.

## Software Design

In the Software Design phase, we present a Java program that realises the functions specified in the Software Specification document. This program is an intermediate step towards writing the PP2 code that controls the sorting machine.

# Coding Standards

The java pseudo code follows the Google Java Style.   
Source to Google Java Style: [https://google-styleguide.googlecode.com/svn/trunk/javaguide.html](https://google-styleguide.googlecode.com/svn/trunk/javaguide.html#_blank).

PHP code used in this project follows the Zend Framework Coding Standard for PHP.  
Source: [http://framework.zend.com/manual/1.12/en/coding-standard.html](http://framework.zend.com/manual/1.12/en/coding-standard.html#_blank).

## Translating to pseudo java:

The java program starts by declaring the output variables. The names of the output variables will keep their original name, without spaces, in a camelCase form. The variable type will be determined from the Output table.

The inputs follow the same pattern.

Every state is represented as a function, keeping their name in the camelCase fashion, they will be all void functions due to the fact that they do not return anything.

Every state function will run preconditions if any, then check for specific input values using if statements, if an if statement is satisfied, there will be changes to the output values to match the next states output values, also the display is set to output the next states number, and then the next state function is called according to the state transition diagram, if no if statement is satisfied the current function is recalled.

The program is always looping, consequence of no deadlocks in the state machine as proven by the UPPAAL model test.

Example: Initial -> Calibrate\_Sensor

So in this example the function initial is currently running, there are no preconditions to be checked, if the inputs have the desired value, in our case we check if the push button is pressed by the sorter, if so we will have the sorter moved down by activating the sorter motor via having the Hbridge0 variable set to 1. After this we set the display to showcase the number $branchTO where to branch to2 then call calibrateSensor function and if the if statement wasn’t satisfied we recall initial entering a loop.

## Translating from Java to PHP

The java code was written such that the conversion process to php is as easy as possible.

All variable in java will have the “$” sign added at the beginning of their name to comply with the php standards. The “$” sign has no influence in the java program variable naming, while in php it is mandatory.

## Design decisions for the Java code

In translating our transition table to a Java program we made a number of decisions shaping the code, these decisions are outlined in this section.

We started by looking at our transition table, in this table we had our transitions ordered by the “current state”, the state where the transition starts. Then there were some inputs that could trigger a transition from this state to a number of other states. Because of this we thought it would make sense to write a function for each state, since it would allow our code to essentially be a condensed version of the transition table. Where the code would be ordered by the “current state”, and each state would have a number of outgoing transitions to other states. This resulted in the following blueprint for each of our functions:

void function(){

timerManage(); // The function that manages the outputs and PWM

$temp = getButtons(); // Store the buttons currently being pressed in a temporary variable

if( condition for transition ){ // Do this once for every outgoing transition from this state

Changes required to change to the new statement;

}

function(); // Call on the same function again to recheck the buttons and continue running the machine with timerManage()

}

Then we made an extra function which will be called from each function to do the PWM. This function is called timerManage. This function firstly gets the voltage which the output needs from the array.

This function has a variable called counter which increments each time the outputs have been set. That value is take modulo 12. So it will leave the outputs which need 12 volts on all the time. The reason why the values which need less than 12 volt will be turned off after they have been on for long enough. That goes as follows. First it checks if the engine needs to be on by checking if the voltage it needs is higher than counter. If the output needs to be on then it gets the location of the value in the array. And then does 2 to the power of the location. So now the correct output will be set on. Then the value of 2 to the power will be added to the variable engines. Then after all 7 outputs have been through that loop then it will set the output to the value of engines. So the lights which needed to be on will be on. Now the value of counter will increment each time and take modulo 12.

We also choose to save certain values, which may not be expected to be saved. In this section I will explain why we save the 2 variables. The first one is the variable of the location of the code. This has been saved because then we then we are capable of changing the return address after the timer interrupt. Because when an timer interrupt occurs we want to return to the initial state and the position where we were before. We also saved the original position of the stack pointer for when we come back from the timer interrupt to make sure that we empty the stack. Because there may be some values on the stack from before the timer interrupt. Thus to remove them we set the stack pointer to its original value.

# Validation

### Validation of java to transition table

Every state is represented by a function. The if statements in that function are the transitions which can occur from that state. The timer interrupt and the abort transitions are not represented as if statements, because interrupts go to a separate state(function). In those if statements the values that have to change are changed. The display will also be updated to the correct number of the state. The function timerManage is called in each state. Because with that function we make sure that the all outputs have the correct voltage.

We checked that all states are represented in the java code by a function. We also checked if they have all the transitions as if statements and that the correct values are changed.

### Validation of timerManage

Loop invariant:

All elements before the current element of the array have been set on if they had to be on.

Initialize:

We start with the first element. Thus there are no elements before it and the loop invariant holds.

Step case:

If we’re at element k, then according to the loop invariant all elements before k have been set on if they had to be on. Then if k has to be on (value of k>counter) it will be set on else it will stay off. So now the loop invariant holds for the element k+1

Termination:

The loop will terminate when k is greater than 7. Because we do not have any more outputs.

### Control flow validation

Because the Java code has been validated to the state description and the transition table, which, in turn, have been validated with the UPPAAL model and shown to be correct and in tune with the initial description of the sorting machine. This means that the Java program, being a one-to-one translation of the finite state automaton, also has a correct control flow.

# Software Implementation and Integration

Now we show the data representation and coding standard we chose that is used to write the Assembly Language.

## Java to PHP

The Java to PHP conversion is usually natural, the two languages sharing most syntax but there are some differences we must note down. We are not required to create a class in PHP. The initialization will differ in PHP from Java, but they share the same core in the end. Also while we have some of the variables initialized globally in Java, in PHP they will be local. Having no class will make the class initialization irrelevant in PHP and that’s why its missing. The later functions in the Java code right after the function TimerManage are included in the PHP code using “include “functions.php”;”. In TimerManage, % operation is replaced by the mod() function. Due to our PHP compiler limitations we are required to use variables as arguments when calling certain functions like for example storeData. The PHP code has been added as appendix 3.

## Example of Java to PHP

## Example of PHP to Assembly

To make things more clear, we will show you an example of how the PHP is transformed into Assembly:

|  |  |
| --- | --- |
| PHP | Assembly |
| 197 *//state 3* |  |
| 198 function running() |  |
| 199 { |  |
| 200 timerManage(); | 265 running: BRS timerManage |
| 201 |  |
| 202 *//check if we need to pause* |  |
| 203 $startStop = getButtonPressed(0); | 266 PUSH R3 |
|  | 267 LOAD R3 0 |
|  | 268 BRS \_pressed |
|  | 269 PULL R3 |
|  | 270 SUB SP 5 |
|  | 271 PULL R3 |
|  | 272 ADD SP 4 |
| 204 if ($startStop == 1) { | 273 CMP R3 1 |
|  | 274 BEQ conditional3 |
| 205 *//stop the feeder engine* |  |
| 206 $temp = 0; | 289 conditional3: LOAD R4 0 |
| 207 storeData($temp, 'outputs', FEEDERENGINE); | 290 STOR R4 [GB +outputs + FEEDERENGINE] |
| 208 unset($temp); | 291 |
| 209 |  |
| 210 *//exit after 1 rotation of the belt* |  |
|  | 292 PUSH R5 *;reset timer* |
|  | 293 PUSH R4 |
|  | 294 LOAD R5 -16 |
|  | 295 LOAD R4 0 |
|  | 296 SUB R4 [R5+13] |
|  | 297 STOR R4 [R5+13] *;set timer* |
|  | 298 LOAD R4 BELT \* 10 |
|  | 299 STOR R4 [R5+13] |
|  | 300 PULL R4 |
| 211 setCountdown(BELT \* 10); | 301 PULL R5 |
| 212 |  |
| 213 *//update the state* |  |
| 214 $state = 9;*//TODO: echte state* | 302 LOAD R4 9 *;$state = 9* |
| 215 storeData($state, 'state', 0); | 303 STOR R4 [GB +state + 0] |
| 216 unset($state); | 304 |
| 217 |  |
| 218 runningTimer(); | 305 BRA runningTimer |
| 219 |  |
| 220 } |  |
| 221 unset($startStop); | 275 return3: |
| 222 |  |
| 223 *//check if a disk is at the position detector* |  |
| 224 $position = getButtonPressed(7); | 276 PUSH R3 |
|  | 277 LOAD R3 7 |
|  | 278 BRS \_pressed |
|  | 279 PULL R3 |
|  | 280 SUB SP 5 |
|  | 281 PULL R3 |
|  | 282 ADD SP 4 |
| 225 if ($position == 1) { | 283 CMP R3 1 |
|  | 284 BEQ conditional4 |
| 226 *//reset the countdown, because a disk was just detected* |  |
| 227 setCountdown(COUNTDOWN); | 308 conditional4: PUSH R5 *;reset timer* |
|  | 309 PUSH R4 |
|  | 310 LOAD R5 -16 |
|  | 311 LOAD R4 0 |
|  | 312 SUB R4 [R5+13] |
|  | 313 STOR R4 [R5+13] *;set timer* |
|  | 314 LOAD R4 COUNTDOWN |
|  | 315 STOR R4 [R5+13] |
|  | 316 PULL R4 |
|  | 317 PULL R5 |
| 228 |  |
| 229 *//update the state* |  |
| 230 $state = 4; | 318 LOAD R4 4 |
| 231 storeData($state, 'state', 0); | 319 STOR R4 [GB +state + 0] |
| 232 unset($state); | 320 |
| 233 runningWait(); | 321 BRA runningWait |
| 234 } |  |
| 235 unset($position); | 285 return4: |
| 236 |  |
| 237 *//loop* |  |
| 238 running(); | 286 BRA running |
| 239 } |  |

Important things to note:  
The line numbers of the assembly jump at some points, for example at assembly line number 274. This is because in assembly you will first get the whole function and then at the bottom the if statements in this function. In PHP however the if statements are inline.

Another thing that is different is some functions that need more code in assembly. For example the function “getbuttonpressed” which is used on PHP line 203 takes a few lines more lines in assembly.

## Java to PHP

The Java to PHP conversion is usually natural, the two languages sharing most syntax but there are some differences we must note down. We are not required to create a class in PHP. The initialization will differ in PHP from Java, but they share the same core in the end. Also while we have some of the variables initialized globally in Java, in PHP they will be local. Having no class will make the class initialization irrelevant in PHP and that’s why its missing. The later functions in the Java code right after the function TimerManage are included in the PHP code using “include “functions.php”;”. In TimerManage, % operation is replaced by the mod() function. Due to our PHP compiler limitations we are required to use variables as arguments when calling certain functions like for example storeData. The PHP code has been added as appendix 5.

## Validation of Java to PHP

Because of the natural similarity and ease of conversion, the PHP codes correctness can be correlated to its java counterpart, the correctness of the java code was validated in the Validation part of the Software Design.

## System Validation and Testing

Finally, we demonstrate that the final product meets its initial requirements, i.e. we prove that the executable code correctly implements the System Level Requirements, and that the implementation doesn’t do more than is expected.

### Validation Policy

In our documents we have validated every element of contents in a separate Validation section at the end of the document or near to it.

Machine Design will have at the end of the document a Validation section(pg. ) which includes the Validation of High Level Specifications and the Validation of the System Level Requirements, also adding Validation to Design Priorities.

Software Specification Document will have a Validation section that will contain the validation of the Inputs and Outputs, the Relation of Inputs and Outputs, the Description of States, the State Transitions, the Finite State Automaton and the UPPAAL model.

Software Design will have a Validation section (pg. 42)close to the end of the document being afterwards followed by the Program Code. The Validation will contain the validation of the java code to the transition table( from the Software Specification), validation of the timerManage function ( this function needed separate formal proof for its inner loop) and Control flow validation.

Software Implementation and Integration Document will have at the end a Validation section(pg. 43) containing validation of the PHP code to java and the validation of the Assembly code to the PHP compiler.

### Validating the machine to the priorities

We validated the machine to be reliable by making it run and sort 100 discs, the results of multiple test concluded that the machine had faulted once in sorting one disc during the 100 discs test, thus exceeding the 95 % reliability we determined the machine needed to be considered reliable.  
Throughout tests of the machine we determined that a full container of 12 discs, 6 black and 6 white randomly placed in the container, is sorted in 11 seconds. This results meets our expectancy to sort more than a disc per second.  
During previous tests the machine didn’t break physically, thus we consider the machine to be robust.

The machine is user accessible, once set up as described in the documentation the user is only required to utilize two push buttons and insert all the discs in the container. During testing all push buttons worked as intended and the sorter didn’t create problems of any sort, due to carefully placed walls and the movement direction imposed by the feeder and conveyer belt the discs during testing ended up only in their specific trays, most of the machine is opened so if the machine is aborted any discs is in reach.

The machine was built on only one floorboard indirectly limiting our space and such obtaining a normal sized machine.

The machine was built in time to respect the group established dead line. Thus we consider easy to build.

The overall machine doesn’t use more parts then necessary, the machine contains a conglomerate of pieces that replaces a single piece, with the same functionality, only in the case that the single piece is unavailable or doesn’t offer the same advantage as the conglomerate when querying trough the higher priorities, the most common is that a single part doesn’t provide enough robustness or might make the machine fault.

### Validating the machine to the USE-cases

The machine was tested in real life, during the tests the behavior was according to the USE-cases (Machine Design). The machine booted up, it started once the START/STOP button was pressed and stopped when the START/STOP button was pressed again and the last disc on the conveyer belt was sorted. When the ABORT button was pressed during the running phase the plastic wear halted immediately. The display outputted correctly every state in which the machine was, during the tests the discs were sorted properly and when there were no more discs left, the machine stopped after under 4 seconds. The machine was then powered off with no difficulty.

## Conclusion

The machine delivers satisfactory results, it accomplishes the project goal and fulfilled the group expectations.

# Process

## Work Plan

To streamline the group process we needed a Work Plan. We started this Work Plan with the inventory of the goals and objectives of each phase of the project. For the roles in the group we chose to have them the same as described in /Project Guide Design Based Learning "DBL 2IO70" "Sort It Out"/.

Then we come to the definition of our terms. We chose to have abbreviations of the phases and the tasks. This way we can refer to them without having to waste a lot of space if we mention them multiple times. Also the roles have their abbreviations.

Before we use those abbreviations we first have an inventory of the amount of work and an overview of the main deliverables. The amount of work is given per phase and week in a nifty table. The overview of deliverables contains who's responsible for a certain deliverable and the date and week the deliverable is due.

Then we come to the weekly tables. Tuesday and Friday we have a tutor meeting and we work afterwards till in the afternoon. On Wednesday we have Data Structures in the morning and work on the project afterwards. Those times are included in the tables. Everyone has his column with his role if applicable. For every hour and person it's defined what he will be working on.

With this Work Plan and the collective logbook we're able to have an indication of how much time was spent on each task by each member. If necessary action can be taken based on this indication.

If unforeseen problems arise and the deadline is close, this means we have to work harder. Deadlines aren't easily moved. If someone spends too less time according to the Work Plan it's expected he does his work at home.

## Workday

For us, a normal workday is structured as follows: we start each workday with a list of items that needs to be done in order to complete the document for that week. The list is written on the whiteboard that is available in the room. Then members are assigned to a task in consultation. After the completion of a task, it is checked off or removed from the whiteboard, and the member that was responsible for it continues to work on the next item of the inventory until there are no more available assignments. Next, they will help another group member with their duty. This cycle repeats itself whenever we are together. On Wednesday, the document is wrapped up and cross-read. The person that bears the responsibility for the document hands in the current document for feedback when possible. On Friday, the document is updated according to the feedback given by the tutor. Subsequently, the finalised document is cross-read, and handed in by the person responsible for the document.

## Problems

There was a problem with the group not functioning as was expected. The logbook indicated that some members contributed less than other members. As a result, other members had to compensate for it by spending more time on the project. Therefore, we decided to address this problem in the meetings and to distribute the workload more evenly.

## Conclusion

Over the course of these past 8 weeks we worked on making a sorting machine and the software that runs it. We did this by going through multiple phases, starting with Machine Design, where we designed the machine itself. Moving to Software Specification, where we created a finite state automaton, then Software Design and Software Implementation and Integration where we respectively designed a pseudo-Java program and then translated that into Assembly for the PP2. While making these documents we validated each part to what we did before to make sure that we made the right decision every time. While the project took a lot of our time each week, we liked doing it, and the end result was very satisfying. We hope that the skills we have acquired over the course of this project, both those for designing and building a product and those for working in a group, will help us in future projects both here in the TU/e and beyond.

## Appendix 1: UPPAAL model

# Appendix 2: Table of the display of states

|  |  |
| --- | --- |
| Number | State |
|  | Boot |
| 0 | Initial State |
| 1 | Calibrate Sorter |
| 2 | Resting State |
| 3 | Running State |
| 4 | Running Wait |
| 5 | Running Timer |
| 6 | Motor up |
| 7 | White Wait |
| 8 | Motor Down |
| 9 | Running Timer |
| 10 | Motor Up Timer |
| 11 | White Wait Timer |
| 12 | Motor Down Timer |
| 13 | Running Stop |
| 14 | Motor Up Stop |
| 15 | White Wait Stop |
| 16 | Motor Down Stop |
| 17 | Aborted |

# 

## Appendix 3: Java Program

1 */\*\**

2  *\* Sort of a simulation of the PP2 program*

3  *\* controlling the Fischer*

4  *\* Technik in order to sort black and white discs.*

5  *\**

6  *\* @author Maarten Keet*

7  *\* @author Stefan van den Berg*

8  *\* @author Rolf Verschuuren*

9  *\* @author Wigger Boelens*

10  *\* @team Group 16*

11  *\* @since 13/3/2015*

12  *\*/*

13

14

15 **class** **SoftwareDesign** {

16 *//\*\*@CODE\*\**

17 *//inputs*

18 int $push, $startStop, $abort, $position,

19 $colour;

20

21 *//variables*

22 int $state = 0;

23 int $sleep = 0;

24 int $temp = 0;

25 int $location;

26 int $counter = 0;

27 int $engines;

28

29

30 *//constants*

31 **final** int TIMEMOTORDOWN = 30;

32 **final** int BELTROUND = 2000;

33 **final** int BELT = 1200;

34 **final** int SORT = 850;

35 **final** int LENSLAMPPOSITION = 5,

36 LENSLAMPSORTER = 6,

37 HBRIDGE0 = 0,

38 HBRIDGE1 = 1,

39 CONVEYORBELT = 3,

40 FEEDERENGINE = 7,

41 DISPLAY = 8,

42 LEDSTATEINDICATOR = 9;

43

44 **public** **static** void main(String args[]) {

45 SoftwareDesign SoftwareDesign = **new**

46 SoftwareDesign();

47

48

49 *//values for the data segment*

50 SoftwareDesign.initVar("outputs", 12);

51 SoftwareDesign.initVar("stackpointer", 1);

52 SoftwareDesign.initVar("offset", 1);

53

54 *//store the offset of the programm,this*

55 *// is used in the interrupt*

56 SoftwareDesign.storeData(startofthecode,

57 "offset", 0);

58

59 *//store the vlue of the stackpointer,so*

60 *// we can clear the stack*

61 *// easily*

62 SoftwareDesign.storeData(SP,

63 "stackpointer",

64 0);

65

66 $counter = 0;

67

68

69 *//reset outputs*

70 SoftwareDesign.storeData(0, "outputs",

71 SoftwareDesign

72 .HBRIDGE1);

73 SoftwareDesign.storeData(0, "outputs",

74 SoftwareDesign

75 .LENSLAMPPOSITION);

76 SoftwareDesign.storeData(0, "outputs",

77 SoftwareDesign

78 .LENSLAMPSORTER);

79 SoftwareDesign.storeData(0, "outputs",

80 SoftwareDesign

81 .LEDSTATEINDICATOR);

82 SoftwareDesign.storeData(0, "outputs",

83 SoftwareDesign

84 .DISPLAY);

85 SoftwareDesign.storeData(0, "outputs",

86 SoftwareDesign

87 .CONVEYORBELT);

88 SoftwareDesign.storeData(0, "outputs",

89 SoftwareDesign

90 .FEEDERENGINE);

91

92 *//start moving the sorter up*

93 SoftwareDesign.storeData(9, "outputs",

94 SoftwareDesign

95 .HBRIDGE0);

96

97 *//go to the first state and set the*

98 *// value for the display*

99 SoftwareDesign.$state = 0;

100 SoftwareDesign.initial();

101 }

102

103 *//state0*

104 void initial() {

105 setStackPointer(

106 getData("stackpointer", 0));

107 timerManage();

108 *//check if the sorter push button is*

109 *// pressed*

110 $push = getButtonPressed(5);

111 **if** ($push == 1) {

112 *//move the sorter down*

113 storeData(0, "outputs", HBRIDGE0);

114 storeData(9, "outputs", HBRIDGE1);

115 *//update the state*

116 $state = 1;

117 *//reset sleep for the next function*

118 $sleep = 0;

119 calibrateSorter();

120

121 }

122 *//loop*

123 initial();

124 }

125

126 *//state 1*

127 void calibrateSorter() {

128 timerManage();

129 *//the sorter is now moving down,*

130 *//and we're waitng for it to reach the*

131 *// bottom*

132 **if** ($sleep == TIMEMOTORDOWN \* 1000) {

133 *//stop the sorter*

134 storeData(0, "outputs", HBRIDGE1);

135 *//update the state*

136 $state = 2;

137 *//reset sleep*

138 $sleep = 0;

139 resting();

140 }

141 *//loop*

142 $sleep++;

143 calibrateSorter();

144 }

145

146 *//state 2*

147 void resting() {

148 timerManage();

149 *//the program waits for the user to*

150 *// press the start/stop*

151 $startStop = getButtonPressed(0);

152 **if** ($startStop == 1) {

153 *//sleep so we don't go to the pause*

154 *// immediatly*

155 sleep(2000);

156 *//power up the lights*

157 storeData(12, "outputs",

158 LENSLAMPPOSITION);

159 storeData(12, "outputs",

160 LENSLAMPSORTER);

161 *//start up the belt and the feeder*

162 storeData(9, "outputs", CONVEYORBELT);

163 storeData(5, "outputs", FEEDERENGINE);

164 *//set and start the countdown*

165 setCountdown(BELTROUND + BELT);

166 startCountdown();

167 *//update the state*

168 $state = 3;

169 running();

170 }

171 *//loop*

172 resting();

173 }

174

175 *//state 3*

176 void running() {

177 timerManage();

178 *//check if we need to pause*

179 $startStop = getButtonPressed(0);

180 **if** ($startStop == 1) {

181 *//stop the feeder engine*

182 storeData(0, "outputs", FEEDERENGINE);

183 *//set the timer*

184 setCountdown(BELT);

185 *//update the state*

186 $state = 9;

187 runningTimer();

188 }

189 *//check if a disk is at the position*

190 *// detector*

191 $position = getButtonPressed(7);

192 **if** ($position == 1) {

193 *//reset the countdown,because a*

194 *// disk was detected*

195 setCountdown(BELTROUND + BELT);

196 *//update the state*

197 $state = 4;

198 runningWait();

199 }

200 *//loop*

201 running();

202 }

203

204 void runningWait() {

205 timerManage();

206 *//check if we need to pause*

207 $startStop = getButtonPressed(0);

208 **if** ($startStop == 1) {

209 *//stop the feeder engine*

210 storeData(0, "outputs", FEEDERENGINE);

211 *//set the timer*

212 setCountdown(BELT);

213 *//update the state*

214 $state = 9;

215 runningTimer();

216 }

217 *//check if a disk is at the positiond*

218 *// detector*

219 $position = getButtonPressed(7);

220 **if** ($position == 0) {

221 *//reset the countdown,because a*

222 *// disk was detected*

223 setCountdown(BELTROUND + BELT);

224 *//update the state*

225 $state = 5;

226 runningTimerReset();

227 }

228 *//check if a white disk is at the color*

229 *// detector*

230 $colour = getButtonPressed(6);

231 **if** ($colour == 1) {

232 *//move the sorter up*

233 storeData(9, "outputs", HBRIDGE0);

234 *//update the state*

235 $state = 6;

236 motorUp();

237 }

238 *//loop*

239 runningWait();

240 }

241

242 *//state 5*

243 void runningTimerReset() {

244 timerManage();

245 *//update the state*

246 $state = 5;

247 runningWait();

248 }

249

250 *//state 6*

251 void motorUp() {

252 timerManage();

253 *//check if we need to pause*

254 $startStop = getButtonPressed(0);

255 **if** ($startStop == 1) {

256 *//stop the feeder engine*

257 storeData(0, "outputs", FEEDERENGINE);

258 *//set the timer*

259 setCountdown(BELT);

260 motorUpTimer();

261 }

262 *//check if the sorter push button is*

263 *// pressed*

264 $push = getButtonPressed(5);

265 **if** ($push == 1) {

266 *//stop the engine,because it is in*

267 *// the right position*

268 storeData(0, "outputs", HBRIDGE0);

269 *//update the state*

270 $state = 7;

271 whiteWait();

272 }

273 *//loop*

274 motorUp();

275 }

276

277 *//state 7*

278 void whiteWait() {

279 timerManage();

280 *//we are waiting for the white disk to*

281 *// be sorted*

282 **if** ($sleep == SORT \* 1000) {

283 *//start moving the sorter down*

284 storeData(9, "outputs", HBRIDGE1);

285 *//update the state*

286 $state = 8;

287 *//reset sleep for the next function*

288 $sleep = 0;

289 motorDown();

290

291 }

292 *//check if we need to pause*

293 $startStop = getButtonPressed(0);

294 **if** ($startStop == 1) {

295 *//stop the feeder engine*

296 storeData(0, "outputs", FEEDERENGINE);

297 *//set the timer*

298 setCountdown(BELT);

299 *//update the state*

300 $state = 11;

301 whiteWaitTimer();

302 }

303 *//loop*

304 $sleep++;

305 whiteWait();

306 }

307

308 *//state 8*

309 void motorDown() {

310 timerManage();

311 *//the sorter is moving down*

312 **if** ($sleep == TIMEMOTORDOWN \* 1000) {

313 *//stop the sorter*

314 storeData(0, "outputs", HBRIDGE1);

315 *//update the state*

316 $state = 9;

317 *//reset sleep for the next function*

318 $sleep = 0;

319 runningWait();

320 }

321 *//check if we need to pause*

322 $startStop = getButtonPressed(0);

323 **if** ($startStop == 1) {

324 *//stop the feeder engine*

325 storeData(0, "outputs", FEEDERENGINE);

326 *//set the timer*

327 setCountdown(BELT);

328 motorDownTimer();

329 }

330 *//loop*

331 $sleep++;

332 motorDown();

333

334 }

335

336 *//state 9*

337 void runningTimer() {

338 timerManage();

339 *//update state*

340 $state = 13;

341 runningStop();

342 }

343

344 *//state 10*

345 void motorUpTimer() {

346 timerManage();

347 *//update state*

348 $state = 14;

349 motorUpStop();

350 }

351

352 *//state 11*

353 void whiteWaitTimer() {

354 timerManage();

355 *//update state*

356 $state = 15;

357 whiteWaitStop();

358 }

359

360 *//state 12*

361 void motorDownTimer() {

362 timerManage();

363 *//update state*

364 $state = 16;

365 motorDownStop();

366 }

367

368 *//state 13*

369 void runningStop() {

370 timerManage();

371 *//check if a white disk is at the*

372 *// colour detector*

373 $colour = getButtonPressed(6);

374 **if** ($colour == 1) {

375 *//move the sorter engine up*

376 storeData(9, "outputs", HBRIDGE0);

377 *//update the state*

378 $state = 10;

379 motorUpStop();

380 }

381 *//loop*

382 runningStop();

383 }

384

385 *//state 14*

386 void motorUpStop() {

387 timerManage();

388 *//check if the sorter push button is*

389 *// pressed*

390 $push = getButtonPressed(5);

391 **if** ($push == 1) {

392 *//stop the engien for the sorter*

393 storeData(0, "outputs", HBRIDGE0);

394 *//update the state*

395 $state = 11;

396 whiteWaitStop();

397 }

398 motorUpStop();

399 }

400

401 *//state 15*

402 void whiteWaitStop() {

403 timerManage();

404 *//check if the white disk has been sorted*

405 **if** ($sleep == SORT \* 1000) {

406 *//start moving the sorter down*

407 storeData(9, "outputs", HBRIDGE1);

408 *//update the state*

409 $state = 12;

410 *//reset the sleep for the next*

411 *// function*

412 $sleep = 0;

413 motorDown();

414 }

415 *//loop*

416 $sleep++;

417 whiteWaitStop();

418 }

419

420 *//state 16*

421 void motorDownStop() {

422 timerManage();

423 *//check if the sorter has moved down*

424 **if** ($sleep == TIMEMOTORDOWN) {

425 *//stop the engine of the sorter*

426 storeData(0, "outputs", HBRIDGE1);

427 *//update the state*

428 $state = 9;

429 *//reset sleep for the next function*

430 $sleep = 0;

431 runningWait();

432 }

433 *//loop*

434 $sleep++;

435 motorDownStop();

436 }

437

438 *//not a state*

439 void timerInterrupt() {

440 *//show that we have timer interrupt*

441 $state = 18;

442 *//make the sorter move up*

443 storeData(9, "outputs", HBRIDGE0);

444 *//stop all other outputs*

445 storeData(0, "outputs", HBRIDGE1);

446 storeData(0, "outputs", LENSLAMPPOSITION);

447 storeData(0, "outputs", LENSLAMPSORTER);

448 storeData(0, "outputs",

449 LEDSTATEINDICATOR);

450 storeData(0, "outputs", DISPLAY);

451 storeData(0, "outputs", CONVEYORBELT);

452 storeData(0, "outputs", FEEDERENGINE);

453 *//make sure that the outputs get set*

454 *// immediatly*

455 timerManage();

456 *//set the display to the state of initial*

457 $state = 0;

458

459 initial();

460

461 }

462

463 void abort() {

464 *//stop all outputs*

465 storeData(0, "outputs", HBRIDGE0);

466 storeData(0, "outputs", HBRIDGE1);

467 storeData(0, "outputs", LENSLAMPPOSITION);

468 storeData(0, "outputs", LENSLAMPSORTER);

469 storeData(0, "outputs",

470 LEDSTATEINDICATOR);

471 storeData(0, "outputs", DISPLAY);

472 storeData(0, "outputs", CONVEYORBELT);

473 storeData(0, "outputs", FEEDERENGINE);

474 *//make sure the outputs stop immediatly*

475 timerManage();

476 *//update the state to be correct in*

477 *// aborted*

478 $state = 17;

479 aborted();

480

481 }

482

483 *//state 17*

484 void aborted() {

485 timerManage();

486 *//check if we can start again*

487 $startStop = getButtonPressed(0);

488 **if** ($startStop == 1) {

489 *//start moving the sorter up for*

490 *// calibration*

491 storeData(1, "outputs", HBRIDGE0);

492 *//update the state*

493 $state = 0;

494 initial();

495 }

496 *//loop*

497 aborted();

498

499 }

500

501 void timerManage() {

502

503

504 *//make sure that when counter can not*

505 *// be higher than 12*

506 mod(13, $counter);

507 *//get the voltage of output $location*

508 int $voltage = getData("outputs",

509 $location);

510 *//power up the output when it needs to*

511 **if** ($voltage > $counter) {

512 $engines += pow(2, $voltage);

513 }

514 *//check if we are in a new itteration*

515 **if** ($counter == 0) {

516 *//set the first part of the display*

517 $temp = getData("state", 0);

518 mod(10, $temp);

519 display($temp, "display", "1");

520

521

522 }

523 *//check if we are at the end of the*

524 *// itteration*

525 **if** ($counter == 12) {

526 *//set the second part of the display;*

527 $temp = getData("state", 0);

528 $temp = $temp / 10;

529 mod(10, $temp);

530 display($temp, "display", "01");

531

532 }

533 *//check if we did all outputs*

534 **if** ($location > 7) {

535 display($engines, "leds", "");

536 *//set the variables for the next run*

537 $engines = 0;

538 $location = 0;

539 $counter++;

540

541 *//check if abort is pressed*

542 $abort = getButtonPressed(1);

543 **if** ($abort == 1) {

544 abort();*//stop the machine*

545 }

546 **return**;

547 }

548

549

550 $location++;

551 timerManage();

552 }

553 }

## Appendix 4: Explanation of the compiler

The compiler works in phases. We will go through these phases 1 by 1 to explain how the compiler does its job: compiling PHP-like code to assembly. Throughout the phases the compiler keeps track of the line number of the PHP code it is currently compiling and uses that, when an error occurs, to give information where the error is. The compiler is written in PHP5.6 and uses a command line interface.

### Preprocessing

In the first phase, the input code will be made ready for the next steps. A few things happen in this phase: First the file is read into the memory. The next step is that all comments, newlines and extra spaces are stripped from the file. The file is then split into single lines using the “;” symbol that denotes the end of a line. The code is divided in three segments. The first segment starts at //\*\*COMPILER, everything before this statement is ignored.

The preprocessor further removes some special statements that are needed to make valid php such as “global” and changes some shortcuts in their full version. For example $abc++ will be changed into $abc+=1. This ensures that the compiler only needs to be able to handle $abc+=1.

### Splitting

In the second phase the code is split up by function. Every function gets his own array with all the lines that are in that function. The code not inside of a function goes into a separate array.

### Compiling

The third phase is the most important one. It starts by compiling the code that is at the start and not inside a function. While compiling it keeps track of what functions are called and adds these, if they are not already compiled, to the toCompile queue. This helps in making sure there is no dead code, as a function that is never called, will not be compiled. The compiler adds the function “main”, which is the default start point of the code, to the queue and starts processing it.

After compiling the main function it will continue in the next function in the toCompile queue and keep doing this till the toCompile queue is empty.

The compiling itself is not a lot more than a lot of regex and switch statements that look at the input and make a output from that. At the first notion of a variable a register is assigned to it. The code then uses this register in place of the variable. Some more difficult statements, like the function display which displays something, will BRS to premade assembly code that handles that. The compiler keeps track of which segments of the premade assembly code are used.

When the compiler meets an if statement, it saves the code inside it to a new function named “condtionali” where i is the amount of conditionals that have already been seen. It then places this function in the toCompile queue. It also saves the location of the end of the if statement, so it will later know where to return when the if function has ended.

For every line it compiles, it takes the corresponding line of PHP and inserts it as a comment in the assembly. This is to help in debugging.

### Combining

After there are no functions left in the toCompile queue, the combining phase starts. In this phase all the functions and the code outside the functions are combined into a single array. This phase also adds the used premade functions at the top and inserts the return statements at the correct position.

### Formatting

The last phase is the least interesting. It goes through the, now compiled code, and formats it. It uses either the length of the longest function name or the number 25 depending on which is larger to insert spaces in front of every line of code in a way everything lines up nicely. It also makes sure the comments line up nicely.

The last step the compiler takes is writing the compiled code to a file and using the assembler provided to create the hex code.

## Appendix 5: Explanation of the compiler functions

storeRam($location, $value)

Store a value in the ram.

$location The location (a variable) to store the value in the ram

$value The value to store, needs to be a variable

return void

getRam($location)

Get a value from the ram.

$location The location (a variable) where the value is stored

return The value that is stored at the location

display($what, $onWhat, $location = '000001')

Display something on either the display or the leds.

Possible values for $onwhat:

* leds: the leds at the top
* leds2: the leds to the right
* display: the display

$what What to display, must be a variable

$onWhat On what to display

$location Where to show the value when using the display, defaults to the right position

return void

pow($number,$power)

Get the power of a number

$number The number to power

$power The power value

return Int; The result

mod($what, $variable)

Take the modulo of a number

$what Modulo what

$variable Variable to modulo over

return void

getInput($writeTo, $type)

Get button or analog input. When you just want the input of 1 button, use getButtonPressed instead.

$writeTo Variable to write the input to

$type Type of input, possible values are: buttons, analog

return void

getButtonPressed($button)

Check if a button is pressed. Puts the result into R5.

$button Which button to check (input a variable)

return Int; Whether or not the button is pressed.

installCountdown($functionName)

Install the countdown.

$functionName The name of the function where the timer should go to

return void

startCountdown()

Start the countdown.

Retrun void

pushStack($variable)

Push a variable to the stack

$variable The variable to push to the stack

return void

pullStack($variable)

Pull a variable from the stack.

$variable The variable where the pulled variable is put into

return void

setCountdown($countdown)

Set the timer interrupt to a value. It will first reset the timer to 0.

$countdown How long the countdown should wait, in timer ticks

return void

getData($location, $offset)

Get data. Use offset 0 when it is just a single value.

$location The location where the variable is stored

$offset The offset of the location

return The value of the data segment

storeData($variable, $location, $offset)

Store data. Use offset 0 when it is just a single value.

$variable The variable to store

$location The name of the location where the variable is stored

$offset The offset of the location

return void

sleep($howLong)

Pause the program.

$howLong How long to sleep in clockticks

return void

initVar($variable,$places)

Initialize a variable that is used in that data segment.

$variable The name of the variable

$places How long the array is

return void

branch($branchTO)

Branch to a function.

$branchTO where to branch to

return void

moveFunction($branchTO)

Move a function in the assembly code.

$branchTO Where to branch to

return void

## Appendix 6: PHP Program

1 <?php

2 */\* vim: set expandtab tabstop=4 shiftwidth=4 softtabstop=4: \*/*

3

4 */\*\**

5  *\* Sort of a simulation of the PP2 program controlling the Fischer Technik in order to sort black and white discs.*

6  *\* @team Group 16*

7  *\* @author Stefan van den Berg*

8  *\* @author Rolf Verschuuren*

9  *\* @author Wigger Boelens*

10  *\* @since 13/3/2015*

11  *\*/*

12 **include** 'functions.php';

13 *//\*\*COMPILER\*\**

14 moveFunction('timerInterrupt', 1);

15 moveFunction('timerManage', 50);

16

17 *//\*\*DATA\*\**

18 initVar('offset', 1);

19 initVar('stackPointer', 1);

20 initVar('outputs', 12);

21 initVar('state', 1);

22

23 *//\*\*CODE\*\**

24 define('TIMEMOTORDOWN', 150); *//how long the sorter takes to move down*

25 define('BELT', 2000);

26 define('BELTROUND', 2000);*//Time for the belt to make a rotation*

27 define('SORT', 200);*//Clockticks to make a rotation*

28 define('COUNTDOWN', 30000);

29 *//outputs*

30 define('LENSLAMPPOSITION', 2);

31 define('LENSLAMPSORTER', 6);

32 define('HBRIDGE0', 0);

33 define('HBRIDGE1', 1);

34 define('CONVEYORBELT', 7);

35 define('FEEDERENGINE', 3);

36 define('DISPLAY', 8);

37 define('LEDSTATEINDICATOR', 9);

38

39 *//not a state*

40 **function** main()

41 {

42 **global** $counter, $location;

43

44 *//store the offset of the program, this is used in the interrupt*

45 storeData(R5, 'offset', 0);

46 *//install the countdown*

47 installCountdown('timerInterrupt');

48

49 *//save the location of the stackPointer, so we can clear the stack*

50 storeData(SP, 'stackPointer', 0);

51

52 *//the variables that are the same throughout the program:*

53 $counter = 0;

54 $location = 0;

55 $sleep = 0;

56

57

58 *//stop everything*

59 $temp = 0;

60 storeData($temp, 'outputs', HBRIDGE1);

61 storeData($temp, 'outputs', LENSLAMPPOSITION);

62 storeData($temp, 'outputs', LENSLAMPSORTER);

63 storeData($temp, 'outputs', LEDSTATEINDICATOR);

64 storeData($temp, 'outputs', DISPLAY);

65 storeData($temp, 'outputs', CONVEYORBELT);

66 storeData($temp, 'outputs', FEEDERENGINE);

67

68 *//sh0w the state*

69 $state = 0;

70 storeData($state, 'state', 0);

71

72 *//set HBridge so the sorter starts moving up*

73 $temp = 10;

74 storeData($temp, 'outputs', HBRIDGE0);

75 unset($temp, $state);

76

77 *//go to the first state*

78 initial();

79 }

80

81 *//state 0*

82 **function** initial()

83 {

84 **global** $sleep;

85 *//disable the lights on the right hand side*

86 $temp = 0;

87 display($temp, 'leds2');

88

89 $temp = getData('stackPointer', 0);

90 setStackPointer($temp);

91

92 timerManage();

93

94 *//check if the sorter push button is pressed*

95 $push = getButtonPressed(5);

96 **if** ($push == 1) {

97 *//move sorter down*

98 $temp = 0;

99 storeData($temp, 'outputs', HBRIDGE0);

100 $temp = 10;

101 storeData($temp, 'outputs', HBRIDGE1);

102

103 *//update state*

104 $temp = 1;

105 storeData($temp, 'state', 0);

106 unset($temp);

107

108 *//reset sleep for the next function*

109 $sleep = 0;

110 calibrateSorter();

111

112 }

113 unset($push);

114

115 *//loop*

116 initial();

117 }

118

119 *//state 1*

120 **function** calibrateSorter()

121 {

122 **global** $sleep;

123 timerManage();

124

125 *//the sorter is now moving down,*

126 *//we're waiting for it to reach its bottom position*

127 **if** ($sleep == TIMEMOTORDOWN) {

128 *//stop the sorter*

129 $temp = 0;

130 storeData($temp, 'outputs', HBRIDGE1);

131

132 *//update the state*

133 $state = 2;

134 storeData($state, 'state', 0);

135 unset($state);

136

137 *//reset sleep for the next state*

138 $sleep = 0;

139 resting();

140 }

141

142 *//loop*

143 $sleep++;

144 calibrateSorter();

145 }

146

147 *//state 2*

148 **function** resting()

149 {

150 timerManage();

151

152 *//the program is now waiting for the user to press start/stop*

153 $startStop = getButtonPressed(0);

154 **if** ($startStop == 1) {

155 *//sleep so we don't go to pause immediately*

156

157

158 *//power up the lamps*

159 $temp = 12;

160 storeData($temp, 'outputs', LENSLAMPPOSITION);

161 unset($temp);

162 timerManage();

163 sleep(1000);

164 $temp = 12;

165 storeData($temp, 'outputs', LENSLAMPSORTER);

166 unset($temp);

167 timerManage();

168 sleep(2000);

169

170

171 *//start up the belt and feeder*

172 $temp = 9;

173 storeData($temp, 'outputs', CONVEYORBELT);

174 $temp = 9;

175 storeData($temp, 'outputs', FEEDERENGINE);

176 unset($temp);

177

178 *//set and start the countdown for the moment there are no more disks*

179 *//this countdown will reset every time a disk is found*

180 *//when it triggers, timerInterrupt will be ran.*

181 setCountdown(COUNTDOWN);

182 startCountdown();

183

184 *//update the state*

185 $state = 3;

186 storeData($state, 'state', 0);

187 unset($state);

188

189 running();

190 }

191 unset($startStop);

192

193 *//loop*

194 resting();

195 }

196

197 *//state 3*

198 **function** running()

199 {

200 timerManage();

201

202 *//check if we need to pause*

203 $startStop = getButtonPressed(0);

204 **if** ($startStop == 1) {

205 *//stop the feeder engine*

206 $temp = 0;

207 storeData($temp, 'outputs', FEEDERENGINE);

208 unset($temp);

209

210 *//exit after 1 rotation of the belt*

211 setCountdown(BELT \* 10);

212

213 *//update the state*

214 $state = 9;*//TODO: echte state*

215 storeData($state, 'state', 0);

216 unset($state);

217

218 runningTimer();

219

220 }

221 unset($startStop);

222

223 *//check if a disk is at the position detector*

224 $position = getButtonPressed(7);

225 **if** ($position == 0) {

226 *//reset the countdown, because a disk was just detected*

227 setCountdown(COUNTDOWN);

228

229 *//update the state*

230 $state = 4;

231 storeData($state, 'state', 0);

232 unset($state);

233 runningWait();

234 }

235 unset($position);

236

237 *//loop*

238 running();

239 }

240

241 *//state 4*

242 **function** runningWait()

243 {

244 timerManage();

245

246 *//check if we need to pause*

247 $startStop = getButtonPressed(0);

248 **if** ($startStop == 1) {

249 *//stop the feeder engine*

250 $temp = 0;

251 storeData($temp, 'outputs', FEEDERENGINE);

252 unset($temp);

253

254 *//exit after 1 rotation of the belt*

255 setCountdown(BELT \* 10);

256

257 *//update the state*

258 $state = 9;

259 storeData($state, 'state', 0);

260 unset($state);

261

262 runningTimer();

263

264 }

265 unset($startStop);

266

267 *//check if a disk is at the position detector*

268 $position = getButtonPressed(7);

269 **if** ($position == 0) {

270 *//reset the countdown, because a disk was just detected*

271 setCountdown(COUNTDOWN);

272

273 *//update state*

274 $state = 5;

275 storeData($state, 'state', 0);

276 unset($state);

277

278 runningTimerReset();

279

280 }

281 unset($position);

282

283 *//check if a white disk is at the colour detector*

284 $colour = getButtonPressed(6);

285 **if** ($colour == 1) {

286 *//move the sorter up so the disk goes to the correct box*

287 $temp = 10;

288 storeData($temp, 'outputs', HBRIDGE0);

289

290 *//stop the feeder engine*

291 $temp = 0;

292 storeData($temp, 'outputs', FEEDERENGINE);

293 unset($temp);

294

295 *//update state*

296 $state = 6;

297 storeData($state, 'state', 0);

298 unset($state);

299

300 motorUp();

301 }

302 unset($colour);

303

304 *//loop*

305 runningWait();

306 }

307

308 *//state 5*

309 **function** runningTimerReset()

310 {

311 timerManage();

312

313 *//update state*

314 $state = 4;

315 storeData($state, 'state', 0);

316 unset($state);

317

318 runningWait();

319 }

320

321 *//state 6*

322 **function** motorUp()

323 {

324 **global** $sleep;

325 timerManage();

326

327 *//check if we need to pause*

328 $startStop = getButtonPressed(0);

329 **if** ($startStop == 1) {

330 *//stop the feeder engine*

331 $temp = 0;

332 storeData($temp, 'outputs', FEEDERENGINE);

333 unset($temp);

334

335 *//exit after 1 rotation of the belt*

336 setCountdown(BELT \* 10);

337

338 *//update the state*

339 $state = 10;

340 storeData($state, 'state', 0);

341 unset($state);

342

343 motorUpTimer();

344

345 }

346 unset($startStop);

347

348 *//check if the sorter push button is pressed*

349 $push = getButtonPressed(5);

350 **if** ($push == 1) {

351 *//stop the sorter engine, because its at its highest position*

352 $temp = 0;

353 storeData($temp, 'outputs', HBRIDGE0);

354 unset($temp);

355

356 *//update state*

357 $state = 7;

358 storeData($state, 'state', 0);

359 unset($state);

360

361 *//set sleep for the next function*

362 $sleep = 0;

363

364 whiteWait();

365 }

366 unset($push);

367

368 *//loop*

369 motorUp();

370 }

371

372 *//state 7*

373 **function** whiteWait()

374 {

375 **global** $sleep;

376 timerManage();

377

378 *//we are waiting for the white disk to be sorted*

379 **if** ($sleep == SORT) {

380 *//start moving the sorter down*

381 $temp = 10;

382 storeData($temp, 'outputs', HBRIDGE1);

383 unset($temp);

384

385 *//make sure the timerinterrupt is correct*

386 setCountdown(COUNTDOWN);

387

388 *//update state*

389 $state = 8;

390 storeData($state, 'state', 0);

391 unset($state);

392

393 *//reset sleep for the next function*

394 $sleep = 0;

395 motorDown();

396

397 }

398

399 *//check if we need to pause*

400 $startStop = getButtonPressed(0);

401 **if** ($startStop == 1) {

402 *//stop the feeder engine*

403 $temp = 0;

404 storeData($temp, 'outputs', FEEDERENGINE);

405 unset($temp);

406

407 *//exit after 1 rotation of the belt*

408 setCountdown(BELT \* 10);

409

410 *//update the state*

411 $state = 11;

412 storeData($state, 'state', 0);

413 unset($state);

414

415 whiteWaitTimer();

416 }

417 unset($startStop);

418

419 *//loop*

420 $sleep++;

421 whiteWait();

422 }

423

424 *//state 8*

425 **function** motorDown()

426 {

427 **global** $sleep;

428 timerManage();

429

430

431 *//check if a white disk is at the colour detector*

432 $colour = getButtonPressed(6);

433 **if** ($colour == 1) {

434 *//move the sorter up so the disk goes to the correct box*

435 $temp=0;

436 storeData($temp,'outputs',HBRIDGE1);

437 $temp = 10;

438 storeData($temp, 'outputs', HBRIDGE0);

439 unset($temp);

440

441 *//update state*

442 $state = 6;

443 storeData($state, 'state', 0);

444 $sleep=0;

445 unset($state);

446

447 motorUp();

448 }

449 unset($colour);

450

451

452 *//the sorter is moving down, we are waiting for that to complete*

453 **if** ($sleep == TIMEMOTORDOWN) {

454 *//stop the sorter, its where it should be*

455 $temp = 0;

456 storeData($temp, 'outputs', HBRIDGE1);

457 $temp = 7;

458 storeData($temp, 'outputs', FEEDERENGINE);

459 unset($temp);

460

461 *//update state*

462 $state = 4;

463 storeData($state, 'state', 0);

464 *//reset sleep for the next function*

465 $sleep = 0;

466 unset($state);

467

468 runningWait();

469 }

470

471 *//check if we need to pause*

472 $startStop = getButtonPressed(0);

473 **if** ($startStop == 1) {

474 *//stop the feeder engine*

475 $temp = 0;

476 storeData($temp, 'outputs', FEEDERENGINE);

477 unset($temp);

478

479 *//exit after 1 rotation of the belt*

480 setCountdown(BELT \* 10);

481

482 *//update the state*

483 $state = 12;

484 storeData($state, 'state', 0);

485 unset($state);

486

487 motorDownTimer();

488 }

489 unset($startStop);

490

491 *//loop*

492 $sleep++;

493 motorDown();

494

495 }

496

497 *//state 9*

498 **function** runningTimer()

499 {

500 timerManage();

501

502 *//update state*

503 $state = 13;

504 storeData($state, 'state', 0);

505 unset($state);

506

507 runningStop();

508 }

509

510 *//state 10*

511 **function** motorUpTimer()

512 {

513 timerManage();

514

515 *//update state*

516 $state = 14;

517 storeData($state, 'state', 0);

518 unset($state);

519

520 motorUpStop();

521 }

522

523 *//state 11*

524 **function** whiteWaitTimer()

525 {

526 timerManage();

527

528 *//update state*

529 $state = 15;

530 storeData($state, 'state', 0);

531 unset($state);

532

533 whiteWaitStop();

534 }

535

536 *//state 12*

537 **function** motorDownTimer()

538 {

539 timerManage();

540

541 *//update state*

542 $state = 16;

543 storeData($state, 'state', 0);

544 unset($state);

545

546 motorDownStop();

547 }

548

549 *//state 13*

550 **function** runningStop()

551 {

552 timerManage();

553

554 *//check if a white disk is at the colour detector*

555 $colour = getButtonPressed(6);

556 **if** ($colour == 1) {

557 *//stop the sorter engine, because its at its highest position*

558 $temp = 10;

559 storeData($temp, 'outputs', HBRIDGE0);

560

561 *//stop the feeder engine*

562 $temp = 0;

563 storeData($temp, 'outputs', FEEDERENGINE);

564 unset($temp);

565

566 *//update state*

567 $state = 10;

568 storeData($state, 'state', 0);

569 unset($state);

570

571 motorUpStop();

572 }

573 unset($colour);

574

575 *//loop*

576 runningStop();

577 }

578

579 *//state 14*

580 **function** motorUpStop()

581 {

582 timerManage();

583

584 *//check if the sorter push button is pressed*

585 $push = getButtonPressed(5);

586 **if** ($push == 1) {

587 *//stop the engine of the sorter*

588 $temp = 0;

589 storeData($temp, 'outputs', HBRIDGE0);

590 unset($temp);

591

592 *//update state*

593 $state = 11;

594 storeData($state, 'state', 0);

595 unset($state);

596

597 whiteWaitStop();

598 }

599 unset($push);

600

601 *//loop*

602 motorUpStop();

603 }

604

605 *//state 15*

606 **function** whiteWaitStop()

607 {

608 **global** $sleep;

609 timerManage();

610

611 *//check if the white disk has been sorted*

612 **if** ($sleep == SORT) {

613 *//it has, so lets start moving the sorter down*

614 $temp = 10;

615 storeData($temp, 'outputs', HBRIDGE1);

616 $temp = 0;

617 storeData($temp, 'outputs', FEEDERENGINE);

618 unset($temp);

619

620 *//update state*

621 $state = 12;

622 storeData($state, 'state', 0);

623 unset($state);

624

625 $sleep = 0;

626 motorDownStop();

627 }

628

629 *//loop*

630 $sleep++;

631 whiteWaitStop();

632 }

633

634 *//state 16*

635 **function** motorDownStop()

636 {

637 **global** $sleep;

638 timerManage();

639

640 *//check if the sorter has moved down*

641 **if** ($sleep == TIMEMOTORDOWN) {

642 *//it has, so lets stop it*

643 $temp = 0;

644 storeData($temp, 'outputs', HBRIDGE1);

645 unset($temp);

646

647 *//update the state*

648 $state = 9;

649 storeData($state, 'state', 0);

650 unset($state);

651

652 $sleep = 0;

653 runningStop();

654 }

655

656 *//loop*

657 $sleep++;

658 motorDownStop();

659 }

660

661 *//not a state*

662 **function** timerInterrupt()

663 {

664 timerManage();

665 *//show that we are in the timer interrupt*

666 $temp = 5;

667 display($temp, 'display');

668

669 *//start moving the sorter up, to start the calibration*

670 $temp = 10;

671 storeData($temp, 'outputs', HBRIDGE0);

672

673 *//stop the rest*

674 $temp = 0;

675 storeData($temp, 'outputs', LENSLAMPPOSITION);

676 storeData($temp, 'outputs', LENSLAMPSORTER);

677 storeData($temp, 'outputs', LEDSTATEINDICATOR);

678 storeData($temp, 'outputs', DISPLAY);

679 storeData($temp, 'outputs', CONVEYORBELT);

680 storeData($temp, 'outputs', FEEDERENGINE);

681

682

683 *//reset, because we will no longer be in timerInterrupt*

684 display($temp, 'display');

685 unset($temp);

686

687 *//go back to initial*

688 $temp = getData('offset', 0);

689 $temp2 = getFuncLocation('initial');

690 $temp += $temp2;

691

692

693 addStackPointer(2);

694 pushStack($temp);

695 addStackPointer(-1);

696 }

697

698 *//not a state*

699 **function** abort()

700 {

701 *//free some memory*

702 unset($engines);

703

704 *//prevent timerinterrupt*

705 setCountdown(1000);

706 $temp = getData('stackPointer', 0);

707 setStackPointer($temp);

708

709 *//stop everything*

710 $temp = 0;

711 storeData($temp, 'outputs', HBRIDGE1);

712 storeData($temp, 'outputs', HBRIDGE0);

713 storeData($temp, 'outputs', LENSLAMPPOSITION);

714 storeData($temp, 'outputs', LENSLAMPSORTER);

715 storeData($temp, 'outputs', LEDSTATEINDICATOR);

716 storeData($temp, 'outputs', DISPLAY);

717 storeData($temp, 'outputs', CONVEYORBELT);

718 storeData($temp, 'outputs', FEEDERENGINE);

719 unset($temp);

720

721 *//apply the changes to actually stop it*

722 timerManage();

723

724 *//update the state*

725 $state = 17;

726 storeData($state, 'state', 0);

727

728

729 *//show we aborted*

730 $state = 7;

731 display($state, 'leds2', 0);

732 unset($state);

733

734 aborted();

735 }

736

737 *//state 17*

738 **function** aborted()

739 {

740 *//prevent timer interrupt*

741 setCountdown(1000);

742 timerManage();

743 *//check if we can start again*

744 $startStop = getButtonPressed(0);

745 **if** ($startStop == 1) {

746 *//start moving the sorter up, to start the calibration*

747 $temp = 10;

748 storeData($temp, 'outputs', HBRIDGE0);

749 unset($temp);

750

751 *//update the state*

752 $state = 0;

753 storeData($state, 'state', 0);

754 unset($state);

755

756 initial();

757 }

758 unset($startStop);

759 aborted();

760

761 }

762

763 *//not a state*

764 **function** timerManage()

765 {

766 **global** $location, $counter, $engine, $sleep;

767

768 **if** ($location == 0) {

769 $engines = 0;

770 }

771

772 *//makes sure that when $counter >12 it will reset to 0*

773 mod(12, $counter);

774

775 *//get the voltage of output $location*

776 $voltage = getData('outputs', $location);

777

778 *//power up the output when it needs to*

779 **if** ($voltage > $counter) {

780 $voltage = $location;

781 $voltage = pow(2, $voltage);

782 $engines += $voltage;

783 }

784

785 *//check if we did all outputs*

786 **if** ($location == 7) {

787 *//actually output the result*

788 sleep(1);

789 display($engines, 'leds');

790

791

792 unset($voltage);

793 *//check if abort is pressed*

794 $abort = getButtonPressed(1);

795 **if** ($abort == 1) {

796 abort();*//STOP THE MACHINE!*

797 }

798 unset($abort);

799

800 *//check if we are in a new iteration*

801 **if** ($counter == 6) {

802 *//set the first part of the display*

803 $temp = getData('state', 0);

804 mod(10, $temp);

805 display($temp, 'display', 1);

806 unset($temp);

807 }

808 *//check if we are at the end of the iteration*

809 **if** ($counter == 11) {

810 *//set the second part of the display;*

811 pushStack($sleep);

812

813 $temp = getData('state', 0);

814 *//get the last digit of the state*

815 *//we have no variables left, so we use $sleep*

816

817 $sleep = $temp;

818 mod(10, $sleep);

819 $temp -= $sleep;

820 $temp /= 10;

821 *//display the last digit*

822 display($temp, 'display', 2);

823

824 pullStack($sleep);

825 unset($temp);

826 }

827

828

829 *//set the variables for the next run*

830 $engines = 0;

831 $location = 0;

832 $counter++;

833

834 *//and return to where we came from*

835 **return**;

836 }

837

838 *//loop*

839 $location++;

840 branch('timerManage');

841 }

## Appendix 7: Assembly Program

1 @DATA

2 offset DS 1

3 stackPointer DS 1

4 outputs DS 12

5 state DS 1

6

7 @CODE

8

9 TIMEMOTORDOWN **EQU** 150

10 BELT **EQU** 2000

11 BELTROUND **EQU** 2000

12 SORT **EQU** 200

13 COUNTDOWN **EQU** 30000

14 LENSLAMPPOSITION **EQU** 2

15 LENSLAMPSORTER **EQU** 6

16 HBRIDGE0 **EQU** 0

17 HBRIDGE1 **EQU** 1

18 CONVEYORBELT **EQU** 7

19 FEEDERENGINE **EQU** 3

20 DISPLAY **EQU** 8

21 LEDSTATEINDICATOR **EQU** 9

22 begin: BRA main

23

24

25 *;sleep*

26 \_timer: MULS R5 10

27 PUSH R4

28 LOAD R4 R5

29 LOAD R5 -16

30 LOAD R5 [R5+13]

31 SUB R5 R4

32 LOAD R4 -16

33 \_wait: CMP R5 [R4+13] *; Compare the timer to 0*

34 BMI \_wait

35 PULL R4

36 RTS

37

38 \_pressed: PUSH R4 *;make sure all vars are the same at the end*

39 PUSH R5

40 LOAD R4 R3

41 LOAD R5 2

42 BRS \_pow

43 LOAD R3 R5

44 LOAD R5 -16

45 LOAD R4 [R5+7]

46 DIV R4 R3

47 MOD R4 2

48

49 PUSH R4 *;the result*

50 ADD SP 1 *;decrease the SP so we get the correct pulls*

51

52 PULL R5

53 PULL R4

54

55 RTS

56

57 \_pow: CMP R4 0

58 BEQ \_pow1

59 CMP R4 1

60 BEQ \_powR

61 PUSH R3

62 PUSH R4

63 SUB R4 1

64 LOAD R3 R5

65 \_powLoop: MULS R5 R3

66 SUB R4 1

67 CMP R4 0

68 BEQ \_powReturn

69 BRA \_powLoop

70 \_powReturn: PULL R4

71 PULL R3

72 RTS

73 \_pow1: LOAD R5 1

74 RTS

75 \_powR: RTS

76

77 *;display*

78 \_Hex7Seg: BRS \_Hex7Seg\_bgn *; push address(tbl) onto stack and proceed at bgn*

79 \_Hex7Seg\_tbl: CONS %01111110 *; 7-segment pattern for '0'*

80 CONS %00110000 *; 7-segment pattern for '1'*

81 CONS %01101101 *; 7-segment pattern for '2'*

82 CONS %01111001 *; 7-segment pattern for '3'*

83 CONS %00110011 *; 7-segment pattern for '4'*

84 CONS %01011011 *; 7-segment pattern for '5'*

85 CONS %01011111 *; 7-segment pattern for '6'*

86 CONS %01110000 *; 7-segment pattern for '7'*

87 CONS %01111111 *; 7-segment pattern for '8'*

88 CONS %01111011 *; 7-segment pattern for '9'*

89 CONS %01110111 *; 7-segment pattern for 'A'*

90 CONS %00011111 *; 7-segment pattern for 'b'*

91 CONS %01001110 *; 7-segment pattern for 'C'*

92 CONS %00111101 *; 7-segment pattern for 'd'*

93 CONS %01001111 *; 7-segment pattern for 'E'*

94 CONS %01000111 *; 7-segment pattern for 'F'*

95 \_Hex7Seg\_bgn: AND R5 %01111 *; R0 = R0 MOD 16 , just to be safe...*

96 LOAD R4 [SP++] *; R4 = address(tbl) (retrieve from stack)*

97 LOAD R4 [R4+R5] *; R4 = tbl[R0]*

98 LOAD R5 -16

99 STOR R4 [R5+8] *; and place this in the Display Element*

100 RTS

101 main: STOR R5 [GB +offset + 0] *;storeData(R5, 'offset', 0)*

102 LOAD R0 timerInterrupt *;installCountdown('timerInterrupt')*

103 ADD R0 R5

104 LOAD R1 16

105 STOR R0 [R1]

106

107 LOAD R5 -16

108

109 *; Set the timer to 0*

110 LOAD R0 0

111 SUB R0 [R5+13]

112 STOR R0 [R5+13]

113 STOR SP [GB +stackPointer + 0] *;storeData(SP, 'stackPointer', 0)*

114 LOAD R0 0 *;$counter = 0*

115 LOAD R1 0 *;$location = 0*

116 LOAD R2 0 *;$sleep = 0*

117 LOAD R3 0 *;$temp = 0*

118 STOR R3 [GB +outputs + HBRIDGE1] *;storeData($temp, 'outputs', HBRIDGE1)*

119 STOR R3 [GB +outputs + LENSLAMPPOSITION] *;storeData($temp, 'outputs', LENSLAMPPOSITION)*

120 STOR R3 [GB +outputs + LENSLAMPSORTER] *;storeData($temp, 'outputs', LENSLAMPSORTER)*

121 STOR R3 [GB +outputs + LEDSTATEINDICATOR] *;storeData($temp, 'outputs', LEDSTATEINDICATOR)*

122 STOR R3 [GB +outputs + DISPLAY] *;storeData($temp, 'outputs', DISPLAY)*

123 STOR R3 [GB +outputs + CONVEYORBELT] *;storeData($temp, 'outputs', CONVEYORBELT)*

124 STOR R3 [GB +outputs + FEEDERENGINE] *;storeData($temp, 'outputs', FEEDERENGINE)*

125 LOAD R4 0 *;$state = 0*

126 STOR R4 [GB +state + 0] *;storeData($state, 'state', 0)*

127 LOAD R3 10 *;$temp = 10*

128 STOR R3 [GB +outputs + HBRIDGE0] *;storeData($temp, 'outputs', HBRIDGE0)*

129 *;unset($temp, $state)*

130 BRA initial *;initial()*

131

132 timerInterrupt: BRS timerManage *;timerManage()*

133 LOAD R3 5 *;$temp = 5*

134 PUSH R5 *;display($temp, 'display')*

135 PUSH R4

136 LOAD R5 R3

137 BRS \_Hex7Seg

138 LOAD R4 %0000001

139 STOR R4 [R5+9]

140 PULL R4

141 PULL R5

142 LOAD R3 10 *;$temp = 10*

143 STOR R3 [GB +outputs + HBRIDGE0] *;storeData($temp, 'outputs', HBRIDGE0)*

144 LOAD R3 0 *;$temp = 0*

145 STOR R3 [GB +outputs + LENSLAMPPOSITION] *;storeData($temp, 'outputs', LENSLAMPPOSITION)*

146 STOR R3 [GB +outputs + LENSLAMPSORTER] *;storeData($temp, 'outputs', LENSLAMPSORTER)*

147 STOR R3 [GB +outputs + LEDSTATEINDICATOR] *;storeData($temp, 'outputs', LEDSTATEINDICATOR)*

148 STOR R3 [GB +outputs + DISPLAY] *;storeData($temp, 'outputs', DISPLAY)*

149 STOR R3 [GB +outputs + CONVEYORBELT] *;storeData($temp, 'outputs', CONVEYORBELT)*

150 STOR R3 [GB +outputs + FEEDERENGINE] *;storeData($temp, 'outputs', FEEDERENGINE)*

151 PUSH R5 *;display($temp, 'display')*

152 PUSH R4

153 LOAD R5 R3

154 BRS \_Hex7Seg

155 LOAD R4 %0000001

156 STOR R4 [R5+9]

157 PULL R4

158 PULL R5

159 *;unset($temp)*

160 LOAD R3 [ GB + offset + 0 ] *;$temp = getData('offset', 0)*

161 LOAD R4 initial *;$temp2 = getFuncLocation('initial')*

162 ADD R3 R4 *;$temp += $temp2*

163 ADD SP 2 *;addStackPointer(2)*

164 PUSH R3 *;pushStack($temp)*

165 ADD SP -1 *;addStackPointer(-1)*

166 RTE

167

168 initial: LOAD R3 0 *;$temp = 0*

169 PUSH R5 *;display($temp, 'leds2')*

170 LOAD R5 -16

171 STOR R3 [R5+10]

172 PULL R5

173 LOAD R3 [ GB + stackPointer + 0 ] *;$temp = getData('stackPointer', 0)*

174 LOAD SP R3 *;setStackPointer($temp)*

175 BRS timerManage *;timerManage()*

176 PUSH R3 *;$push = getButtonPressed(5)*

177 LOAD R3 5

178 BRS \_pressed

179 PULL R3

180 SUB SP 5

181 PULL R4

182 ADD SP 4

183 CMP R4 1 *;if ($push == 1) {*

184 BEQ conditional0

185 return0: *;unset($push)*

186 BRA initial *;initial()*

187

188 *;if ($push == 1) {*

189 conditional0: LOAD R3 0 *;$temp = 0*

190 STOR R3 [GB +outputs + HBRIDGE0] *;storeData($temp, 'outputs', HBRIDGE0)*

191 LOAD R3 10 *;$temp = 10*

192 STOR R3 [GB +outputs + HBRIDGE1] *;storeData($temp, 'outputs', HBRIDGE1)*

193 LOAD R3 1 *;$temp = 1*

194 STOR R3 [GB +state + 0] *;storeData($temp, 'state', 0)*

195 *;unset($temp)*

196 LOAD R2 0 *;$sleep = 0*

197 BRA calibrateSorter *;calibrateSorter()*

198

199 calibrateSorter: BRS timerManage *;timerManage()*

200 CMP R2 TIMEMOTORDOWN *;if ($sleep == TIMEMOTORDOWN) {*

201 BEQ conditional1

202 return1: ADD R2 1 *;$sleep+=1*

203 BRA calibrateSorter *;calibrateSorter()*

204

205 *;if ($sleep == TIMEMOTORDOWN) {*

206 conditional1: LOAD R3 0 *;$temp = 0*

207 STOR R3 [GB +outputs + HBRIDGE1] *;storeData($temp, 'outputs', HBRIDGE1)*

208 LOAD R4 2 *;$state = 2*

209 STOR R4 [GB +state + 0] *;storeData($state, 'state', 0)*

210 *;unset($state)*

211 LOAD R2 0 *;$sleep = 0*

212 BRA resting *;resting()*

213

214 resting: BRS timerManage *;timerManage()*

215 PUSH R3 *;$startStop = getButtonPressed(0)*

216 LOAD R3 0

217 BRS \_pressed

218 PULL R3

219 SUB SP 5

220 PULL R4

221 ADD SP 4

222 CMP R4 1 *;if ($startStop == 1) {*

223 BEQ conditional2

224 return2: *;unset($startStop)*

225 BRA resting *;resting()*

226

227 *;if ($startStop == 1) {*

228 conditional2: LOAD R3 12 *;$temp = 12*

229 STOR R3 [GB +outputs + LENSLAMPPOSITION] *;storeData($temp, 'outputs', LENSLAMPPOSITION)*

230 *;unset($temp)*

231 BRS timerManage *;timerManage()*

232 PUSH R5 *;sleep(1000)*

233 LOAD R5 1000

234 BRS \_timer

235 PULL R5

236 LOAD R3 12 *;$temp = 12*

237 STOR R3 [GB +outputs + LENSLAMPSORTER] *;storeData($temp, 'outputs', LENSLAMPSORTER)*

238 *;unset($temp)*

239 BRS timerManage *;timerManage()*

240 PUSH R5 *;sleep(2000)*

241 LOAD R5 2000

242 BRS \_timer

243 PULL R5

244 LOAD R3 9 *;$temp = 9*

245 STOR R3 [GB +outputs + CONVEYORBELT] *;storeData($temp, 'outputs', CONVEYORBELT)*

246 LOAD R3 9 *;$temp = 9*

247 STOR R3 [GB +outputs + FEEDERENGINE] *;storeData($temp, 'outputs', FEEDERENGINE)*

248 *;unset($temp)*

249 PUSH R5 *;reset timer ;setCountdown(COUNTDOWN)*

250 PUSH R4

251 LOAD R5 -16

252 LOAD R4 0

253 SUB R4 [R5+13]

254 STOR R4 [R5+13] *;set timer*

255 LOAD R4 COUNTDOWN

256 STOR R4 [R5+13]

257 PULL R4

258 PULL R5

259 SETI 8 *;startCountdown()*

260 LOAD R3 3 *;$state = 3*

261 STOR R3 [GB +state + 0] *;storeData($state, 'state', 0)*

262 *;unset($state)*

263 BRA running *;running()*

264

265 running: BRS timerManage *;timerManage()*

266 PUSH R3 *;$startStop = getButtonPressed(0)*

267 LOAD R3 0

268 BRS \_pressed

269 PULL R3

270 SUB SP 5

271 PULL R3

272 ADD SP 4

273 CMP R3 1 *;if ($startStop == 1) {*

274 BEQ conditional3

275 return3: *;unset($startStop)*

276 PUSH R3 *;$position = getButtonPressed(7)*

277 LOAD R3 7

278 BRS \_pressed

279 PULL R3

280 SUB SP 5

281 PULL R3

282 ADD SP 4

283 CMP R3 1 *;if ($position == 1) {*

284 BEQ conditional4

285 return4: *;unset($position)*

286 BRA running *;running()*

287

288 *;if ($startStop == 1) {*

289 conditional3: LOAD R4 0 *;$temp = 0*

290 STOR R4 [GB +outputs + FEEDERENGINE] *;storeData($temp, 'outputs', FEEDERENGINE)*

291 *;unset($temp)*

292 PUSH R5 *;reset timer ;setCountdown(BELT \* 10)*

293 PUSH R4

294 LOAD R5 -16

295 LOAD R4 0

296 SUB R4 [R5+13]

297 STOR R4 [R5+13] *;set timer*

298 LOAD R4 BELT \* 10

299 STOR R4 [R5+13]

300 PULL R4

301 PULL R5

302 LOAD R4 9 *;$state = 9*

303 STOR R4 [GB +state + 0] *;storeData($state, 'state', 0)*

304 *;unset($state)*

305 BRA runningTimer *;runningTimer()*

306

307 *;if ($position == 1) {*

308 conditional4: PUSH R5 *;reset timer ;setCountdown(COUNTDOWN)*

309 PUSH R4

310 LOAD R5 -16

311 LOAD R4 0

312 SUB R4 [R5+13]

313 STOR R4 [R5+13] *;set timer*

314 LOAD R4 COUNTDOWN

315 STOR R4 [R5+13]

316 PULL R4

317 PULL R5

318 LOAD R4 4 *;$state = 4*

319 STOR R4 [GB +state + 0] *;storeData($state, 'state', 0)*

320 *;unset($state)*

321 BRA runningWait *;runningWait()*

322

323 runningWait: BRS timerManage *;timerManage()*

324 PUSH R3 *;$startStop = getButtonPressed(0)*

325 LOAD R3 0

326 BRS \_pressed

327 PULL R3

328 SUB SP 5

329 PULL R3

330 ADD SP 4

331 CMP R3 1 *;if ($startStop == 1) {*

332 BEQ conditional5

333 return5: *;unset($startStop)*

334 PUSH R3 *;$position = getButtonPressed(7)*

335 LOAD R3 7

336 BRS \_pressed

337 PULL R3

338 SUB SP 5

339 PULL R3

340 ADD SP 4

341 CMP R3 0 *;if ($position == 0) {*

342 BEQ conditional6

343 return6: *;unset($position)*

344 PUSH R3 *;$colour = getButtonPressed(6)*

345 LOAD R3 6

346 BRS \_pressed

347 PULL R3

348 SUB SP 5

349 PULL R3

350 ADD SP 4

351 CMP R3 1 *;if ($colour == 1) {*

352 BEQ conditional7

353 return7: *;unset($colour)*

354 BRA runningWait *;runningWait()*

355

356 *;if ($startStop == 1) {*

357 conditional5: LOAD R4 0 *;$temp = 0*

358 STOR R4 [GB +outputs + FEEDERENGINE] *;storeData($temp, 'outputs', FEEDERENGINE)*

359 *;unset($temp)*

360 PUSH R5 *;reset timer ;setCountdown(BELT \* 10)*

361 PUSH R4

362 LOAD R5 -16

363 LOAD R4 0

364 SUB R4 [R5+13]

365 STOR R4 [R5+13] *;set timer*

366 LOAD R4 BELT \* 10

367 STOR R4 [R5+13]

368 PULL R4

369 PULL R5

370 LOAD R4 9 *;$state = 9*

371 STOR R4 [GB +state + 0] *;storeData($state, 'state', 0)*

372 *;unset($state)*

373 BRA runningTimer *;runningTimer()*

374

375 *;if ($position == 0) {*

376 conditional6: PUSH R5 *;reset timer ;setCountdown(COUNTDOWN)*

377 PUSH R4

378 LOAD R5 -16

379 LOAD R4 0

380 SUB R4 [R5+13]

381 STOR R4 [R5+13] *;set timer*

382 LOAD R4 COUNTDOWN

383 STOR R4 [R5+13]

384 PULL R4

385 PULL R5

386 LOAD R4 5 *;$state = 5*

387 STOR R4 [GB +state + 0] *;storeData($state, 'state', 0)*

388 *;unset($state)*

389 BRA runningTimerReset *;runningTimerReset()*

390

391 *;if ($colour == 1) {*

392 conditional7: LOAD R4 10 *;$temp = 10*

393 STOR R4 [GB +outputs + HBRIDGE0] *;storeData($temp, 'outputs', HBRIDGE0)*

394 LOAD R4 0 *;$temp = 0*

395 STOR R4 [GB +outputs + FEEDERENGINE] *;storeData($temp, 'outputs', FEEDERENGINE)*

396 *;unset($temp)*

397 LOAD R4 6 *;$state = 6*

398 STOR R4 [GB +state + 0] *;storeData($state, 'state', 0)*

399 *;unset($state)*

400 BRA motorUp *;motorUp()*

401

402 motorUp: BRS timerManage *;timerManage()*

403 PUSH R3 *;$startStop = getButtonPressed(0)*

404 LOAD R3 0

405 BRS \_pressed

406 PULL R3

407 SUB SP 5

408 PULL R3

409 ADD SP 4

410 CMP R3 1 *;if ($startStop == 1) {*

411 BEQ conditional8

412 return8: *;unset($startStop)*

413 PUSH R3 *;$push = getButtonPressed(5)*

414 LOAD R3 5

415 BRS \_pressed

416 PULL R3

417 SUB SP 5

418 PULL R3

419 ADD SP 4

420 CMP R3 1 *;if ($push == 1) {*

421 BEQ conditional9

422 return9: *;unset($push)*

423 BRA motorUp *;motorUp()*

424

425 *;if ($startStop == 1) {*

426 conditional8: LOAD R4 0 *;$temp = 0*

427 STOR R4 [GB +outputs + FEEDERENGINE] *;storeData($temp, 'outputs', FEEDERENGINE)*

428 *;unset($temp)*

429 PUSH R5 *;reset timer ;setCountdown(BELT \* 10)*

430 PUSH R4

431 LOAD R5 -16

432 LOAD R4 0

433 SUB R4 [R5+13]

434 STOR R4 [R5+13] *;set timer*

435 LOAD R4 BELT \* 10

436 STOR R4 [R5+13]

437 PULL R4

438 PULL R5

439 LOAD R4 10 *;$state = 10*

440 STOR R4 [GB +state + 0] *;storeData($state, 'state', 0)*

441 *;unset($state)*

442 BRA motorUpTimer *;motorUpTimer()*

443

444 *;if ($push == 1) {*

445 conditional9: LOAD R4 0 *;$temp = 0*

446 STOR R4 [GB +outputs + HBRIDGE0] *;storeData($temp, 'outputs', HBRIDGE0)*

447 *;unset($temp)*

448 LOAD R4 7 *;$state = 7*

449 STOR R4 [GB +state + 0] *;storeData($state, 'state', 0)*

450 *;unset($state)*

451 LOAD R2 0 *;$sleep = 0*

452 BRA whiteWait *;whiteWait()*

453

454 whiteWait: BRS timerManage *;timerManage()*

455 CMP R2 SORT *;if ($sleep == SORT) {*

456 BEQ conditional10

457 return10: PUSH R3 *;$startStop = getButtonPressed(0)*

458 LOAD R3 0

459 BRS \_pressed

460 PULL R3

461 SUB SP 5

462 PULL R3

463 ADD SP 4

464 CMP R3 1 *;if ($startStop == 1) {*

465 BEQ conditional11

466 return11: *;unset($startStop)*

467 ADD R2 1 *;$sleep+=1*

468 BRA whiteWait *;whiteWait()*

469

470 *;if ($sleep == SORT) {*

471 conditional10: LOAD R3 10 *;$temp = 10*

472 STOR R3 [GB +outputs + HBRIDGE1] *;storeData($temp, 'outputs', HBRIDGE1)*

473 *;unset($temp)*

474 PUSH R5 *;reset timer ;setCountdown(COUNTDOWN)*

475 PUSH R4

476 LOAD R5 -16

477 LOAD R4 0

478 SUB R4 [R5+13]

479 STOR R4 [R5+13] *;set timer*

480 LOAD R4 COUNTDOWN

481 STOR R4 [R5+13]

482 PULL R4

483 PULL R5

484 LOAD R3 8 *;$state = 8*

485 STOR R3 [GB +state + 0] *;storeData($state, 'state', 0)*

486 *;unset($state)*

487 LOAD R2 0 *;$sleep = 0*

488 BRA motorDown *;motorDown()*

489

490 *;if ($startStop == 1) {*

491 conditional11: LOAD R4 0 *;$temp = 0*

492 STOR R4 [GB +outputs + FEEDERENGINE] *;storeData($temp, 'outputs', FEEDERENGINE)*

493 *;unset($temp)*

494 PUSH R5 *;reset timer ;setCountdown(BELT \* 10)*

495 PUSH R4

496 LOAD R5 -16

497 LOAD R4 0

498 SUB R4 [R5+13]

499 STOR R4 [R5+13] *;set timer*

500 LOAD R4 BELT \* 10

501 STOR R4 [R5+13]

502 PULL R4

503 PULL R5

504 LOAD R4 11 *;$state = 11*

505 STOR R4 [GB +state + 0] *;storeData($state, 'state', 0)*

506 *;unset($state)*

507 BRA whiteWaitTimer *;whiteWaitTimer()*

508

509 whiteWaitTimer: BRS timerManage *;timerManage()*

510 LOAD R3 15 *;$state = 15*

511 STOR R3 [GB +state + 0] *;storeData($state, 'state', 0)*

512 *;unset($state)*

513 BRA whiteWaitStop *;whiteWaitStop()*

514

515 whiteWaitStop: BRS timerManage *;timerManage()*

516 CMP R2 SORT *;if ($sleep == SORT) {*

517 BEQ conditional12

518 return12: ADD R2 1 *;$sleep+=1*

519 BRA whiteWaitStop *;whiteWaitStop()*

520

521 *;if ($sleep == SORT) {*

522 conditional12: LOAD R3 10 *;$temp = 10*

523 STOR R3 [GB +outputs + HBRIDGE1] *;storeData($temp, 'outputs', HBRIDGE1)*

524 LOAD R3 0 *;$temp = 0*

525 STOR R3 [GB +outputs + FEEDERENGINE] *;storeData($temp, 'outputs', FEEDERENGINE)*

526 *;unset($temp)*

527 LOAD R3 12 *;$state = 12*

528 STOR R3 [GB +state + 0] *;storeData($state, 'state', 0)*

529 *;unset($state)*

530 LOAD R2 0 *;$sleep = 0*

531 BRA motorDownStop *;motorDownStop()*

532

533 motorDownStop: BRS timerManage *;timerManage()*

534 CMP R2 TIMEMOTORDOWN *;if ($sleep == TIMEMOTORDOWN) {*

535 BEQ conditional13

536 return13: ADD R2 1 *;$sleep+=1*

537 BRA motorDownStop *;motorDownStop()*

538

539 *;if ($sleep == TIMEMOTORDOWN) {*

540 conditional13: LOAD R3 0 *;$temp = 0*

541 STOR R3 [GB +outputs + HBRIDGE1] *;storeData($temp, 'outputs', HBRIDGE1)*

542 *;unset($temp)*

543 LOAD R3 9 *;$state = 9*

544 STOR R3 [GB +state + 0] *;storeData($state, 'state', 0)*

545 *;unset($state)*

546 LOAD R2 0 *;$sleep = 0*

547 BRA runningStop *;runningStop()*

548

549 runningStop: BRS timerManage *;timerManage()*

550 PUSH R3 *;$colour = getButtonPressed(6)*

551 LOAD R3 6

552 BRS \_pressed

553 PULL R3

554 SUB SP 5

555 PULL R3

556 ADD SP 4

557 CMP R3 1 *;if ($colour == 1) {*

558 BEQ conditional14

559 return14: *;unset($colour)*

560 BRA runningStop *;runningStop()*

561

562 *;if ($colour == 1) {*

563 conditional14: LOAD R4 10 *;$temp = 10*

564 STOR R4 [GB +outputs + HBRIDGE0] *;storeData($temp, 'outputs', HBRIDGE0)*

565 LOAD R4 0 *;$temp = 0*

566 STOR R4 [GB +outputs + FEEDERENGINE] *;storeData($temp, 'outputs', FEEDERENGINE)*

567 *;unset($temp)*

568 LOAD R4 10 *;$state = 10*

569 STOR R4 [GB +state + 0] *;storeData($state, 'state', 0)*

570 *;unset($state)*

571 BRA motorUpStop *;motorUpStop()*

572

573 motorUpStop: BRS timerManage *;timerManage()*

574 PUSH R3 *;$push = getButtonPressed(5)*

575 LOAD R3 5

576 BRS \_pressed

577 PULL R3

578 SUB SP 5

579 PULL R3

580 ADD SP 4

581 CMP R3 1 *;if ($push == 1) {*

582 BEQ conditional15

583 return15: *;unset($push)*

584 BRA motorUpStop *;motorUpStop()*

585

586 *;if ($push == 1) {*

587 conditional15: LOAD R4 0 *;$temp = 0*

588 STOR R4 [GB +outputs + HBRIDGE0] *;storeData($temp, 'outputs', HBRIDGE0)*

589 *;unset($temp)*

590 LOAD R4 11 *;$state = 11*

591 STOR R4 [GB +state + 0] *;storeData($state, 'state', 0)*

592 *;unset($state)*

593 BRA whiteWaitStop *;whiteWaitStop()*

594

595 motorDown: BRS timerManage *;timerManage()*

596 PUSH R3 *;$colour = getButtonPressed(6)*

597 LOAD R3 6

598 BRS \_pressed

599 PULL R3

600 SUB SP 5

601 PULL R3

602 ADD SP 4

603 CMP R3 1 *;if ($colour == 1) {*

604 BEQ conditional16

605 return16: *;unset($colour)*

606 CMP R2 TIMEMOTORDOWN *;if ($sleep == TIMEMOTORDOWN) {*

607 BEQ conditional17

608 return17: PUSH R3 *;$startStop = getButtonPressed(0)*

609 LOAD R3 0

610 BRS \_pressed

611 PULL R3

612 SUB SP 5

613 PULL R3

614 ADD SP 4

615 CMP R3 1 *;if ($startStop == 1) {*

616 BEQ conditional18

617 return18: *;unset($startStop)*

618 ADD R2 1 *;$sleep+=1*

619 BRA motorDown *;motorDown()*

620

621 *;if ($colour == 1) {*

622 conditional16: LOAD R4 0 *;$temp=0*

623 STOR R4 [GB +outputs + HBRIDGE1] *;storeData($temp,'outputs',HBRIDGE1)*

624 LOAD R4 10 *;$temp = 10*

625 STOR R4 [GB +outputs + HBRIDGE0] *;storeData($temp, 'outputs', HBRIDGE0)*

626 *;unset($temp)*

627 LOAD R4 6 *;$state = 6*

628 STOR R4 [GB +state + 0] *;storeData($state, 'state', 0)*

629 LOAD R2 0 *;$sleep=0*

630 *;unset($state)*

631 BRA motorUp *;motorUp()*

632

633 *;if ($sleep == TIMEMOTORDOWN) {*

634 conditional17: LOAD R3 0 *;$temp = 0*

635 STOR R3 [GB +outputs + HBRIDGE1] *;storeData($temp, 'outputs', HBRIDGE1)*

636 LOAD R3 7 *;$temp = 7*

637 STOR R3 [GB +outputs + FEEDERENGINE] *;storeData($temp, 'outputs', FEEDERENGINE)*

638 *;unset($temp)*

639 LOAD R3 4 *;$state = 4*

640 STOR R3 [GB +state + 0] *;storeData($state, 'state', 0)*

641 LOAD R2 0 *;$sleep = 0*

642 *;unset($state)*

643 BRA runningWait *;runningWait()*

644

645 *;if ($startStop == 1) {*

646 conditional18: LOAD R4 0 *;$temp = 0*

647 STOR R4 [GB +outputs + FEEDERENGINE] *;storeData($temp, 'outputs', FEEDERENGINE)*

648 *;unset($temp)*

649 PUSH R5 *;reset timer ;setCountdown(BELT \* 10)*

650 PUSH R4

651 LOAD R5 -16

652 LOAD R4 0

653 SUB R4 [R5+13]

654 STOR R4 [R5+13] *;set timer*

655 LOAD R4 BELT \* 10

656 STOR R4 [R5+13]

657 PULL R4

658 PULL R5

659 LOAD R4 12 *;$state = 12*

660 STOR R4 [GB +state + 0] *;storeData($state, 'state', 0)*

661 *;unset($state)*

662 BRA motorDownTimer *;motorDownTimer()*

663

664 motorDownTimer: BRS timerManage *;timerManage()*

665 LOAD R3 16 *;$state = 16*

666 STOR R3 [GB +state + 0] *;storeData($state, 'state', 0)*

667 *;unset($state)*

668 BRA motorDownStop *;motorDownStop()*

669

670 motorUpTimer: BRS timerManage *;timerManage()*

671 LOAD R3 14 *;$state = 14*

672 STOR R3 [GB +state + 0] *;storeData($state, 'state', 0)*

673 *;unset($state)*

674 BRA motorUpStop *;motorUpStop()*

675

676 runningTimerReset: BRS timerManage *;timerManage()*

677 LOAD R3 4 *;$state = 4*

678 STOR R3 [GB +state + 0] *;storeData($state, 'state', 0)*

679 *;unset($state)*

680 BRA runningWait *;runningWait()*

681

682 runningTimer: BRS timerManage *;timerManage()*

683 LOAD R3 13 *;$state = 13*

684 STOR R3 [GB +state + 0] *;storeData($state, 'state', 0)*

685 *;unset($state)*

686 BRA runningStop *;runningStop()*

687

688 *;if ($location == 0) {*

689 conditional19: LOAD R3 0 *;$engines = 0*

690 BRA return19 *;}*

691

692 *;if ($voltage > $counter) {*

693 conditional20: LOAD R4 R1 *;$voltage = $location*

694 PUSH R5 *;$voltage = pow(2, $voltage)*

695 LOAD R5 2

696 BRS \_pow

697 LOAD R4 R5

698 PULL R5

699 ADD R3 R4 *;$engines += $voltage*

700 BRA return20 *;}*

701

702 *;if ($location == 7) {*

703 conditional21: PUSH R5 *;sleep(1)*

704 LOAD R5 1

705 BRS \_timer

706 PULL R5

707 PUSH R5 *;display($engines, 'leds')*

708 LOAD R5 -16

709 STOR R3 [R5+11]

710 PULL R5

711 *;unset($voltage)*

712 PUSH R3 *;$abort = getButtonPressed(1)*

713 LOAD R3 1

714 BRS \_pressed

715 PULL R3

716 SUB SP 5

717 PULL R4

718 ADD SP 4

719 CMP R4 1 *;if ($abort == 1) {*

720 BEQ conditional22

721 return22: *;unset($abort)*

722 CMP R0 6 *;if ($counter == 6) {*

723 BEQ conditional23

724 return23: CMP R0 11 *;if ($counter == 11) {*

725 BEQ conditional24

726 return24: LOAD R3 0 *;$engines = 0*

727 LOAD R1 0 *;$location = 0*

728 ADD R0 1 *;$counter+=1*

729 RTS *;return*

730 BRA return21 *;}*

731

732 *;if ($abort == 1) {*

733 conditional22: BRA abort *;abort()*

734 BRA return22 *;}*

735

736 *;if ($counter == 6) {*

737 conditional23: LOAD R4 [ GB + state + 0 ] *;$temp = getData('state', 0)*

738 MOD R4 10 *;mod(10, $temp)*

739 PUSH R5 *;display($temp, 'display', 1)*

740 PUSH R4

741 LOAD R5 R4

742 BRS \_Hex7Seg

743 LOAD R4 %0000001

744 STOR R4 [R5+9]

745 PULL R4

746 PULL R5

747 *;unset($temp)*

748 BRA return23 *;}*

749

750 *;if ($counter == 11) {*

751 conditional24: PUSH R2 *;pushStack($sleep)*

752 LOAD R4 [ GB + state + 0 ] *;$temp = getData('state', 0)*

753 LOAD R2 R4 *;$sleep = $temp*

754 MOD R2 10 *;mod(10, $sleep)*

755 SUB R4 R2 *;$temp -= $sleep*

756 DIV R4 10 *;$temp /= 10*

757 PUSH R5 *;display($temp, 'display', 2)*

758 PUSH R4

759 LOAD R5 R4

760 BRS \_Hex7Seg

761 LOAD R4 %0000010

762 STOR R4 [R5+9]

763 PULL R4

764 PULL R5

765 PULL R2 *;pullStack($sleep)*

766 *;unset($temp)*

767 BRA return24 *;}*

768

769 abort: *;unset($engines)*

770 PUSH R5 *;reset timer ;setCountdown(1000)*

771 PUSH R4

772 LOAD R5 -16

773 LOAD R4 0

774 SUB R4 [R5+13]

775 STOR R4 [R5+13] *;set timer*

776 LOAD R4 1000

777 STOR R4 [R5+13]

778 PULL R4

779 PULL R5

780 LOAD R3 [ GB + stackPointer + 0 ] *;$temp = getData('stackPointer', 0)*

781 LOAD SP R3 *;setStackPointer($temp)*

782 LOAD R3 0 *;$temp = 0*

783 STOR R3 [GB +outputs + HBRIDGE1] *;storeData($temp, 'outputs', HBRIDGE1)*

784 STOR R3 [GB +outputs + HBRIDGE0] *;storeData($temp, 'outputs', HBRIDGE0)*

785 STOR R3 [GB +outputs + LENSLAMPPOSITION] *;storeData($temp, 'outputs', LENSLAMPPOSITION)*

786 STOR R3 [GB +outputs + LENSLAMPSORTER] *;storeData($temp, 'outputs', LENSLAMPSORTER)*

787 STOR R3 [GB +outputs + LEDSTATEINDICATOR] *;storeData($temp, 'outputs', LEDSTATEINDICATOR)*

788 STOR R3 [GB +outputs + DISPLAY] *;storeData($temp, 'outputs', DISPLAY)*

789 STOR R3 [GB +outputs + CONVEYORBELT] *;storeData($temp, 'outputs', CONVEYORBELT)*

790 STOR R3 [GB +outputs + FEEDERENGINE] *;storeData($temp, 'outputs', FEEDERENGINE)*

791 *;unset($temp)*

792 BRS timerManage *;timerManage()*

793 LOAD R3 17 *;$state = 17*

794 STOR R3 [GB +state + 0] *;storeData($state, 'state', 0)*

795 LOAD R3 7 *;$state = 7*

796 PUSH R5 *;display($state, 'leds2', 0)*

797 LOAD R5 -16

798 STOR R3 [R5+10]

799 PULL R5

800 *;unset($state)*

801 BRA aborted *;aborted()*

802

803 aborted: PUSH R5 *;reset timer ;setCountdown(1000)*

804 PUSH R4

805 LOAD R5 -16

806 LOAD R4 0

807 SUB R4 [R5+13]

808 STOR R4 [R5+13] *;set timer*

809 LOAD R4 1000

810 STOR R4 [R5+13]

811 PULL R4

812 PULL R5

813 BRS timerManage *;timerManage()*

814 PUSH R3 *;$startStop = getButtonPressed(0)*

815 LOAD R3 0

816 BRS \_pressed

817 PULL R3

818 SUB SP 5

819 PULL R3

820 ADD SP 4

821 CMP R3 1 *;if ($startStop == 1) {*

822 BEQ conditional25

823 return25: *;unset($startStop)*

824 BRA aborted *;aborted()*

825

826 *;if ($startStop == 1) {*

827 conditional25: LOAD R4 10 *;$temp = 10*

828 STOR R4 [GB +outputs + HBRIDGE0] *;storeData($temp, 'outputs', HBRIDGE0)*

829 *;unset($temp)*

830 LOAD R4 0 *;$state = 0*

831 STOR R4 [GB +state + 0] *;storeData($state, 'state', 0)*

832 *;unset($state)*

833 BRA initial *;initial()*

834

835 timerManage: CMP R1 0 *;if ($location == 0) {*

836 BEQ conditional19

837 return19: MOD R0 12 *;mod(12, $counter)*

838 ADD R1 outputs *;$voltage = getData('outputs', $location)*

839 LOAD R4 [ GB + R1]

840 SUB R1 outputs

841 CMP R4 R0 *;if ($voltage > $counter) {*

842 BGT conditional20

843 return20: CMP R1 7 *;if ($location == 7) {*

844 BEQ conditional21

845 return21: ADD R1 1 *;$location+=1*

846 BRA timerManage *;branch('timerManage')*

847

848 @END