Politecnico di Torino

Masters in Mechatronic Engineering

Master's Thesis

Optimisation of an automatic grafting machine prototype

Ottimizzazione del prototipo di una macchina automatica per l'innesto erbaceo

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Abstract

Grafting is a millennia old horticultural technique utilized in agriculture to produce plants that have higher disease resistanceleading to higher yield of plants & hence greater profit. It essentially involves taking the top of one plant called a scion & attaching it with bottom called rootstock of another plant. This project applies this technique to the tomato plant.Grafting has been a labor-intensive technique & has traditionally been done by hand which has led to greater cost however this project seeks to automate the entire process.

An automatic grafting machine has already been developed at Politecnico di Torino that will remove the manual labor & perform the entire grafting process without human involvement. The project is being done in collaboration with University of Torino's DISAFA department; their machine provides Politecnico's machine with both the plants to be used to create the final grafted plant & then receives the final product.

Following processes are performed by the Politecnico's machine: receiving the plants, cutting the plants, grafting the two plants together & finally delivery of the grafted plant. The machine is composed of pneumatic system which is controlled by electrical signals from the PLC.Composition of the pneumatic system is a combination of grippers, horizontal displacement & vertical displacement cylinders to make five robot arms & two cutters. Rockwell's Allen Bradley brand PLC is being utilized by the machine to control the pneumatic system.

Previous version of the code being implemented on the PLC did not fulfill the requirements to perform the task correctly. Complications arose in communicating with the DISAFA machine & a new code needed to be written according to the updated protocol& requirements that were requested by their team. Following requests were made: to start working on the each of the two plants (to be grafted together to form one plant) independently such that one plant was received and cut without depending on the presence of the seconding plant. Secondly code for the reaction of machine in case of an emergency reset must be written as well as an implementation of a solution on the hardware side in case of an emergency; the machine should start from the starting position when the machine is started again rather than at the point where emergency situation occurred. Thirdly a feedback mechanism needs to be developed for the grippers and blowers since no sensor is associated with them to provide the PLC with a signal indicating if the action has been performed. Then on the hardware level addition of a cover to protect the Machine from the debris of the cutting and for its easy disposal has to be added. Furthermore a Blower has to be added so that removal of the debris from the cover is further facilitated. This Blower has to be connected with the PLC via the pneumatic system and addition in the code made to it. These requirements require a whole new sequential flow chart(GRAFCET) to be written using the Batch Technique.This flow chart will be implemented on the PLC via the ladder logic to control the actual system. Then the system will be checked with the DISAFA machine to verify that it indeed works as required & the interfacing between the two systems is correct. Initially this interfacing is mimicked using switches that act as the inputs from the DISAFA machine & lamps that act as the output to the DISAFA machine. Furthermore a previous version of the code written using Auxilliary Relay Technique by Belluco will be edited to add the Blower to it.

In conclusion this project will automate a once time consuming & labor intensive task of grafting together a tomato plant

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1. Introduction

Since millennia man has been interbreeding plants by cutting plants of varying species and types to grow as one single plant instead of two separate different ones. This Horticultural technique is called ‘’Grafting’’. The picture below shows a grafted plant.

Figure 1: A Grafted Plant

Grafting is analogous to transplanting organs among humans. A single live form is created of two distinct genetically different but compatible parts. So the grafted plant should be composed of two closely related plants. Hence usually this technique is fruitful when species of the genus are used[1].

This chapter will explore the practice of Grafting.

1.1 Terminology

- **Rootstock:** It is the part which becomes the lower portion of the new Grafted plant. It is taken from a plant that usually has a healthy root system. This portion of the plant is responsible for interreacting with the soil, providing nutrients & water to rest of the plant. Additionally, it must resist diseases and pests.

- **Scion:** This part is the upper portion of the new Grafted Plant. This plant forms the stem & branches of the plant. Features of the new plant like leaves, fruits, leaves etc are determined by scion. Picture below shows grafted plants and the scion and rootstock to create it

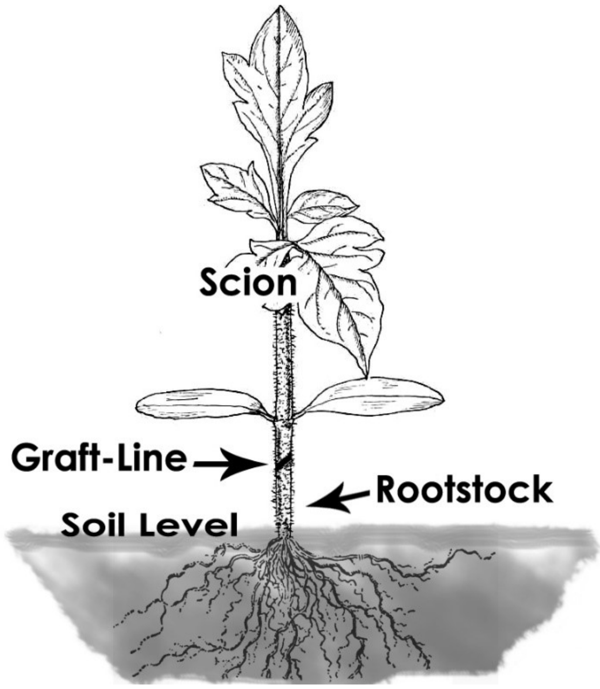


Figure 2: A Grafted Plant with it's Scion and Rootstock components

- **Grafting Union:** This term refers to the place where the scion and rootstock are joined and then grow and meet to form one single part. Picture below shows a graft union on a grafted plant.

Figure 3: A Grafting Union shown on Grafted Tomato Plant

- **Cambium:** It refers to a thin layer of living tissues in-between the bark and the wood. These tissues are responsible for growing the bark and wood tissues in a plant. When a plant is wounded like in the case of grafting these cambium tissues with produce a type of cell called callus. These cells with then be responsible for joining the rootstock and the scion so two separate plants become one. The picture below shows the Cambium

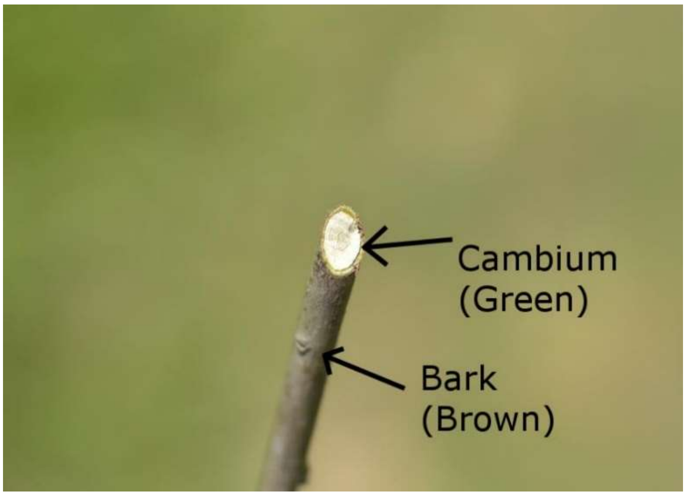


Figure 4: Cambium Layer of a plant

- **Grafting Wax:** It is a wax that is applied across the graft union to stop the new plant from losing water and stops the moisture from outside to come inside.

- **Graft Incompatibility:** When the scion and rootstock are unable to form a union that is needed for the anticipated plant growth. The picture below shows a grafted plant created with an incompatible scion and rootstock.

Figure 5: Example of incompatible graft

- **Grafting Partners:** Refers to some specific scion & rootstock combination.
- **Graft Failure:** Happens when the scion dies. Reason for this occuring can be incombatibility of the scion and rootstock, bad techniqe, damage etc.
- **Hybrid:** This is a type of plant composed of two different 'parents'. These parents can possibly be different species of same genus or variabilities of the same species.

1.2 History of Grafting

Humans had started to collect grains and pulses between 10,000 to 12,000-year BC. The Neolithic era started around 8,000 BC during which there was agricultural progress among humans. During this time areas where cleared by humans so that farming could be done for food. Humans would collect fruits and nuts from trees however they struggled to grow these fruits and nuts trees from seeds since they didn't grow as desired. Instead only date palms, figs, olives etc could be grown since their growth can be done by just cutting their rootstock and planting it.

Around 1,000-BC humans had discovered grafting. No record exists to show how this discovery was made however there is a consensus it was discovered by observing cases of grafting that occurred in nature. This discovery led to the spread of apple, pears orchids.

Theophrastus is known as the "Father of Horticulture". He was a student of Aristotle and wrote numerous works on plants. In his treatise "De Causis Plantarum" he described grafting as:

"...the generative fluid: the bud possesses this when it is fitted into the stock, and getting its food from the latter produces its own type of sprout"

Furthermore, a book "Tsee Ming Yau Su" by Chia Shi-yi from the 3rd Century AD describes the process of grafting a pear tree. This demonstrates that they possessed knowledge back then of the effect of the choice of a rootstock on the quality of fruit given by the scion.

During the period of the Romans the book "De Agri Cultura" by Marcus Porcius Cato was written. In it he went into detail regarding various methods of grafting, many of which are in still use today like the technique of clefting.

Grafting became much more common in Europe when the Crusaders started returning back. There is evidence of apples being produced at least partially by Grafting in France during the 15th Century. However, it's adoption in England came later than the rest of mainland Europe as evidenced by the writings of Leonard Mascall who reproached his people for being slow to adopt the technique[2].

1.3 Advantages of Grafting

Grafting is a widespread Horticultural technique due to the various advantages it provides. Some of these advantages are discussed below:

1. **Plant Propagation**: At times the plants being grown are needed to be uniform. This is hard to achieve via other methods than Grafting. Furthermore, it has utility in cases when a large amount of planting materials is needed in little time.
2. **Increase growth rate of seedlings:** When left to grow naturally the seedlings of many nuts and fruit programs take 8 to 12 years to bear fruit. This period can be greatly shortened by grafting these progeny on existing plants. Additionally, the growth rate can be spurred by grafting multiple seedlings onto a single mature plant.
3. **Using a rootstock for it's features:** Some rootstocks have better growth habits, disease resistance, insect resistance and resistance to droughts. As a result, these rootstocks are used with the chosen scion whose rootstock would be comparatively less desirable.
4. **Repairing Damaged Trees:** Sometimes trees or plants can be damaged due to reasons like disease, weather, tools etc. This damage can be mitigated by planting multiple seedlings around the damaged tree and then graft them across the injury. This will heal the injury to the plant. This technique is known as approach grafting.
5. **To Index Viruses:** Plants can have viruses and many a times they are not easily detectable. Presence of a virus can be established by taking the scion from it and grafting it on another plant that would display the symptoms of the virus.
6. **Cross-Pollination:** Some fruit trees cannot pollinate themselves instead a second tree is needed to pollinate them. An example of this is of Hollie plants. Sometimes they can be of only female or the male type and as a result a female Hollie plant needs male Hollie plant to be near it so that it can be pollinated. When such a case is not possible a scion of a male Hollie plant is grafted onto the female one to pollinate it so that it would give fruit.

7. **Aesthetic Purposes:** Grafting is also done to increase the beauty of a plant. An example of this is of the Bonsai tree. Where a branch on a Bonsai tree is needed but none grows a scion can be grafted on to it to get the desired effect. An example of this is shown in picture below

Figure 6: Bonsai tree with grafting

8. **To Change Variety:** An orchid tree that was made some time ago might be producing trees whose fruits are now considered outdated by the influx of a newer variety. This newer type might have better taste, might offer better resistance to disease or have better yield. Instead of planting a whole new orchid the owner can simply graft the scion of the newer variety onto the older one as long as they are compatible.
9. **To provide support:** Due to high speed of winds a tree might become unstable and need additional anchorage to the ground. This problem can be solved by creating trees with multiple trunks to provide better contact with the ground and make the tree more stable. This can be achieved by grafting multiple rootstocks with a scion.

1.4 Natural Cases of Grafting

Spontaneously occurring cases of grafting occur in nature. Grafting techniques known as shoot and root grafting both occur naturally. That's why it is considered the first humans observed such grafting and then tried to copy it.

Inosculation refers to the phenomena when tree branches or their roots come in contact with one another and become naturally grafted. When roots of two different trees come in contact the layer of barks covering them might be stripped off. As a result, the cambium tissues come in contact with one another. This causes these tissues to grow and form a connection between the roots of the different trees. The picture below shows example of a naturally occurring graft.

Figure 7: Case of natural grafting. The branches of two trees have become grafted together

This way not only two but a network of trees can become connected with one another. As a result, they can share water and nutrients through their grafts. Now the trees that were weaker before are now in a better position since they are getting a better supply of water and nutrients.

Another advantage of these types of grafts is that the root mass of these trees now increases which makes them harder to catch fire. Furthermore, now the trees become much more stable due to better anchorage to the ground.

However, a problem that might arise is that a virus from one tree can now move on to another tree.

1.5 Grafting Techniques

Many grafting techniques exist. The selection of which technique to utilise depends on factors like the skill, preference of the person, how high a chance of success is required, time for the grafting to occur, the size of the plant that is being grafted and the why the grafting is being done.

Some of the grafting techniques will be discussed below:

1. **Cleft Grafting:** In this technique the rootstock is prepared by cutting it from the part where active growth is happening. After that the from the middle the stem is cut in the downwards direction. The scion is made by making a slanting cut from both sides of the base so as to produce a V-Shaped base. Now the base of the scion is then placed inside the cleft at the top of the rootstock which was made previously. For better success two scions can be placed instead of one. The picture below displays how a Cleft Graft is implemented.

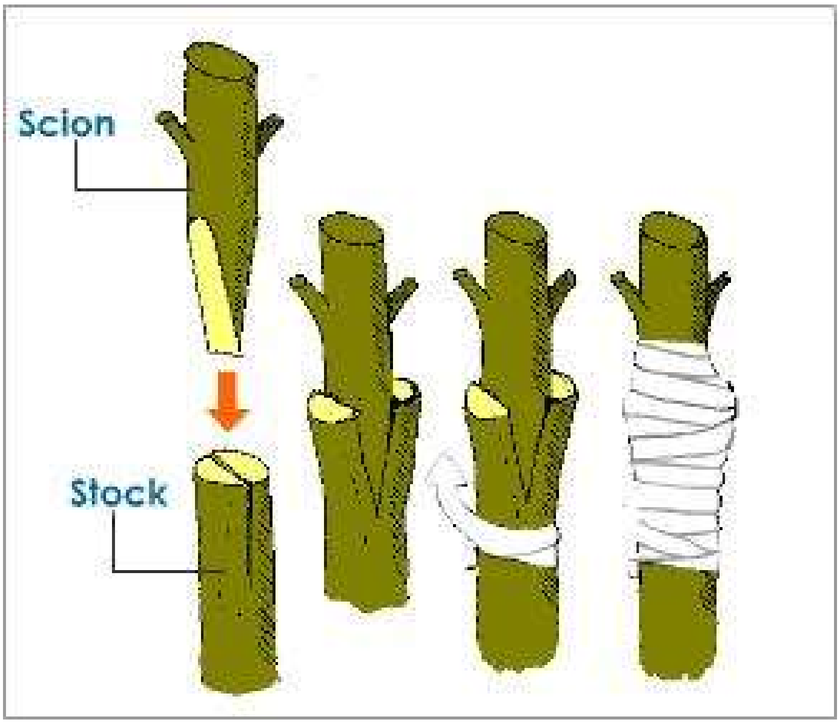


Figure 8: Cleft Grafting

2. **Bark Graft:** This technique is suitable in the case when the scion is small in size however the rootstock is much bigger in size. Rootstock is made by first seperating it from the top part and then a cut is made in linear direction from the stub to the bark. The scion is made by cutting it in a slanting direction from a side to it's base. Then a smaller cute is made on opposite side. Then the scion is placed in between the bark and the wood of the rootstock. Then it is kept in position either by using nails or binding them together. This technique has a few other variations too. Figure 9 shows a Plant which has undergone Bark Graft. Figure 10 shows the Bark Graft technique.

Figure 9: Bark Graft

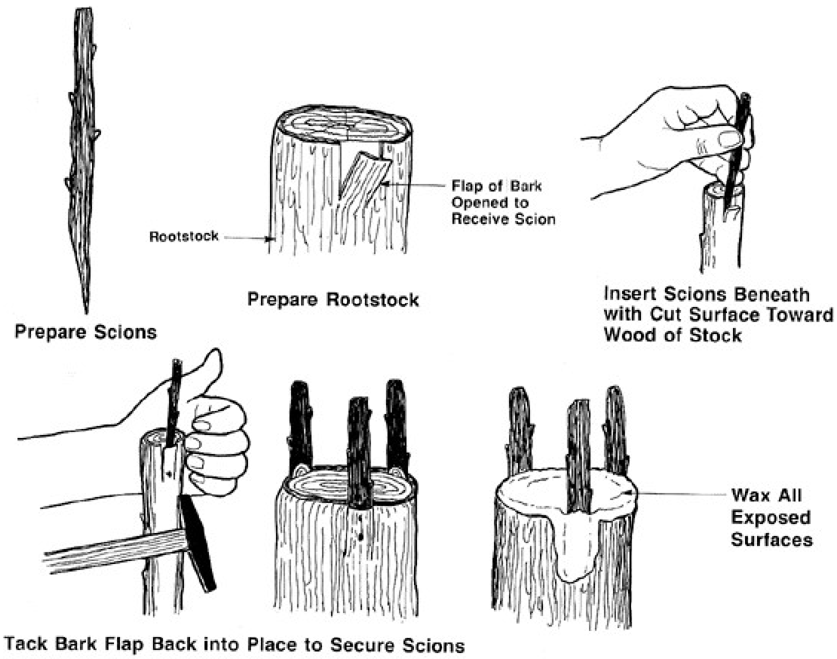


Figure 10: Bark Grafting Technique

3. **Approach Grafting:** This technique is utilised to combine plants that are hard to combine. Both the plants are tightly bound together by removing their barks from a side and pressing those sides together. Both plants have their own roots and top parts. At least one of these plants should be potted. Once the unification has been achieved the upper part of the rootstock plant is removed while the lower part of the scion plant is removed. This technique too has many different methods within it. Figure 11 shows an illustration of approach graft.

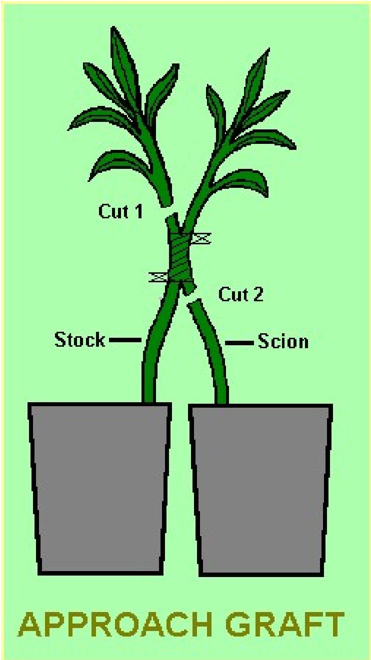


Figure 11: Approach Graft illustration

4. **Bridge Grafting:** This technique is used to repair an injured tree trunk. This is achieved by attaching scions in such a way that they connect the trunk below and above the injured area. So, the essentially bypass the injured area. This also helps provide support to the tree, making it mechanically stable. Scions are selected which are straight and slightly longer than the area to be bridged. A slanting cut is made on each end of the scion. Rootstock is prepared by removing the injured tissue. This way the graft will be on the healthy tissue. A flap is made in the bark of the rootstock having the same width as the scion. This flap is made both on the upper and lower part of the damaged rootstock area. The ends of the scions are then inserted into these flaps. Figure 12 shows an illustration of Bridge Grafting.

Figure 12: Brifge Grafting illustration

1.6 Tomato Grafting

Tomato is the second most grown vegetable on earth with 170million tons being produced in 2017. Tomato was started to be commercially grafted in early 1960s and since then it has become an important cultivation practice in many countries.

The effect of grafting on tomato development and productivity was studied in greenhouse conditions & it was shown that correct selection of scion and rootstock types was important for considerably higher yield[3][4].

The tomato crop is prone to attacks from many soil-based pathogens like Fusarium and Verticillium wilts. To protect the crop the chemical Methyl Bromide is used to fight against the pathogens. Furthermore the chemical has a low cost and has a high rate of effectiveness. In Morocco 58% of the area this chemical is used on is used to grow tomatos. However this chemical has adverse effects too. Most of this chemical escapes into the atmosphere and causes depletion of the ozone layer. In 1987 Montreal Protocol was signed. The purpose of this treaty was to preserve and protect the ozone layer by phasing out the usage and production of chemicals that could harm it. Since then it's production and usage has dropped significantly with EU banning it outright since March 2010[5].

Since then Grafting of Tomato plants has emerged as a method of protecting the plant from the pathogens by utilising rootstock that would be more resistant. Furthermore this technique helps with increasing the yield, the quality of the fruit, ability to survive in low temperature & better growth.

In Morocco the data has shown that Grafted plants show an equal or greater yield compared to non-grafted plants with only half the population(plants/ha). Furthermore it only costs an extra $1290 per hectare compared to non-grafted plants but that cost is more than made up by the extra profits due to the higher yield of the plants[5].

Hence not only is Grafting technique much better for the environment but also it results in higher profits for the farmers. Additionally due to higher yields problem of food shortage can be better addressed since now we can get a higher yield per hectare than before.

2. Automatic Grafting

Though Grafting has many advantages one disadvantage it has traditionally had is that it is quite labor intensive. As a result using it on a large scale can be a problematic since grafting every single plant manually can take far too much time and drive up the cost.

As a result due to this demand for large quantities of grafted plants for large fields since the 1990s semi-automated and fully automated robots have been developed by the Agriculture Industry top help produce the grafted plants faster.

2.1 Manual Grafting

Grafting of tomato plant in North America is achieved by first cutting the plants at an angle and then joined using an elastic plastic tube. This method is referred to as tube grafting method. As the plant expands in diameter this plastic tube falls off.

Depending on the skill of the worker this technique can produce around a 1000 grafts a day and this is done 2-3 weeks after seeding was done[6]. Hence the amount of grafts we get is heavily depended on how many workers we have and their skill level.

If a large amount of grafter plants are needed in a single shipment this can cause a problem. A solution proposed is to store the store the seedlings under dim lighting conditions for 4-6 weeks. But storage protocols right now haven't been developed well enough for this[6].

Semi-automatic or fully automated technology are seen as a more viable solution for the large scale production problem. This way nursery operations are able to address the increasing difficulty of securing the needed number of grafting workers. Though while technology reduces labor costs and increases efficiency it does require a large capital investment. Furthermore technology is being introduced to assist humans rather than completely replace them, this way even unskilled labor can reach the grafting speeds of a skilled labor[7].

2.1 ISO Graft 1100

ISO Graft 1100 is a semi-autonomous grafting machine developed by the ISO Group from Netherlands.

It is ideal for situations where there is low or no automation in the cultivation process. It is operated by two workers. Below is an illustration of the machine.

Figure 13: ISO Graft 1100

This machine can cut the rootstock and scion at the same angle simultaneously which gives the advantage that   the union is much better and hence the success rate is between 98 to a 100%.

The first worker places the rootstock and removes the completed graft while the second person places the scion in the machine. To minimise the risk of disease the machine can be cleaned with steam.

Figure 14 shows the workers working alongside the machine.

Figure 14: Workers working with the machine

The machine has the ability to offer upto a 1000 grafts an hour & the machine requires low maintenance.

Furthermore this machine offers the choice of cutting the scion and rootstock at angles or straight.

2.2 ISO Graft 1200

ISO Graft 1200 is a semi-autonomous machine developed by the ISO Group from the Netherlands. In 2014 it was nominated for the Greentech Innovation Award.

This machine requires only one operator to operate & is easy to operate. The operator can operate the machine using buttons only. The picture below shows the machine.

Figure 15: ISO Graft 1200

It cuts the rootstock and scion simultaneously at the same angle. This results in a better union of the two plants to produce a better graft.

It can be disinfected easily to help minimise risk of the disease. Disinfection is done using steam at 170 degrees celsius.

It can graft upto 1050 plants an hour and can be used on numerous plants. It was tested to give a success rate of over 99%

2.3 AFGR-800CS

This semi-automated robot was developed by the Korean Company Helper Robotech.

Currently 10 of their machines are being used in North America and 73 in rest of the world. The picture below shows the machine.

Figure 16: AFGR-800CS

This machine can be used for the following plants: watermelon, cuccumber, melon, red peeper and tomato.

It requires two workers, one to supply the scion to the machine and the second to supply the rootstock. Figure 17 shows the machine holding the plant.

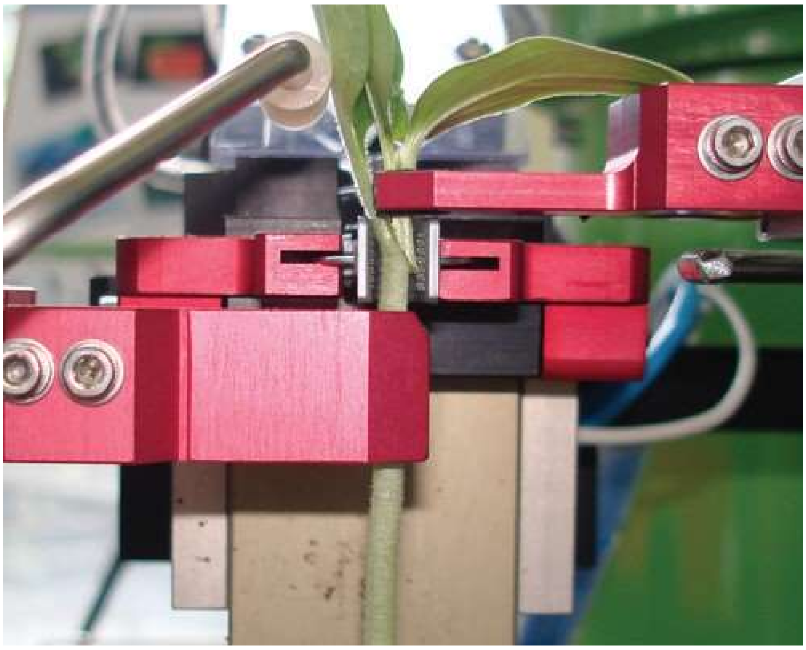


Figure 17: The machine holding the plant

The machine is composed of the grafting robot, clip feeder and an air compressor.

It can graft upto 800 plants an hour but the average is about 625 grafts per hour.

2.4 EMP-300

The EMP-300 is a grafting machine developed bny Conic System a Spanish Company.

Currently 4 machines are being used in North America and 14 in other parts of the world. Picture below shows the Machine.

Figure 18: EMP-300

This machine requires one worker to operate it.

The cut can be made at 3 possible angles: 20, 30 and 40. Furthermore with a few adjustments this machine can graft different types of plants.

The machine allows to easily replace the cutting blades and changing their angle. The picture below shows the machine holding a plant.

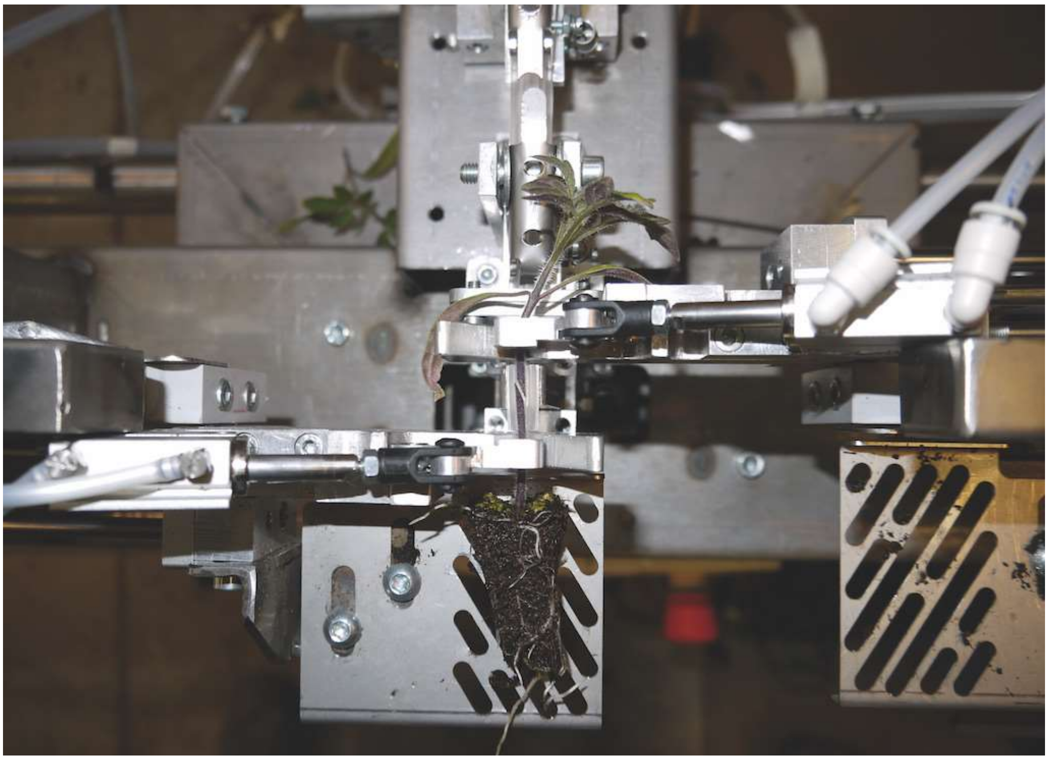


Figure 19: Machine holding the plant

This machine can graft between 400 to 600 plants an hour.

The machine allows for clips of different dimensions to be used with it.

The cutting unit comes with a disinfectant so it can be configured to disinfect the plant itself.

3. DIMEAS Machine

This chapter will cover the prototype machine that has been created in DIMEAS Department at Politecnico di Torino. The areas covered in this chapter will be the components used in the machine, it's physical construction. The DIMEAS Machine is designed keeping in mind that it has to perform the following functions:

1. Receive the Scion from the DISAFA Machine
2. Receive the Rootstock from the DISAFA Machine
3. Cut the Scion
4. Cut the Rootstock
5. Connect the scion and rootstock parts using a rubber clip
6. Handover the final grafter plant to the DISAFA Machine
7. Repeat the above mentioned process till required

The DIMEAS Machine was then constructed to perform these tasks properly.

So as can be ascertained from the above mentioned information the DIMEAS Machine will consist of the hardware part to perform these tasks and another module to control the hardware that will be performing the task. The module to control our Machine will be a PLC. The figure below shows the pneumatic cylinders that are used to produce the required movements.

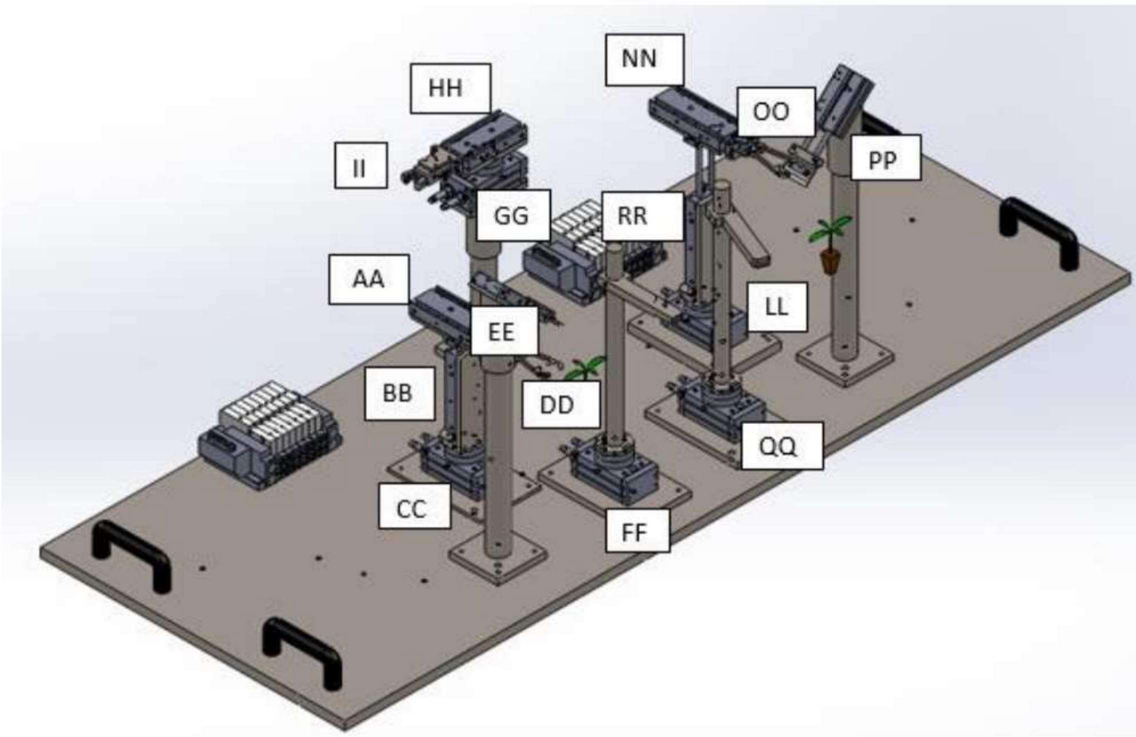


Figure 20: Pneumatic Cylinders to produce movements for the machine

3.1 Description of the Working of DIMEAS Machine

The DIMEAS Machine was created to automate a time intensive and labour intensive task of creating grafted plants with no need for a human operator whatsoever. The Machines discussed in the previous Chapter require one or two human operators working alongside the machine. The DIMEAS Machine's purpose is to eliminate their need too to make the whole process fully automatic.

The DIMEAS Machine works using both electric and pneumatic signals.

The Supply for the Pneumatic signals is provided by a compressor at 5 bar pressure. The input from this supply is fed to the pneumatic circuit via pneumatic valve serving as the emergency stop.

Our pneumatic system has to perform the following operations per cycle to produce a Grafted plant:

1. Receive the Scion from the DISAFA Machine
2. Receive the Rootstock from the DISAFA Machine
3. Cut the Scion
4. Cut the Rootstock
5. Connect the scion and rootstock parts using a rubber clip
6. Handover the final grafter plant to the DISAFA Machine

As can be seen from steps 1 and 2 they are both similar. The only difference being the purpose of the plant they receive. Hence the pneumatic circuit designed to perform these operations will be similar.

To achieve Step 1 and 2 two separate but same pneumatic arms are designed. These pneumatic arms consist of the ability to grasp the plants & move in three dimensions. For the ability to grasp the plants a gripper pneumatic device will be used while to move in three dimensions three separate pneumatic devices will be used: one to move it vertically, one horizontally and one to rotate.

This way the pneumatic arms will be able to move forward and then grasp the plants from the DISAFA Machine.

The next step in Grafting requires us to cut the two plants. So to perform the cutting operation two Cutters will be needed, one for the rootstock and one for the scion. The cutting operation simply requires the blades to move forward and cut away the unneeded part of the two received plants to create the Scion and Rootstock. This cutting operation is implemented using blades attached to a horizontal moving pneumatic element. This Horizontal moving element moves the blade forward quickly which slices through the plant that is being held by the pneumatic arm discussed above. It is required that the cut be made at an angle so this pneumatic element is mounted at an angle.

Now simply moving the blade won't be able to produce a clean cut. To achieve a clean cut we need to basically sandwich the plant between the blade and another hard surface. This is achieved via creating two Supports for this operation. These supports just consist of a pneumatic element to rotate it into position for cutting when needed and a metal slap attached to it to act as the ‘support’ for the blade.

After the cutting operation has been performed the next step is to join the two plants together. In modern grafting techniques this joining is usually done using a rubber clip. In our setup these rubber clips are held in a clip holder.

Now a third pneumatic arm is needed to perform the joining operation by attaching the clip while the other two pneumatic arms hold the two plants in place. This third pneumatic arm’s is built similarly to the previous two pneumatic arms. It first picks up a clip from the clip holder and then moves the clip closer to the two plants till they have become attached using it.

Once the attachment operation is done the next step is to return the Grafted Plant to the DISAFA Machine so it can take it away and then our cycle can restart to produce a new plant. This handing back operation requires only one pneumatic arm. So one of the pneumatic arm will then stop holding the plant leaving it only in the gripper of the second pneumatic arm. This pneumatic arm will then move forward and give the plant back to the DISAFA Machine which will take it away.

Once this operation is complete our cycle can restart.

This whole pneumatic circuit is controlled and manipulated by the PLC, which serves as the electrical part of the machine. It runs on 24V DC Supply.

This PLC will coordinate with the DISAFA Machine to perform the operations at the right time. It will control which step occurs when and if the conditions have been met to perform the next step on our pneumatic circuit. It will give it’s electrical output signals to Solenoid Valves which will control the electrical signals to the pneumatic signals to control our pneumatic elements.

The description of each part mentioned above and how it has been implemented is given in the following sub-chapters in this Chapter.

3.2 Control Module- PLC

To control the DIMEAS Machine a PLC was chosen. The PLC being used is from Rockwell Automation Company. The type of PLC is the Micrologix 1200. The picture of PLC is shown below.

Figure 21: Picture of the PLC

Since we require more input output ports that come in-built the PLC we have also added three expansions to satisfy our requirements. The model of the expansion slot is 1762-OW16 & 1762-I16. Below is the picture of an Output Expansion Module.

Figure 22: Output Expansion Module

The technical specifications of the PLC Module are:

Model Number	L40BXBR
Dimensions	90mm x 160mm x 87mm
Shipping Weight	1.1kg
Inputs	24 Inputs
Outputs	16 Outputs
Power Supply Voltage	24V Dc
Input Circuit Type	Sink/Source
Output Circuit Type	Relay/FET
Operating Temperature	0-55C
Power Supply Usage	40W

The port configuration is illustrated below:

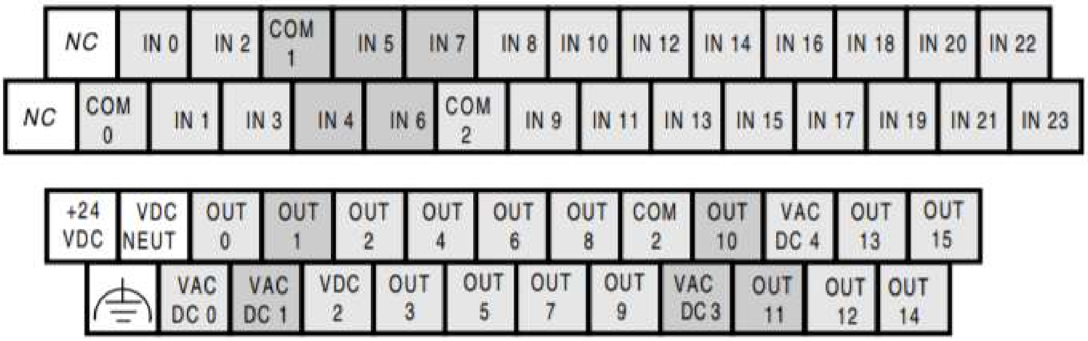


Figure 23: Port Configuration

The PLC comes with 24 Input and 16 Output ports however our Input and Output port requirements exceed that amount(discussed in detail in next topic). So to fulfil our requirements two expansion modules for Outputs is added and one expansion module for inputs is added.

The output module's model number is 17622-OW16 and it contains 16 Output ports. It's configuration is shown below:

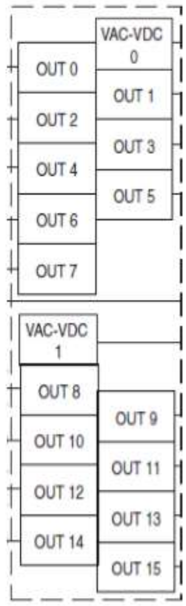


Figure 24: Output Expansion Module Port Configuration

The Input module's model number is 1762-IQ16 and it contains a total of 16 inputs. It's configuration is shown below:

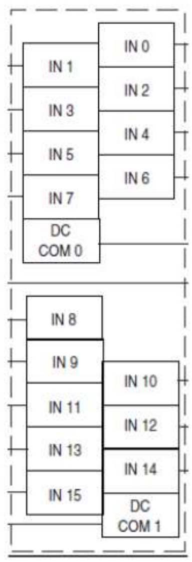


Figure 25: Port Configuration of Input Expansion Module

So in total we have:

Outputs	48 (16+16+16)
Inputs	40

3.3 Input Signal

The input signal to the PLC comes from the Reed switches. The Reed switches that are being used in the machine are made by SMC and their model is DA93-L. Below is a picture of them.

Figure 26: Reed Switches

The working principle of a reed switch is that when a magnet is brought closer to it it pulls one of the reed towards the other and hence completes the circuit causing the current to conduct. This way it can "sense" movement and provide a signal to the PLC.

In total 8 reed switches are used in our machine, two for each actuator. Below is a picture of Reed switches on a pneumatic element.

Figure 27: Reed Switches on a Pneumatic Element

3.4 Output Signal

The output signal from the PLC will be sent to two Solenoid Valve with each having 16 outputs(8 Valves with 2 Outputs each). The Output of these Solenoid valves is of pneumatic type of air pressure equal to 5 bar. Below is the picture of a Solenoid Valve Expansion Block.

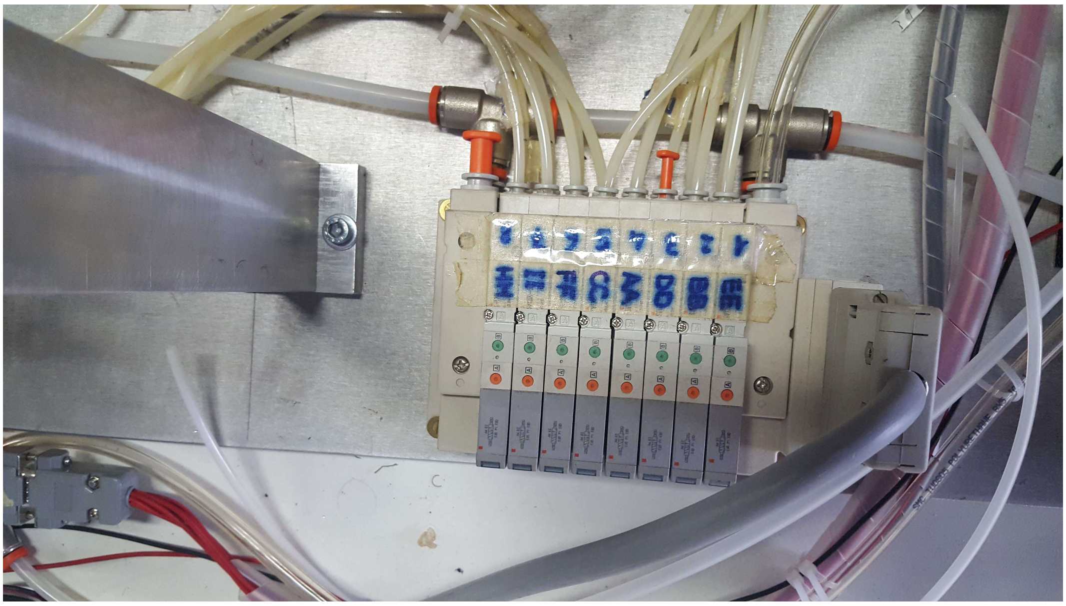


Figure 28: Valve Expansion Block

When the solenoid gets an output signal from the PLC it excites the solenoid inside of it which then operates a bistable valve to move the actuators.

If the power is cut off the solenoid gets de energised but since the valve type is bistable the valve retains its position and does not switch.

3.5 DISAFA Simulator

Initially during our testing phase the DISAFA and DIMEAS Machines will not be connected and we will be testing only the DIMEAS Machine.

As a result it is necessary to have DISFA Simulator to provide us with the inputs that are needed from the DISAFA Machine for the DIMEAS Machine to work. Additionally this simulator should also inform us about whether the output we are sending to the DISAFA machine has been received.

To achieve this a box was made containing three electrical buttons to simulate the three possible outputs from the DISAFA Machine and eight lights to simulate the inputs from the DIMEAS Machine. Below is the picture of the DISAFA Simulator described previously.

Figure 29: DISAFA Simulator

3.6 Grafting Machine

A view of the grafting machine is shown below:

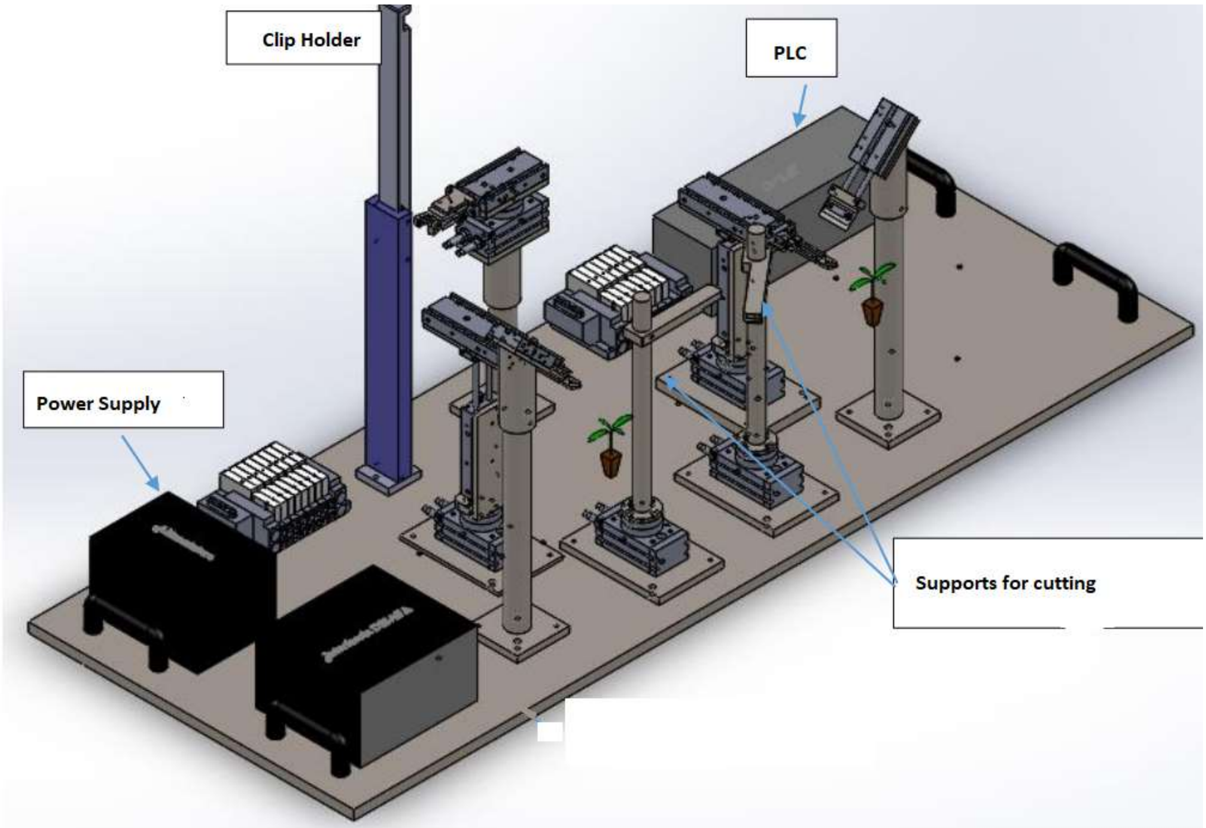


Figure 30: DIMEAS Machine Layout

Our Grafting machine is composed of the following parts:

1. Pneumatic arm to receive the Scion
2. Pneumatic arm to receive the Rootstock
3. Cutting Blade Arm to cut the scion
4. Cutting Blade Arm to cut the Rootstock
5. Support to cut the scion
6. Support to cut the Rootstock
7. Pneumatic arm to apply the clip to join the cut plants
8. A clip holder

3.5.1 Pneumatic arm to receive the Scion

The pneumatic arm to receive the scion is composed of the following pneumatic components:

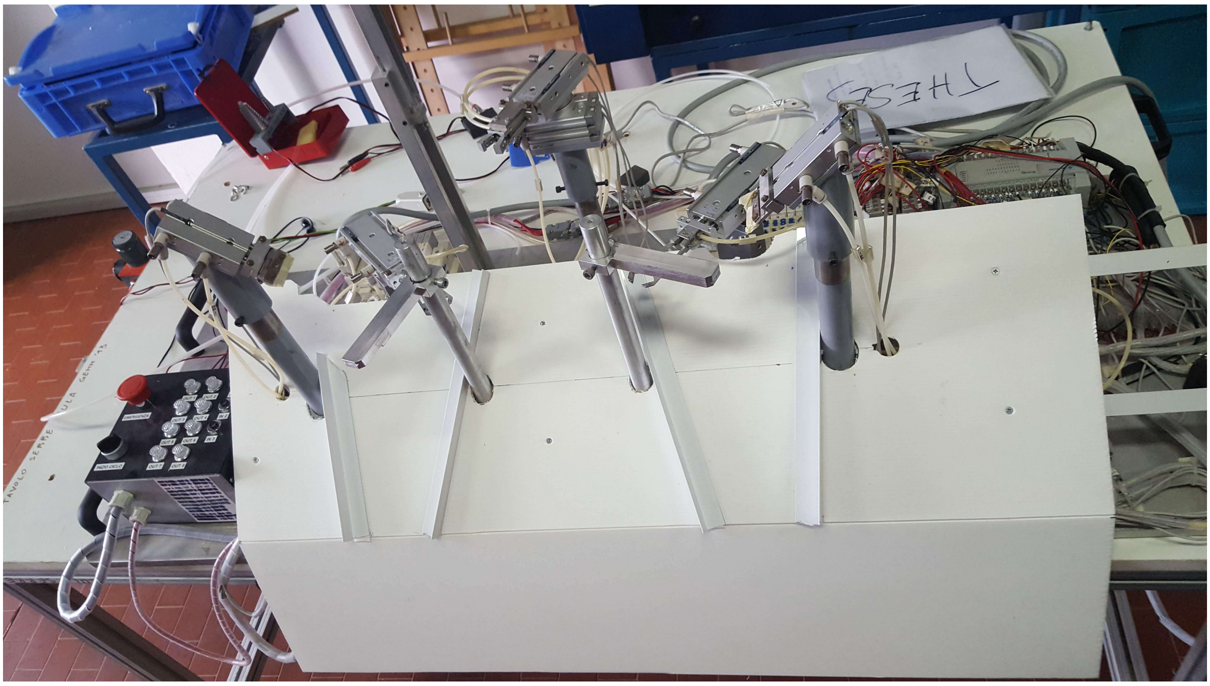
1. Rotational Cylinder
2. Vertical Cylinder
3. Horizontal Cylinder
4. Cylinder for Gripper

The Rotational cylinder allows the pneumatic arm to rotate 90 degrees. On one end of the 90 degrees is the position from which we have to receive the scion from the DISAFA Machine and on the other end is the position at which the cutting and clipping action have to take place

The vertical cylinder allows for the pneumatic arm to move up and down vertically. The cutting action takes place when the pneumatic arm is at the max position vertically while rest of the actions take place at the minimum position.

The Horizontal Cylinder is to allow for the pneumatic arm to go forward and backwards in the horizontal plane.

Cylinder for gripper is to allow for gripper to close to hold on to the scion.



3.5.2 Pneumatic arm to receive the Rootstock

The pneumatic arm to receive the scion is composed of the following pneumatic components:

1. Rotational Cylinder
2. Vertical Cylinder
3. Horizontal Cylinder
4. Cylinder for Gripper

The Rotational cylinder allows the pneumatic arm to rotate 90 degrees. On one end of the 90 degrees is the position from which we have to receive the scion from the DISAFA Machine and on the other end is the position at which the cutting and clipping action have to take place. Below is the picture of the whole pneumatic arm.

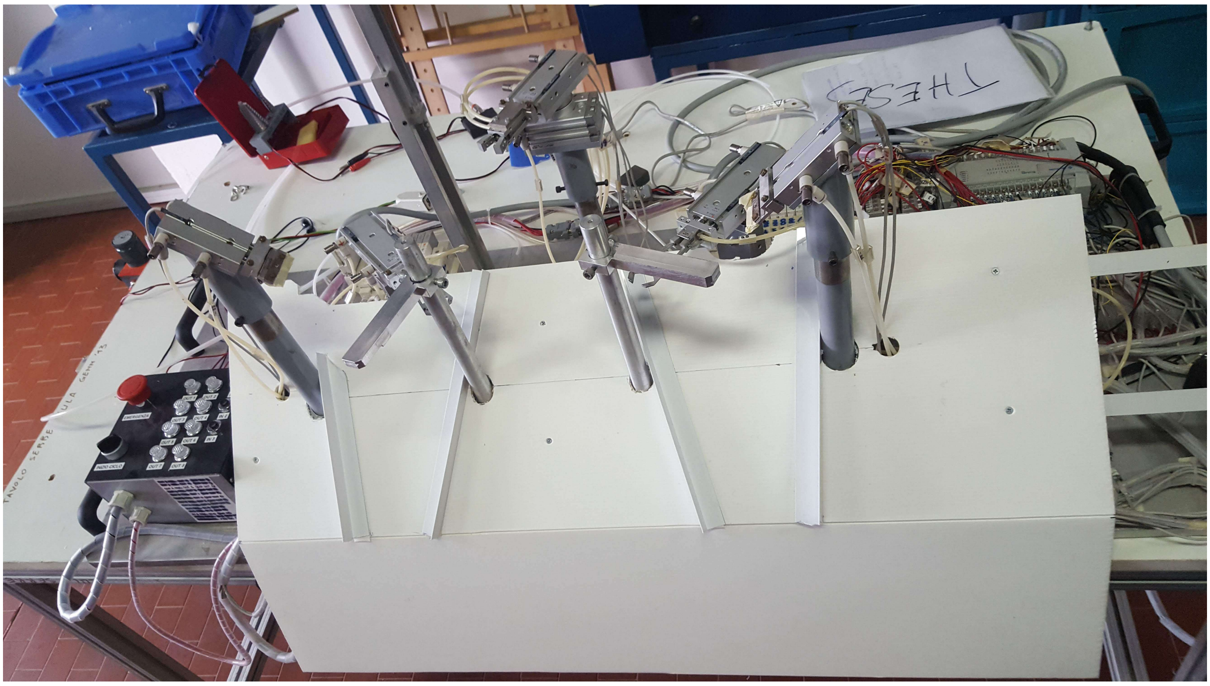


Figure 31: Insert a clear picture of the arm here

The vertical cylinder allows for the pneumatic arm to move up and down vertically. The cutting action takes place when the pneumatic arm is at the max position vertically while rest of the actions take place at the minimum position.

The Horizontal Cylinder is to allow for the pneumatic arm to go forward and backwards in the horizontal plane.

Cylinder for gripper is to allow for gripper to close to hold on to the scion.

3.5.3 Cutting Blade Arm to cut the Scion

The cutting blade arm consists of the following pneumatic components:

1. Horizontal Cylinder

The Horizontal cylinder of the blade arm is connected to the cutting blade. The Horizontal movement of the cylinder moves the blade forward and backwards. The forward movement of the blade is used to cut the scion with the help of the cutting support. Below is the picture of the Cutting Blade arm.

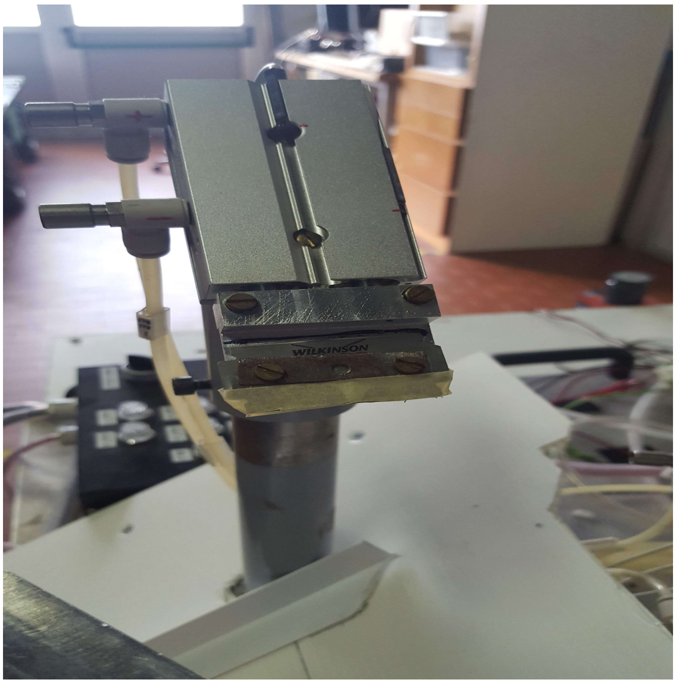


Figure 32: Cutting Blade

The Horizontal cylinder is not aligned horizontally with the plane but instead at an angle facing slightly downwards. Below is the picture of extension made to perform the cut.

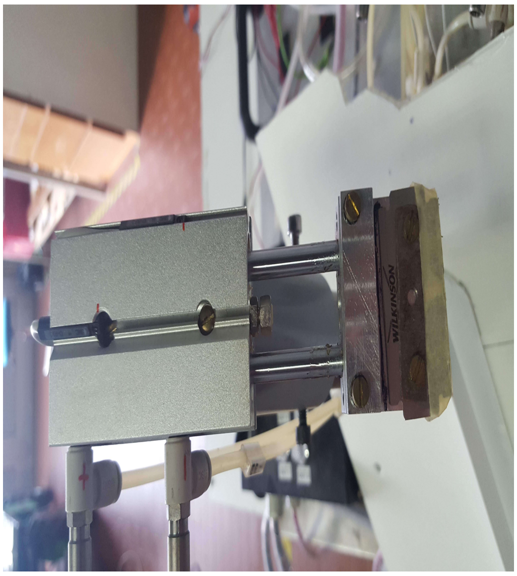


Figure 33: Extension to perform the cut

3.5.4 Cutting Blade Arm to cut the Rootstock

The cutting blade arm consists of the following pneumatic components:

2. Horizontal Cylinder

The Horizontal cylinder of the blade arm is connected to the cutting blade. The Horizontal movement of the cylinder moves the blade forward and backwards. The forward movement of the blade is used to cut the rootstock with the help of the cutting support.

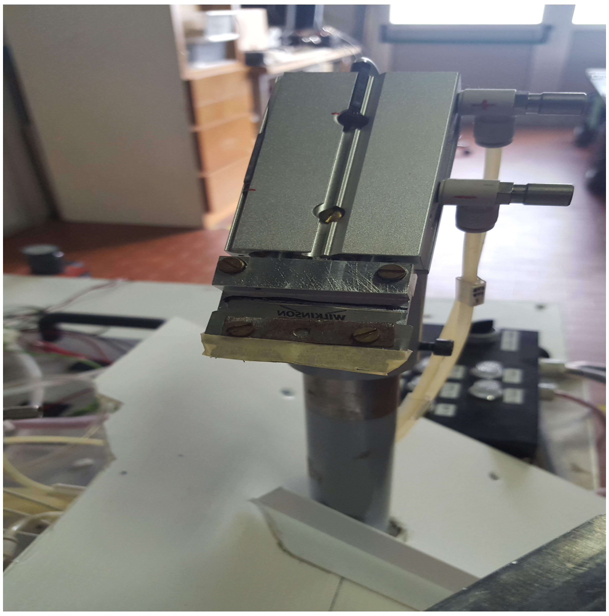


Figure 34: Cutting Blade

The Horizontal cylinder is not aligned horizontally with the plane but instead at an angle facing slightly downwards. Below is the picture of extension to perform the cut.

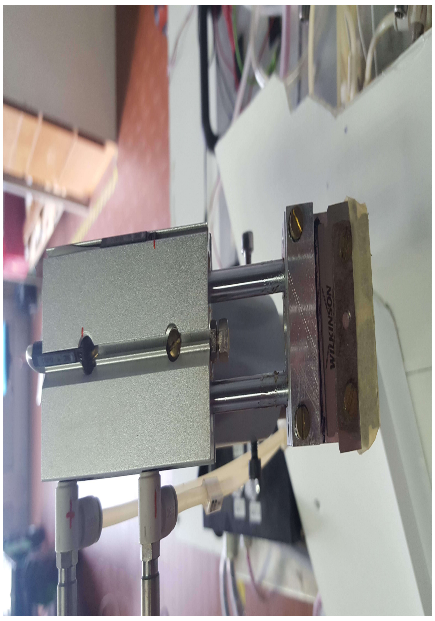


Figure 35: Extension to perform the cut

3.5.5 Support to cut the Scion

The support to cut the scion consists of following parts:

1. Rotational Cylinder

The rotational cylinder is used to align the support so that when the blade moves forward to cut the scion, the scion is trapped between the blade and the support hence providing a cleaner and successful cut.

When not being used the rotational cylinder is activated so that the support is not affecting any other action. Below is a picture of support being provided for the cutting action to take place.

Figure 36: Support for the cut to be made

3.5.6 Support to cut the Rootstock

The support to cut the scion consists of following parts:

1. Rotational Cylinder

The rotational cylinder is used to align the support so that when the blade moves forward to cut the rootstock, the rootstock is trapped between the blade and the support hence providing a cleaner and successful cut.

When not being used the rotational cylinder is activated so that the support is not affecting any other action.

3.5.7 Pneumatic arm to apply the clip to join the cut plants

The pneumatic arm to apply clip to join the cut plants consists of the following pneumatic parts:

1. Rotational Cylinder
2. Horizontal Cylinder
3. Cylinder for Gripper

The rotational cylinder is used to align the arm in two possible working conditions. At one end is the position to pick up the clip from the Clip Holder while on the other end is the position to apply the clip to join the scion and rootstock.

The purpose of the horizontal cylinder is to move the gripper closer to pick up the Clip from the clip holder and to move it closer to apply the clip to the scion and rootstock.

The cylinder for the gripper is used to activate the gripper so that it closes to hold onto the clip.

Below is a picture of the pneumatic arm to apply clips.

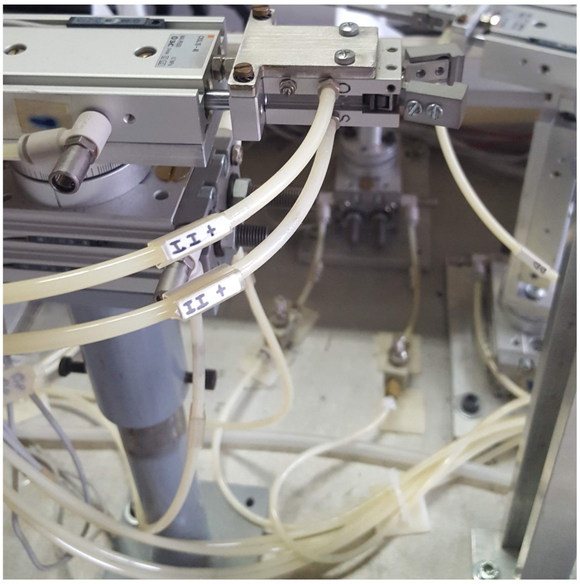


Figure 37: Picture of the Arm

3.5.8 The Clip Holder

The clip holder is a simple non moving part that holds multiple clips. The clips in it are stacked vertically on top of one another. Below is the picture of the clip holder from the side angle.

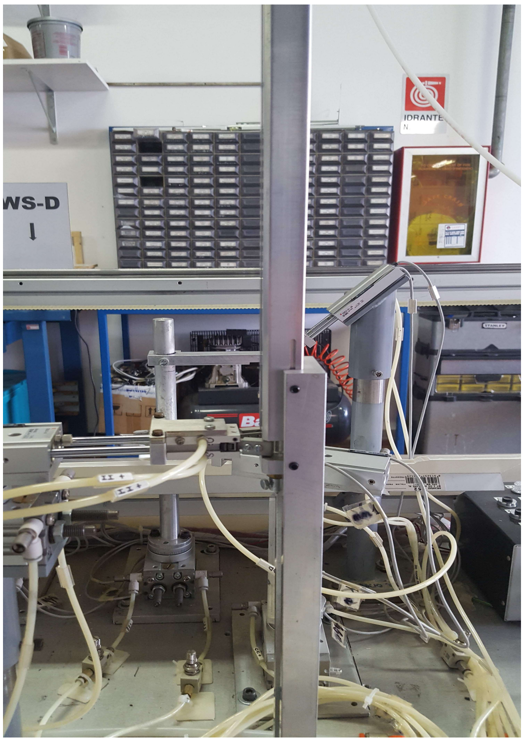


Figure 38: Clip Holder

From the bottom the gripper picks up a clip and due to gravity the clip above it slides down to take it’s place. Below is the picture of the front view of the clip holder.

Figure 39: Front view of clip holder

3.6 Total Pneumatic Components

The table below names each cylinder, it's purpose & movement. This table is used in the PLC code we will write to address each cylinder.

Name	Purpose	Movement
AA	Rootstock Handling	Horizontal
BB	Rootstock Handling	Vertical
CC	Rootstock Handling	Rotational
DD	Rootstock Handling	Close Gripper
EE	Rootstock Cutting	Horizontal
FF	Rootstock Support	Rotational
GG	Grafting	Rotational
HH	Grafting	Horizontal
II	Grafting	Close Gripper
LL	Scion Handling	Rotational
NN	Scion Handling	Horizontal
OO	Scion Handling	Open/close gripper
PP	Scion cutting	Horizontal
QQ	Scion support	Rotational
RR	Scion Handling	Vertical

3.7 Initial Grafting Working Cycle

Initially in the thesis of Alessandro Rizzotti a working cycle was formulated to run the machine. However this code ran into problems when it came to integrating the DIMEAS Machine running it with the DISAFA Machine.

In this initial code a request would be sent at the start to the DISAFA Machine for the holders for the two plants to be grafted together to arrive. Then the two pneumatic arms will operate in parallel and simultaneously to take the plants from the holder.

However over here a problem arose with the integration with the DISAFA Machine because it expected the holders to be released but the logic of the DIMEAS Machine was such that it waited to release them till these two parallel cycles were completed. This problem caused operational problems with the DISAFA Machine.

After this stage however the Machine worked properly and it then performed the cutting and the joining operations properly. After that the grafted plant was returned to the DISAFA Machine.

The logic for this code was created via a technique known as the auxiliary relay technique and it required eight auxiliary relays to operate.

So in this initial working cycle there were issues with the integration with the DISAFA Machine and the input output signals had to be handled properly.

The GRAFCET of this program is shown in figure 41 on the next page. While the Displacement Step Diagram associated with this GRAFCET is shown in Figure 42.

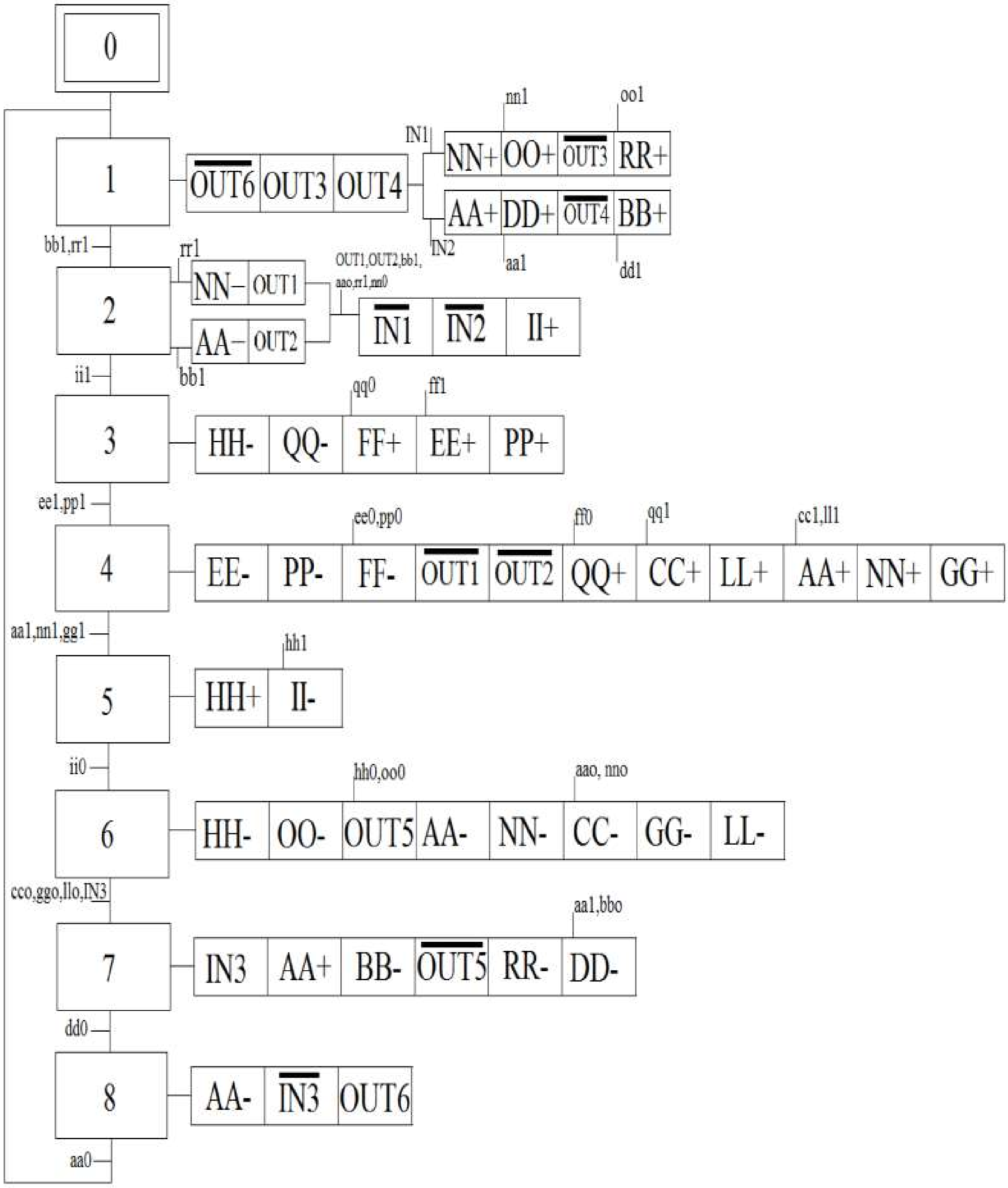


Figure 40: The Initial GRAFCET

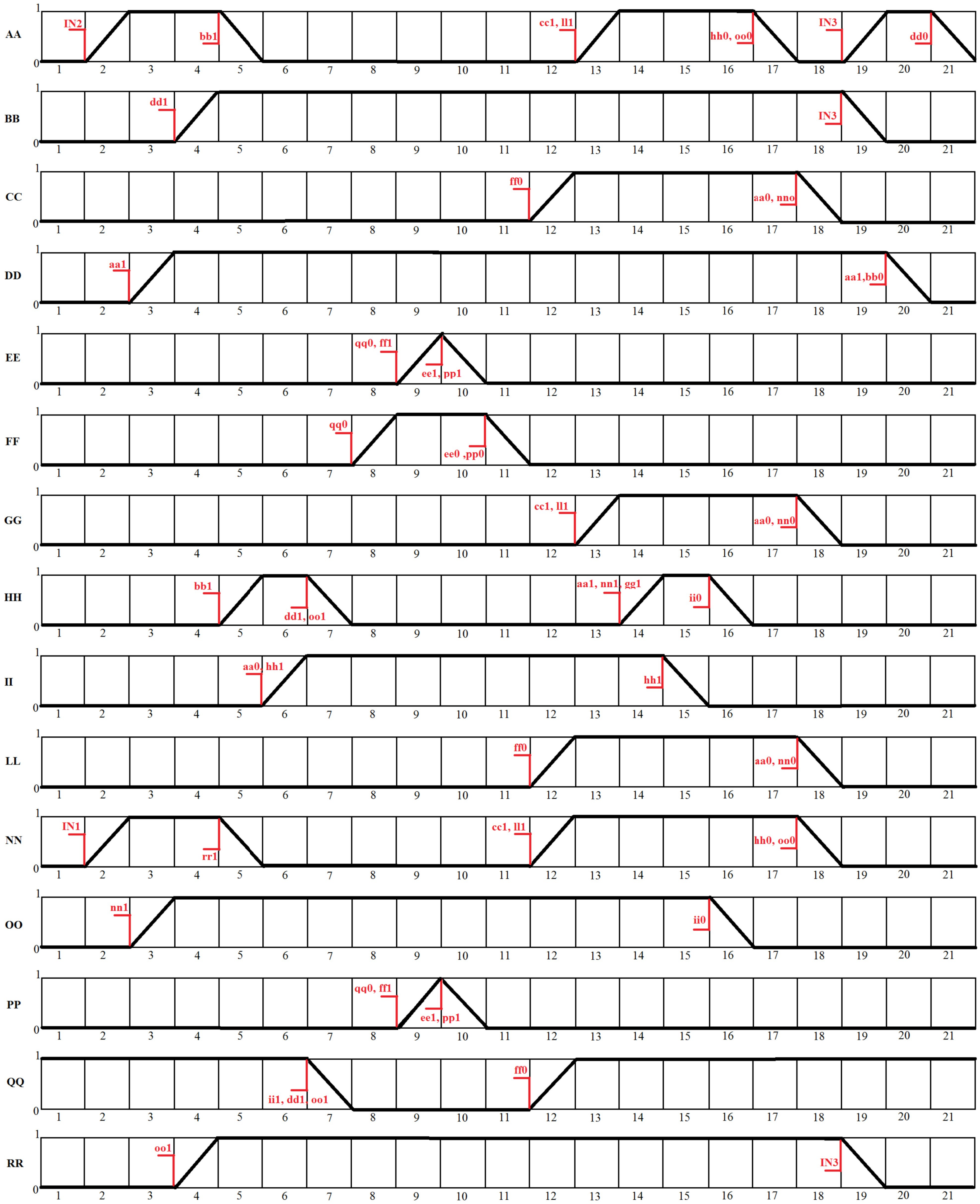


Figure 41: Stroke Movements associated with figure 41

4. DISAFA Machine

The whole System to automate Grafting is composed of two separate machines working together. These two machines are referred to as as the DISAFA Machine & the DIMEAS Machine. The function each of these machines serves is:

- DISAFA Machine: To handle the plants that will be grafted and the final grafted plant. This Machine was developed by the DISAFA Laboratory in the University of Torino's Department of Agricultural, Forest and Food Sciences.
- DIMEAS Machine: To Perform the Grafting Process. This Machine was developed by Politecnico di Torino's Department of Mechanical and Aerospace Engineering.

In this chapter the working of the DISAFA Machine will be explored.

4.1 Machine Structure

The DISAFA Machine is made up of guide rails along which the Carts that handle the plants can move along. The figure below shows the rail and carts:

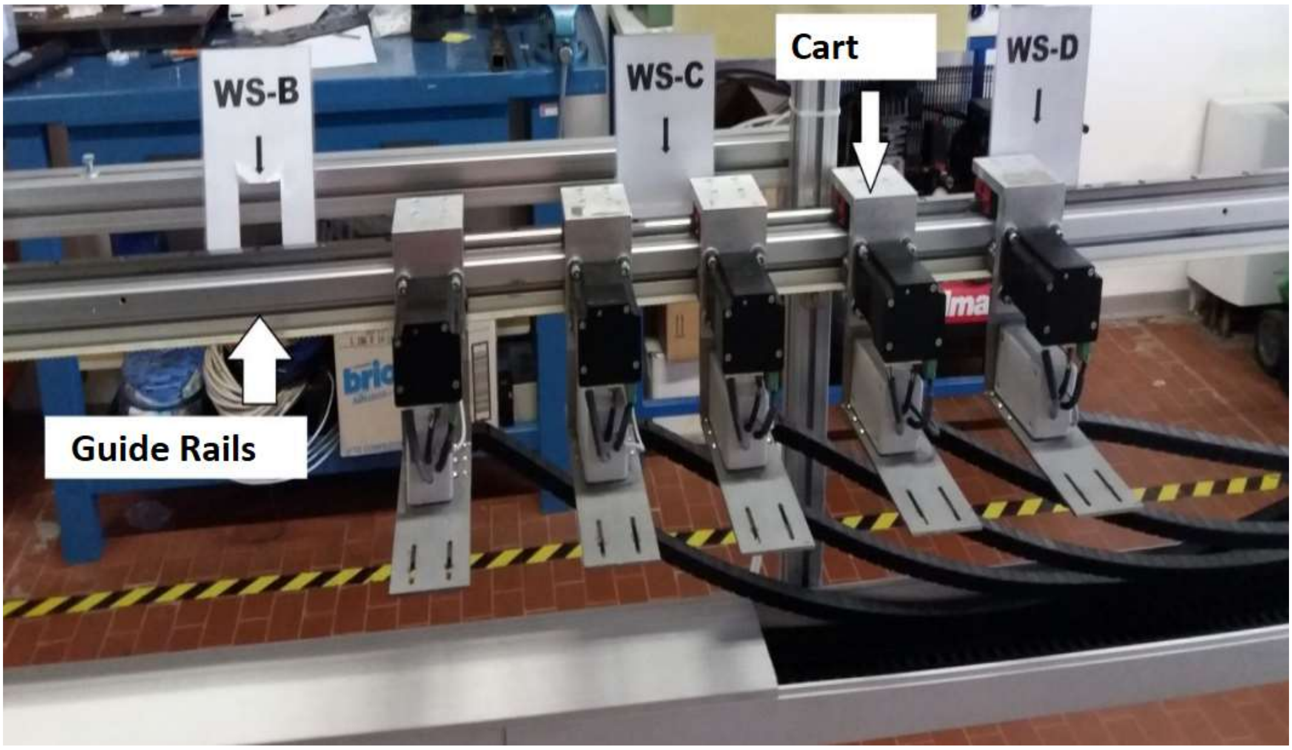


Figure 42: The DISAFA Machine showing guide rails & carts

There are a total of 5 Carts in the DISAFA Machine that are used for plant handling. They are responsible for handling both the Scion and Rootstock delivery as well as for receiving of the Grafted plant from the DISAFA Machine.

Each Cart consists of two horizontal slots cut into it to hold the plants. The figure below shows structure of one of the carts:

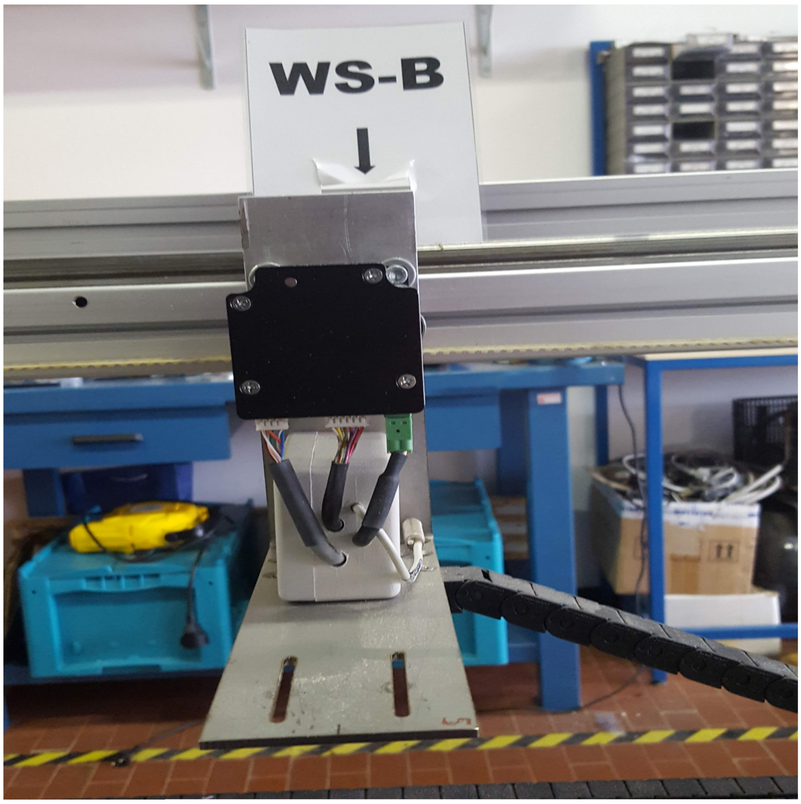


Figure 43: Cart with slots

As can be seen in the figure above there are two slots cut into each Cart. Furthermore the carts will be filled alternately. So at a time only 3 out of 5 carts will be carry a plant. These decisions are taken keeping in mind so that the pliers have a greater room to maneuver without the risk of damaging the nearby plants.

At either ends of the guide rail two control panels are present. The left side panel handles the loading of the scion and rootstock plants while the right side panel handles the deposit of the final grafted plant.

Figure 44: Left Side Control Panel

The picture above shows the left side control panel connected with the DIMEAS Machine. It contains 3 Red Lights, each representing a request from the DIMEAS Machine to the DISAFA machine. The lights represent:

- Request for the Scion
- Request for the Rootstock
- Rejected Plant

Once the Request arrives and the plant is available on the DISAFA Machine to be supplied the Operator will press the Black Button shown on the Figure above. This will block a cart & turn on the green light next to the black button. This indicates that that cart is ready to be operated on & it will be loaded. If the black button isn't pressed by the Operator the Machine can continue to move that Cart. Once the loading operation has been completed the Green button will be pushed to indicate that that trolley is ready for service.

The red button is to stop the machine in case of an emergency situation.

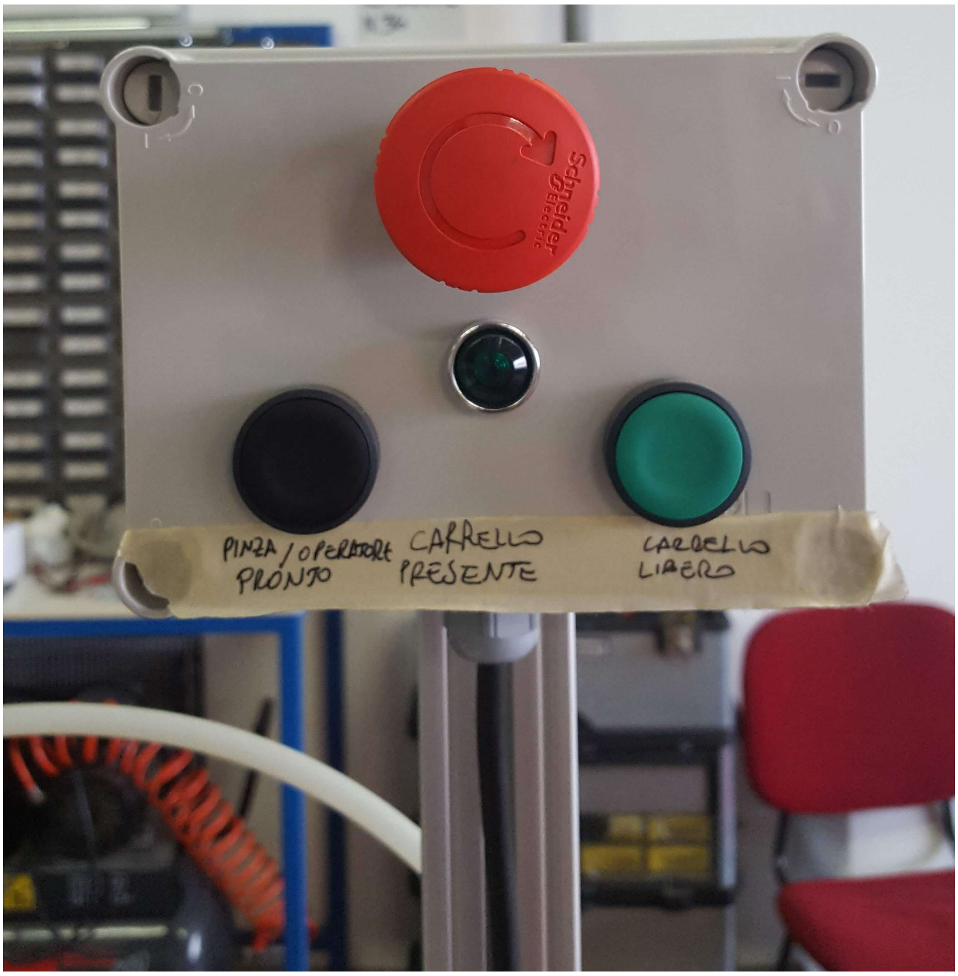


Figure 45: Right Side Control Panel

The figure above shows the right sided control panel. This panel deals with the receiving and unloading of the final grafted plant. The Light shown turns On when the cart carrying the Grafted Plant has arrived. Black button is pushed to block the usage of that Cart while Green button is pushed to make it available again. The Red button is to stop operation in case of an emergency situation.

For safety considerations Reed type limit switches have been positioned at different heights on all the motors. This is so that that they don't collide with end of the guides or against each other.

4.2 Software

The movements of the DISAFA Machine are handled by a program written in MATLAB. It handles:

- Movements of Carts
- Inputs from DIMEAS Machine
- Outputs from DISAFA Machine
- Storage of Plants

At start of the cycle the first operation that is performed is that the Carts are brought to their zero/reset position. They will be brought to this reset/zero position by being managed as a series of steps to be performed.

The guide itself has been divided into 5 distinct zones for better control of the carts. Following are the 5 zones:

- Zone A: This indicates the area containing the limit switches. This is the rest area of the carts. Once these carts leave this zone the machine will remember the plant present in each slot.
- Zone B: This zone contains a viewer to measure the size of each plant. These sizes can be divided into multiple categories as chosen by the user. The chances of a successful graft increases if the two plants chosen belong to the same category.
- Zone C: It is the area where the carts will stop so that the DIMEAS Machine can pick up the Scion and Rootstock they are carrying
- Zone D: It is the area where the carts stop to allow the DIMEAS Machine to deposit the grafted plant
- Zone E: This is the right hand area of the rail guide. This area is dedicated to unload the finished grafted plant.

These Zones are stored in the software with a number of steps predefined to reach them from the zero position.

4.3 Plant Storage

For efficient production management the prototype machine should be able to distinguish between what type of plant it is moving? Whether the plant that is being moved is going to be the Scion or the Rootstock?

This is achieved without feedback control. At the start of each cycle the software of the DISAFA Machine will decide autonomously which slot will hold the Rootstock and which the Scion. Then the Cart will move so that the first slot is in the loading position. A light will then come on to request for the Scion or Rootstock(which ever the software has decided) to be placed in the slot.

However if a mistake is committed in the loading stage & instead of the requested Scion a Rootstock was placed in the slot or vice versa, the Machine will have no way of knowing that a mistake was made. Instead it will continue with the cycle as if the correct loading was done.

To increase the chances of a successful graft between the various predefined categories the Software has been programmed in such a way that there are more loaded Rootstocks than Scions. This results in a better chance of a successful coupling. If there is low possibility of a successful plant the machine will indicate to remove the plant and add in a new one.

4.4 Management of Movements

For higher production times it is needed to optimize the movements of the trolleys. To achieve this a hierarchy of actions needs to be made so it is known which actions should be performed first while which ones can be deferred for later. To create this hierarchy for better optimization a simulation was created in the software and run for whole days to provide the answers.

Essentially a compromise needs to be found between the requests being sent by the DIMEAS Machine (for Scion and Rootstock plants and for DISAFA Machine to take the Grafted plant) and to minimise the number of movements to be carried out. So if the DIMEAS Machine has sent a request to pick up the Grafted plant and another request to ask for the Scion plant the DISAFA Machine has to check the positions of it’s available carts and decides which operation will take lesser time to accomplish.

This can be better visualized through this example: A cart is in Zone A & it is required now in both Zone C and E. It will first go to Zone C and then to E. It won’t go directly to E and then return back to C. In this case Zone C will have a higher precedence as fulfilling it’s request first will minimize the cycle time.

Another case that is implemented in the DISAFA Machine is that it has the ability to know in advance which output will arrive from the DIMEAS Machine. When the Cycle starts the DISAFA Machine knows that sooner or later a request will arrive from the DIMEAS Machine regarding the plants, so the DISAFA Machines starts asking the operator before the output actually arrives. Similarly the DISAFA Machine knows that once it has delivered the plants that will become grafted together the DIMEAS Machine will soon send a request to pick the grafted plant up. This way the Cart to receive the grafted plant is moved into position in advance & made to wait.

5. Input Output signals from DISAFA MACHINE

Our whole system consists of two separate machines:

1. DIMEAS Machine
2. DISAFA Machine

The DIMEAS Machine is responsible for performing the grafting operation while the DISAFA Machine provides the DIMEAS Machine with the scion and rootstock and then later receives it too.

Hence the two Machines need to interact with one another and inform each other about their statuses so that the grafting operation and handling of the plants is performed efficiently with minimal time wastage.

5.1 Signal Descriptions

In our DIMEAS System the Input signal will be referred to as the signals arriving to the DIMEAS Machine from the DISAFA Machine while the Output signals will be signals that will be sent by the DIMEAS Machine PLC to the DISAFA Machine.

So in brief:

- Input: Signals from DISAFA Machine to DIMEAS Machine
- Output: Signals from DIMEAS Machine to the DISAFA Machine

For testing purposes the DISAFA Machine isn't connected while the DIMEAS Machine is tested, however we need these input and output signals. As a result a simulator has been made consisting of buttons to act as input signals and lamps to act as output signals.

A total of 3 possible Input Signals can be sent by the DISAFA Machine depending on the situation while the DIMEAS Machine can send 6 possible output signals.

The DIMEAS Machine requires the presence of these input signals at various times for it to perform it's operations. If these signals are not present the machine will not perform the operation and instead wait for the needed input signal to arrive.

These input signals arrive momentarily to the PLC and then they go low. However we require the signal to remain 'high' for a longer period of time since the subsequent actions of the machine are dependent on the presence of these signals. To solve this issue these input signals are stored in the PLC when they arrive in corresponding memories. Once their usage is finished the memories are cleared, The Output signals are used to to inform the DISAFA Machine to what to do next. These Outputs are used to send requests to ask for the DISAFA Machine to send the Scion, Rootstock and Grafted Plant carts. Additionally requests are sent to allow the DISAFA Machine that it can move the cart without interfering with the operations of the DIMEAS Machine.

The following tables describes each off the Input and Output signals and it's purpose:

Name	**Purpose**
INPUT 1	Indicates Scion has arrived
INPUT 2	Indicates Rootstock has arrived
INPUT 3	Indicates the cart to receive the grafted plant has arrived
Output 1	Signal to allow that the Scion cart can move
Output 2	Signal to allow that the Rootstock cart can move
Output 3	Request sent to DISAFA Machine for Scion to arrive
Output 4	Request sent to DISAFA Machine for Rootstock to arrive
Output 5	Request sent to send the cart for the Cart for the Grafted Plant
Output 6	Allow the Grafted Plant Cart to be moved by the DISAFA Machine

6. Cover for DIMEAS Machine

The DIMEAS Machine has to perform these three main operations:

1. Cut the Rootstock
2. Cut the Scion
3. Graft the Plant

The first two operations produce by-products. The cutting of Rootstock and Scion produce the by-products of the portion of the plants that are not being grafted together and the soil that might be attached with the plants. This waste fall down on our machine and can accumulate since the DIMEAS Machine will be working continuously for long periods of time.

Due to this waste the machine needs to be stopped periodically and the debris cleaned. Not only this creates unwanted wastage of time but also the cleaning of the soil particles and plant parts is tedious and difficult especially due to all the pneumatic and electrical wiring that is present. Furthermore this waste can cause problems in the correct working of the machine by acting as obstacles or effecting the wiring.

The solution to this problem is to protect the DIMEAS Machine from the falling debris by designing a cover over it. The debris instead of falling on out machine falls on the cover that we have put over the machine.

For the cover to do it's job well it will be placed at an angle instead of fully horizontal. This way the debris when it will fall on it will be able to slide away from the machine due to the slope and gravity. The figure on the right shows the illustration of the cover to be implemented.

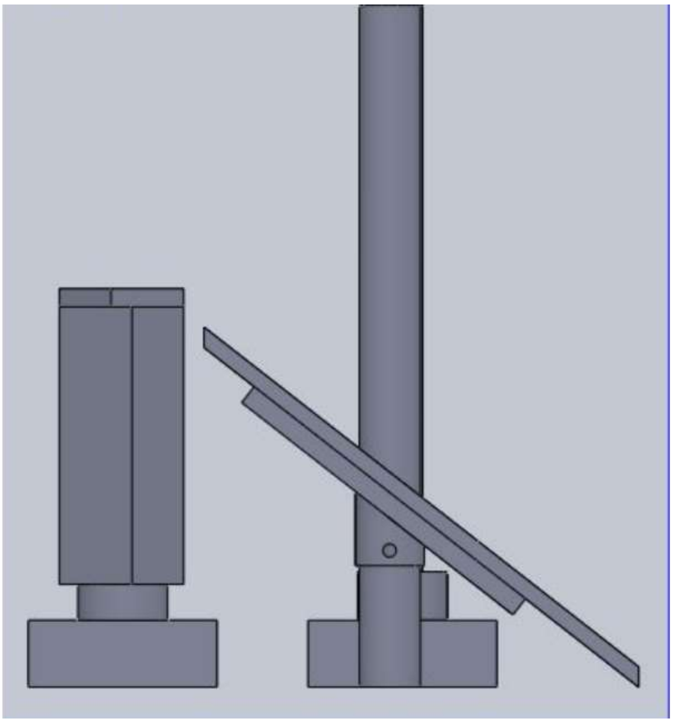


Figure 46: Illustration of the cover

Secondly the cover needs to be placed in a certain way so that it doesn't effect the movements of the Pneumatic arms that handle the scion and rootstock & the cutting supports., Hence the cover is placed just below these arms so that the cut parts fall on the cover.

Holes are made in the cover so that the necks of the Pneumatic arms pass through the cover. As a result there is no space left for the waste to come in contact with the machine. Due to doing this the cover extends all over the machine, providing better protection.The cover for the machine is made up of acrylic material & is mounted on the machine usinng two metal beams along which the cover is placed on. The cover is attached to these two beams with the help of screws. The side view of the cover is shown below.

Figure 47: Side view of the cover

To further guide the debris downwards and avoid unwanted lateral movement L shaped angle sections are placed at either side of the area where the wasted scion and rootstock will drop on the cover. These angle section will further help with keeping the waste contained and guiding it away from the machine. Figure below shows the top view of the cover.

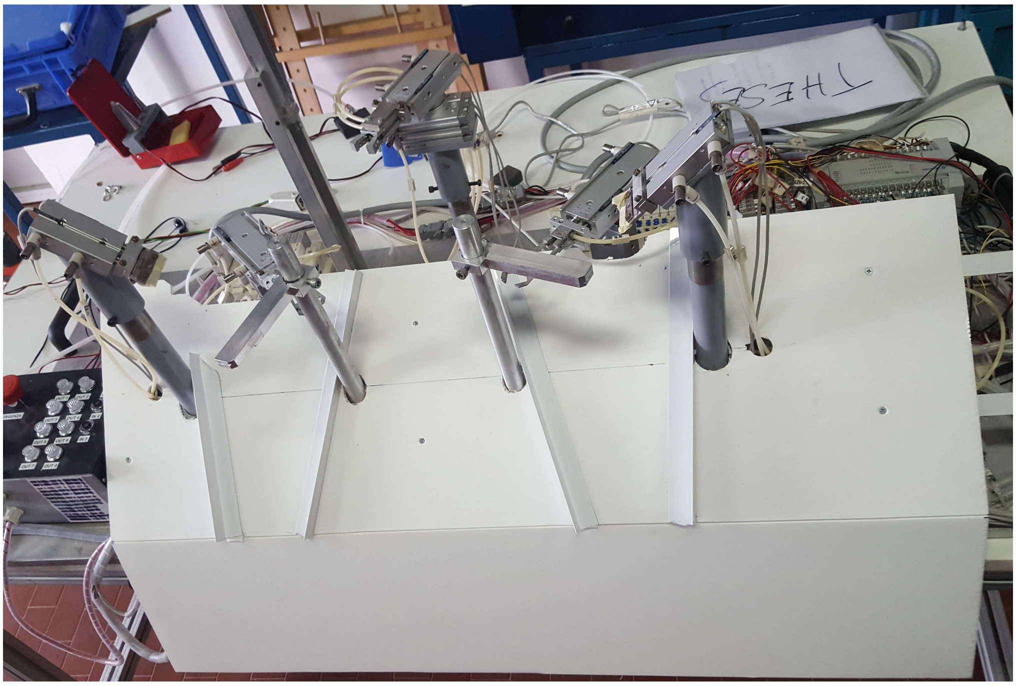


Figure 48: Top View of the Cover

A waste collection bill be placed to gather the waste for easy disposal.

As can be seen from the picture below the residue will fall down within the two L section angles on the cover and then slide down the cover away from the machine.

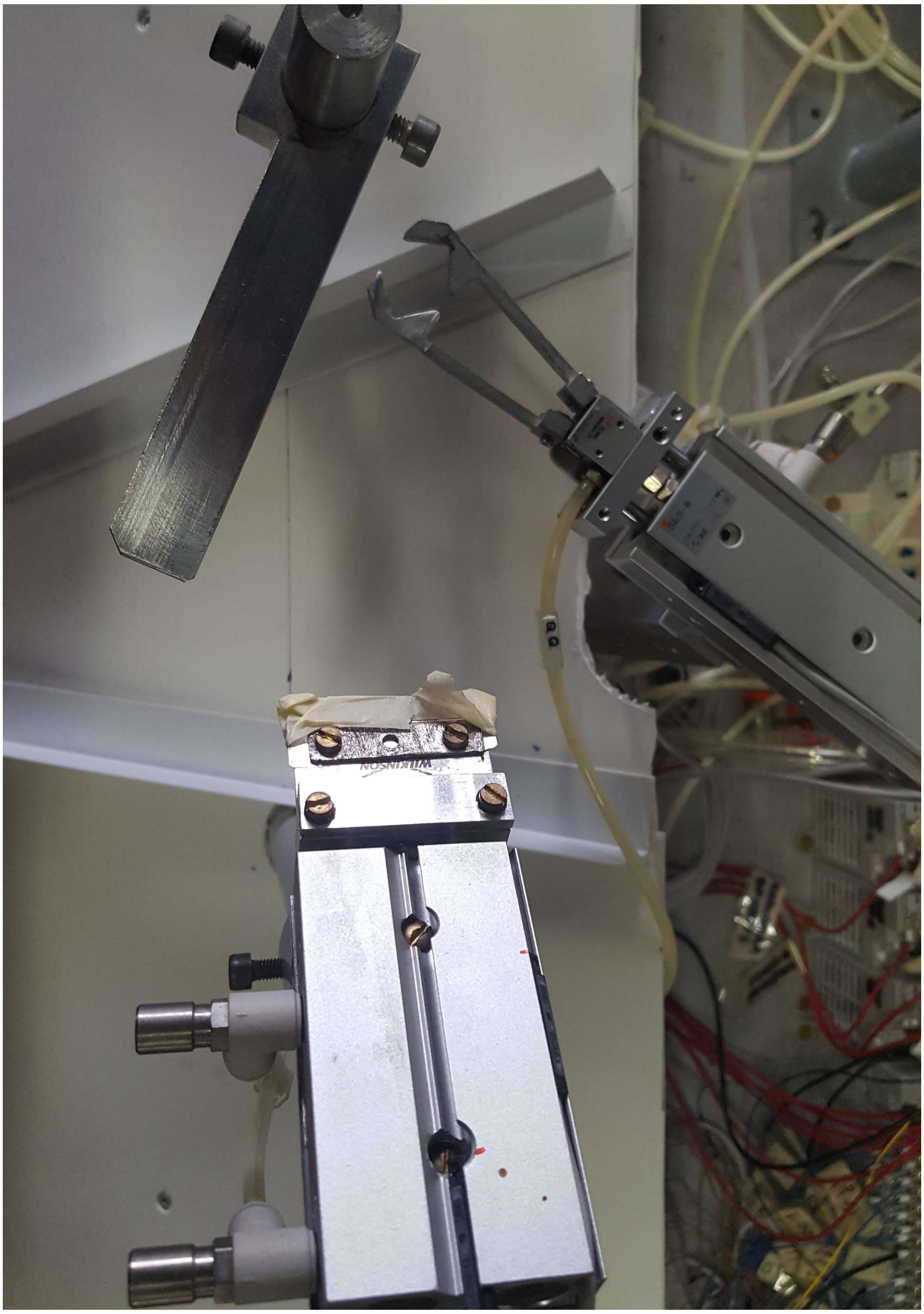


Figure 49: Top View of the Cover

7. Reset Cycle Problem

During the working of the DIMEAS Machine two such situations can occur:

1. A need to shut the Machine down when it is working due to an emergency situation by using the emergency stop button
2. There is a temporary power loss which turns off the machine

When any of these two situation occurs the machine has been turned off but when it is energised again the machine starts working from the same point it had stopped working at.

This quality is undesirable as this could cause problems in the machine's working. Instead it is preferred that the machine stops working on the cycle it was working at and instead starts from the initial position a new cycle.

7.1 The Software issue & Solution

To help resolve this issue a meeting was set up with a representative of the Rockwell Company. He suggested we utilize the First Scan Flag bit feature that comes in-built the PLC.

The First Scan Flag bit is a bit that is set whenever the PLC is turned on from an off state. This bit is set momentarily and retains it's value only for the first scan of a task. After that it goes back to being zero.

This First Scan Flag is then utilized as an indicator of the machine being just turned on & we can use it as a way to stop the PLC from starting from where it had left of.

Since bit is set only momentarily a special memory in the PLC is created to store it's value whenever it is set. Then using this we stop our main code from running and instead run a separate code called the Reset Cycle.

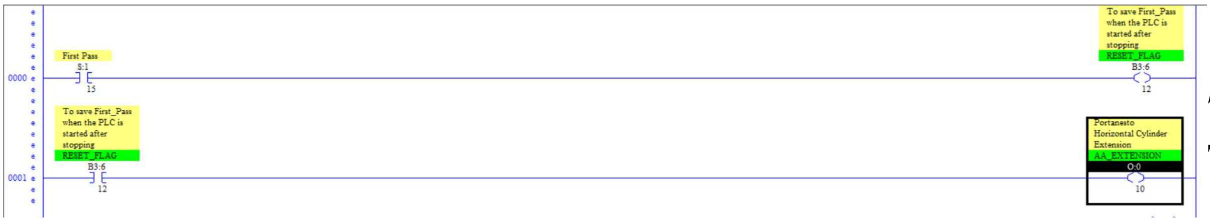
The Reset Cycle code's purpose is simple: to return the state of our DIMEAS Machine to the initial state, the configuration at which it can start running a new cycle from the start. To achieve this all the PLC's memories, timers and Input, Output state's need to be returned to that of initial condition. Then the pneumatic system of the DIMEAS Machine needs to be returned to rest position. The pneumatic arms, cutters, supports are moved to the position that they hold whenever a new cycle starts. If the Machine was holding scion or rootstock or grafted plant when it was turned off that plant is dropped off and is dealt with as waste instead of a needed product.

Hence whenever the DIMEAS Machine is turned off the plants it was handling at the time are wasted and the work resumes from a new set of scion and rootstock to make a grafted plant.

This First Scan Flag is stored in the bit address “S:1/15” in our PLC. Since it is high momentarily it is stored in a separate memory. This separate memory too is reset at the end when all the other memories, timers, inputs, outputs & pneumatic system have been changed to initial state. Once this happens the First Scan Flag storing memory too is reset and our main cycle code starts.

The First Scan flag storing memory is reset too since otherwise it will trigger our reset cycle to start again & instead of running the main code we will be stuck in a loop of Reset Cycle.

Following is the logic for implementation of storing the First Scan. In this example the First Scan is stored in a memory called Reset_Flag and from then on the that memory is used to trigger the next movements, in this case the extension of AA.



7.2 The

Hardware Issue & Solution

Another issue that arises in the Emergency situation is hardware related.

The two Solenoid valve blocks of our system are provided with supply of compressed air via a 3/2 normally closed valve. Once side of this valve is controlled by a spring while the other side by a solenoid.

When our machine is turned on an electric supply comes to this solenoid activating it. This activation allows for the compressed air to flow into our Valve blocks.

However when the emergency button is pressed which cuts off the electrical signal to this Supply Valve it closes. It also closes when there is a loss of power to our machine. In this configuration of the Supply Valve the two Valve Blocks now become connected to the drain of this Supply Solenoid Valve. This exhausts the air in our pneumatic circuit. This causes the elements connected in our pneumatic circuit to move from their position into a new position as there is no air left in the cylinders to hold them in place.

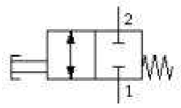
This implementation creates the problem during joining of the two plants the grippers of the Scion & Rootstock pneumatic arms are close together. Due to exhaust of pneumatic signal in their cylinders they move from their position they can have a crash or a get locked together. Then when the reset cycle starts and is air is supplied back in an attempt to move them to the required position this locking together can cause damage to the system since it can prevent movement or provide resistance to it.

Furthermore even in other configurations of the DIMEAS Machine crashes and locking of different pneumatic elements can occur which can damage the machine.

The end goal of the solution is to keep the air trapped inside our pneumatic circuit so that no unwanted movements would occur and elements would maintain their position when emergency button was pressed/ power failure occurred.

However an allowance has to be made for the system to discharge when the machine is closed at the end of the cycle when it is closed at the normal state.

To achieve this a 2/2 valve was used. A 2/2 Valve has two states: either the two terminals will be connected or that they will be disconnected. The control terminal to keep the connection disconnected is connected with a sprint, so that it is the default position. While the other terminal is controlled with the help of a switch.



This 2/2 valve will keep the air trapped in our system when there is power loss/emergency situation as the switch needs to be turned to exhaust the air. In the following picture the 2/2 valve is on the right hand side and the switch is shown in blue.

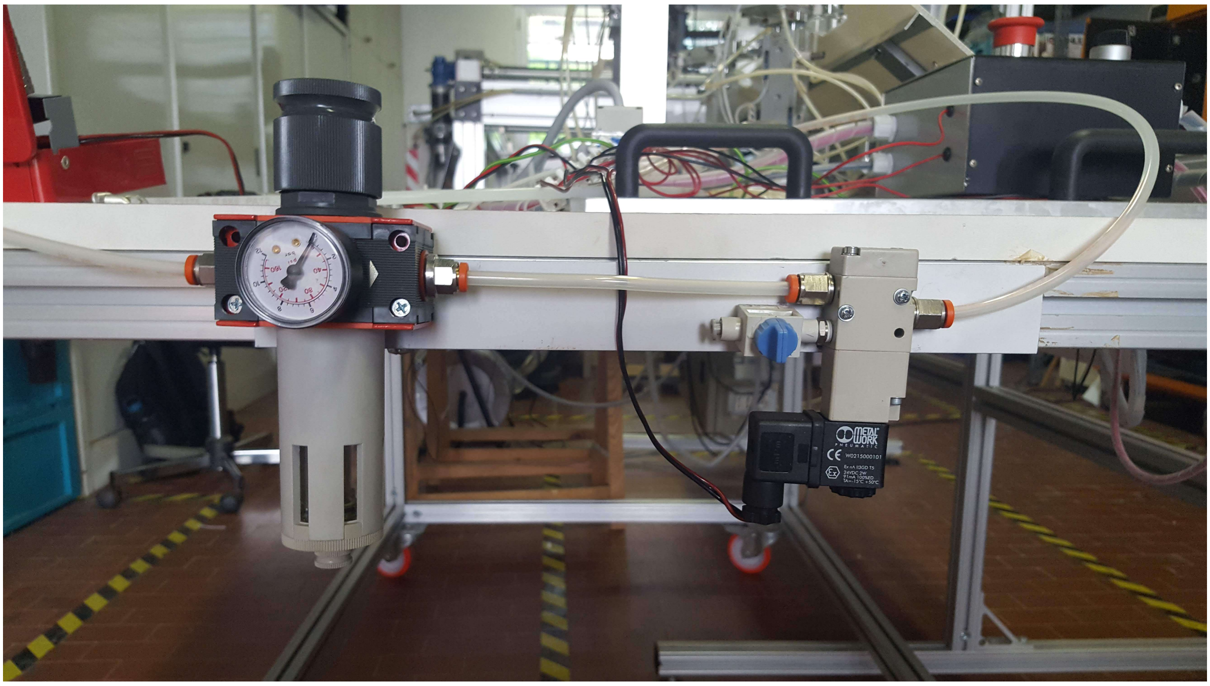


Figure 50: The 2/2 Valve shown with the supply

This 2/2 valve is connected with the Normally Closed 3/2 Valve. This 2/2 valve is connected with the exhaust of the 3/2 Valve. So when emergency button is pressed the exhaust of 3/2 is connected with 2/2 valve which traps the air until it's switch is turned. This way the air stays trapped in the pneumatic circuit even when there is power loss or emergency button is pressed.

However this solution only works for a finite amount of time since naturally there are small leakages in the valves, pipes and the cylinders. They leak the air slowly and eventually enough has been leaked in the system that the pneumatic elements don't maintain their positions and move since not air is left in their cylinders to hold them in place. It is estimated that the system will maintain its position for about 6 minutes in these scenarios.

To solve this problem the solution is to add a 2nd 2/2 Valve. This Valve is provided with supply from the main supply too. The supply is connected with the output of the valve when the switch of it is activated otherwise it is connected with exhaust. So when there is a power loss or we are in emergency condition this switch can be activated to supply the pneumatic circuit with compressed air to keep it's elements in place. This way there will be no effect of leakages on our machine.

So the compressed air supply is connected with the DIMEAS Machine via a pneumatic circuit of two 2/2 Valves and one Normally Closed 3/2 Valve. The schematic of this pneumatic circuit is shown in the figure below

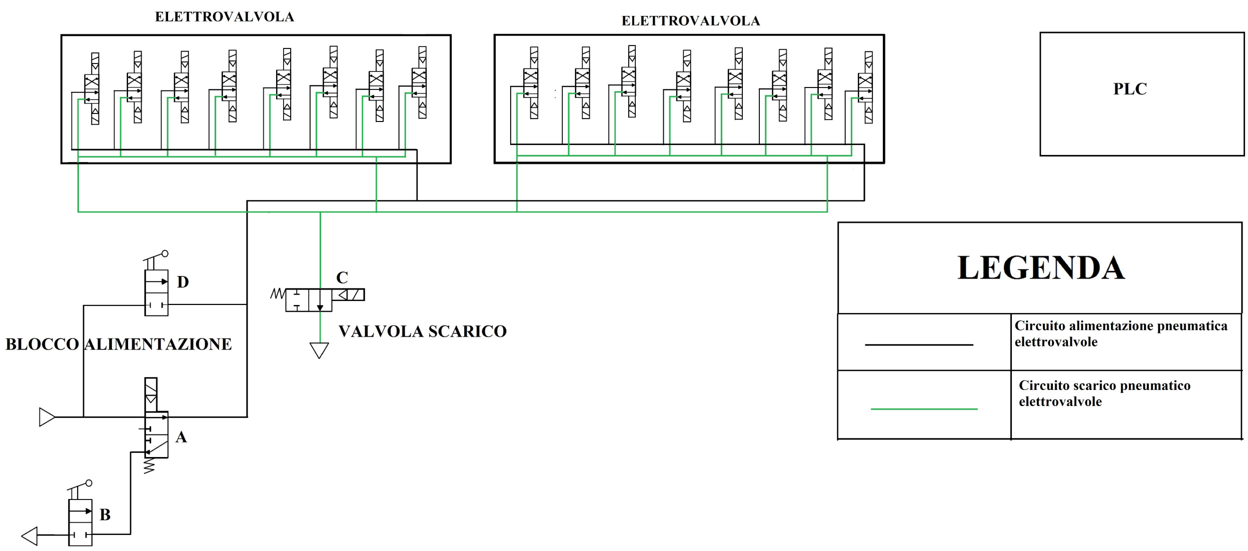


Figure 51: Emergency Schematic

8. Blower Addition

As discussed in Chapter 6 a need was seen to protect the machine from the by-products/wastage being produced by the DIMEAS Machine. The solution implemented was the addition of a cover over the machine to offer protection. The cover was slanting so as to guide the wastage away from the machine rather than it just lying on top of it.

However despite this slant there is a chance the waste may stick to the surface of the cover or have trouble moving easily away from the machine. To provide the ‘push’ needed to achieve this a blower was attached to the surface of the cover.

This blower is not be constantly on as that would be a waste of energy. Instead it is connected to the PLC which will control when it turns on, how long it stays on and then turns it off. So the optimal time to turn this blower on is after the cutting operation has been executed. The time chosen for the blower to stay on is 2 seconds as it is enough time to achieve it’s function. Below is the top view of the blower.

Figure 52: Top View of Blower

Figure 53: Front View of the Blower

This blower is provided with air pressure of 5 bar from the supply. As can be seen from the two pictures above the shape of the blower is flat and has multiple opening along it. As a result the air is thrown across a large cross section of the area and provides better coverage for the blower to act on.

Since it is a new pneumatic device to be added to the system it is connected to one of the outputs of the Solenoid Valve block. We have 2 Solenoid valve blocks with 8 sets of bistable valves in each. 15 of these bistable valves were being used previously and one was free. The blower was attached to this free bistable valve. This bistable valve's input connection was then connected to a free port of the PLC's output expansion block. An input is not needed from the blower as it just needs to be turned on for a pre-set amount of time and then closed.

In the picture below the valve with the '\' marking was the free bistable valve that is now being used as the valve connected to the blower.

Figure 54: Picture of the Valve Block with a free valve shown by \ sign

This bistable valve then needed two inputs from the PLC to control it's operation. Fortunately two output ports were available on the expansion block of the PLC. These two ports were connected to this bistable valve via electrical wiring. The addresses of these two ports are the following:

- O:3/6 : SS_ON
- O:3/7 : SS_OFF

The pictures below shows the ports that the electrical connection is made to, connecting the expansion block of the PLC with the bistable valve chosen for the blower.

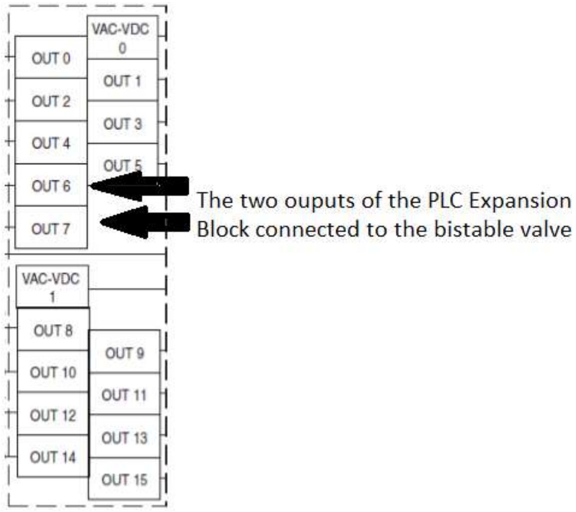


Figure 55: Ports used for the blower

The picture below shows the actual connection that was made:

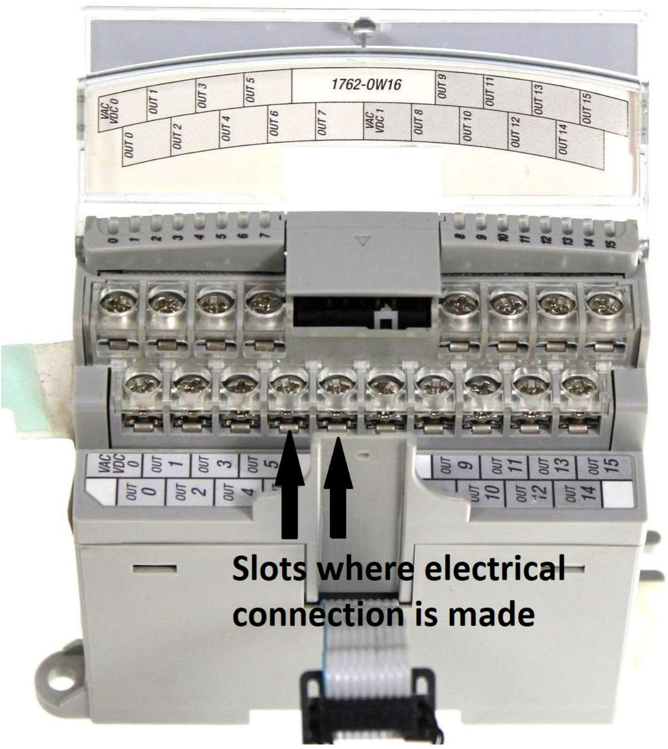


Figure 56: Where the electrical connections are made on the expansion block

9. Batch Technique & GRAFCET formulation

9.1 GRAFCET Introduction

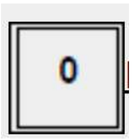
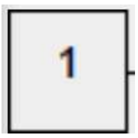
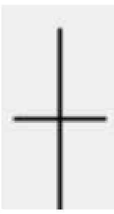
The term GRAFCET stands for: "GRAphe Fonctionnel de Commande Etapes/Transitions" or in English it can be translated as : "Step Transition function chart". It is a standard (DIN EN 60848) valid in Europe defining a graphical design language for the functional description of the behaviour of the sequential part of a control system. This standard was proposed in 1977 and was standardized in 1982[8].

The advantage GRAFCET offers is that the same GRAFCET can be used and understood by professionals from various disciplines. Furthermore GRAFCETs work very well when a program for a PLC needs to be created. The GRAFCET defines an operation by the following principles:

1. Steps with which actions are associated
2. Transitions between the stages & their associated transition conditions.
3. The links between steps and the transitions.

As a result GRAFCET offers a clear and easy to understand visual of how a system operates step by step. It is read top to bottom.

The main symbols of GRAFCET are shown below along with their description:

Symbol	Name	Description
	Initial Stage	The initial stage refers to the initial state of the system at the beginning of the cycle/operation
	Step	Steps are numbered in ascending order. They refer to the corresponding stable state of the system
	Transition & response	Each transition refers to the next possibility in the system. Each transition is associated with a response, If response is present then the transition can occur and the next step reached. It can come from operative part or console itself

	Action	Actions are associated with a step. An action becomes active when cycle reaches it's step. An action can be of many types like activation of a solenoid, activation of a timer etc
	Oriented Link	GRAFCET is read from top to bottom. If it has to be read from bottom to top then an oriented link has to be indicated to show the direction.

The following are the rules according to which GRAFCET operates[9]:

1. GRAFCET always starts with an initial step. This step represents the initial state of the system before a cycle starts.

2. A Transition can only have one of the two states 'Valid' or 'Invalid'. The transition becomes valid only if the condition of all previous steps being active is met. When both transition is valid and associated response present then the transition is crossed and the next step reached.

3. When a transition is passed the following steps becomes active while the previous step is deactivated.

4. Divergence and Convergence can occur in a GRAFCET. A divergence occurs when after one step two possible steps can occur from the same transition. Convergence occurs when two steps independent of one another take place producing their transitions & the step proceeding both of these steps requires transitions from both to be activated.

5. An oriented link can be inserted as a way to jump over steps and go directly to another step. This step can occur later or even earlier.

An example of a GRAFCET is shown below:

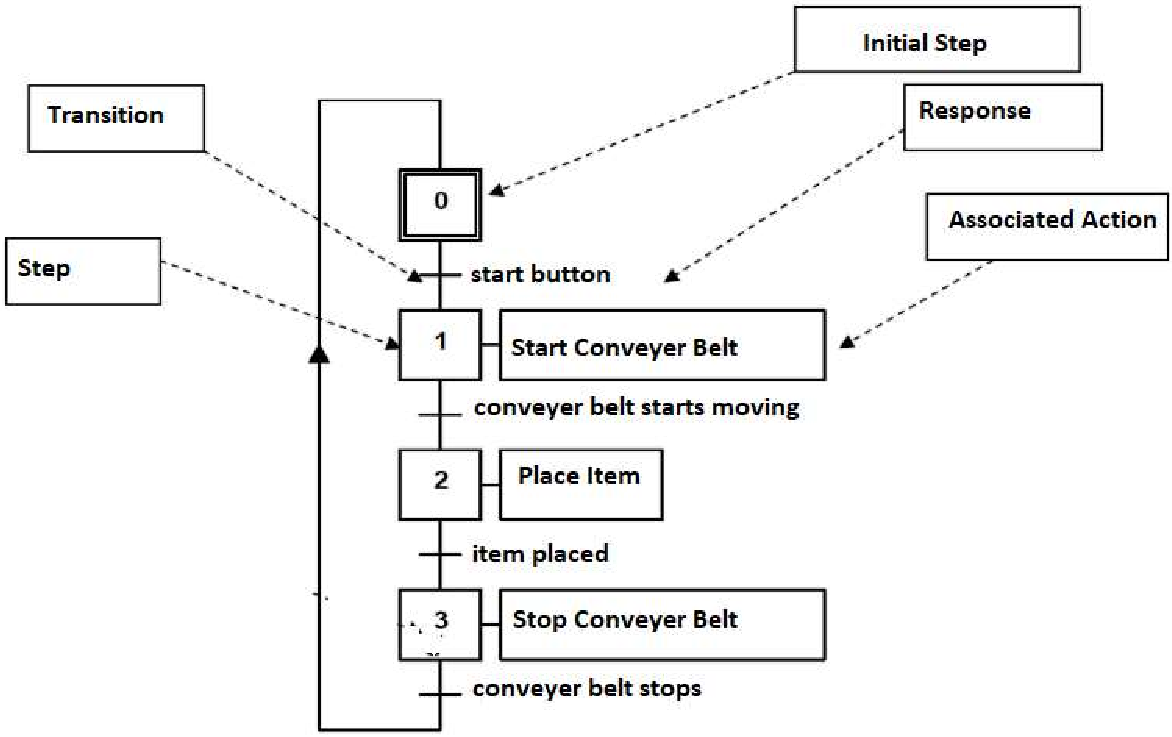


Figure 57: GRAFCET Example

Three actions need to take place in our GRAFCET: conveyor belt has to start moving, item has to be placed on it and then it needs to be stopped.

The response to trigger the conveyor belt to move is the start button. Once it is pressed the conveyor belt starts moving.

The second action that has to take place is to place the item on the belt. This action is triggered by the response that the conveyor belt has started to move. This response is produced when conveyor belt starts to move i.e. the previous step.

When the last step is performed we can see an oriented link going back to the initial step. This indicates the system goes back to the initial state and it can start it's same cycle again.

9.2 Batch Technique

9.2.1 Working Principle

Batch Technique is a technique among a few others to convert the GRAFCET to a Ladder Logic Program for a PLC. Batch Technique will be used to translate the GRAFCET into Ladder Logic for the PLC.

The purpose this technique serves is that it provides power to the action only in the step where it is needed. Once that step passes the power is cut off.

Batch technique works according the following principles:

- Each step is associated with a memory
- If the memory is Set then that step is active.
- If the memory is not set then that step is not active.
- A memory is set when the previous step has been activated thus producing the subsequent transition & the response associated with transition is true. This memory then resets the memory associated with the previous step & so on
- The amount of memories needed for batch technique is equal to number of steps.

9.2.1 Example

Following is an example of a Batch Technique to help better understand it.

The following actions need to take place in the specific order:

- Once the start signal is received activate the valve A
- Once the valve A has been activated then activate Valve B
- Once Valve B is activated then deactivate valve A
- Once Valve A has been deactivated then deactivate Valve B

The following signals are produced:

- Signal a1 is produced when Valve A has been activated
- Signal b1 is produced when Valve B has been activated
- Signal a0 is produced when Valve A has been deactivated
- Signal b0 is produced when Valve B has been deactivated

Using the information given above the following GRAFCET is produced:

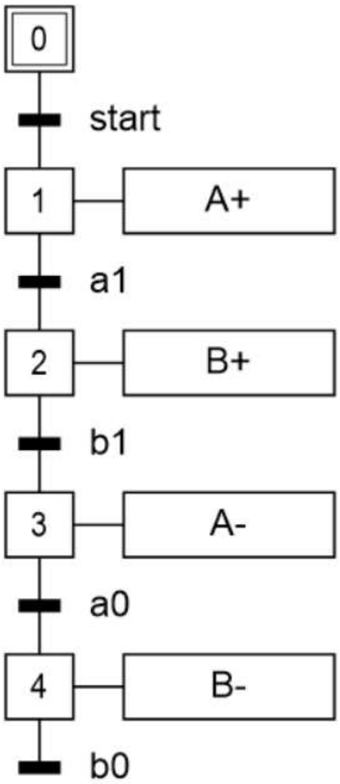


Figure 58: GRAFCET

Next a memory will be associated with each step(each memory associated with an Mx, where x is the memory number):

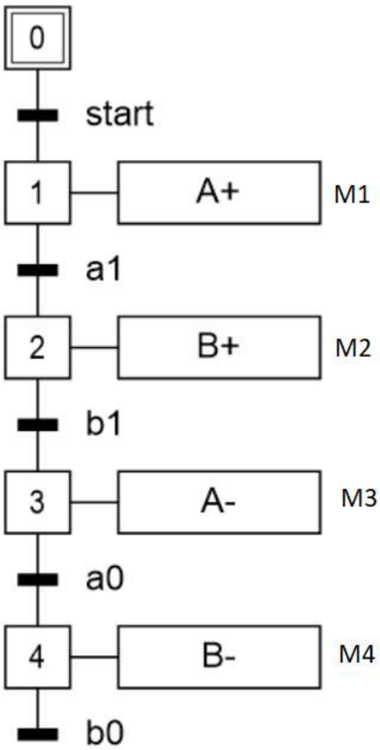


Figure 59: GRAFCET

Two equations are associated with each Memory. One equation defines the conditions to put it in the SET condition and the second equation defines the condition to RESET the Memory.

So the equations are:

Memory	**Equations**
M1	Set M1=start
	Reset M1=M2
M2	Set M1=M2.a1
	Reset M2=M3
M3	Set M3=M2.b1
	Reset M3=M4
M4	Set M4=M3.a0
	Reset M4=M1

So to set a memory action of previous step & the transition condition is used. While the memory is reset by the setting of the next memory.

The PLC implementation of the equations is given in the next figure:

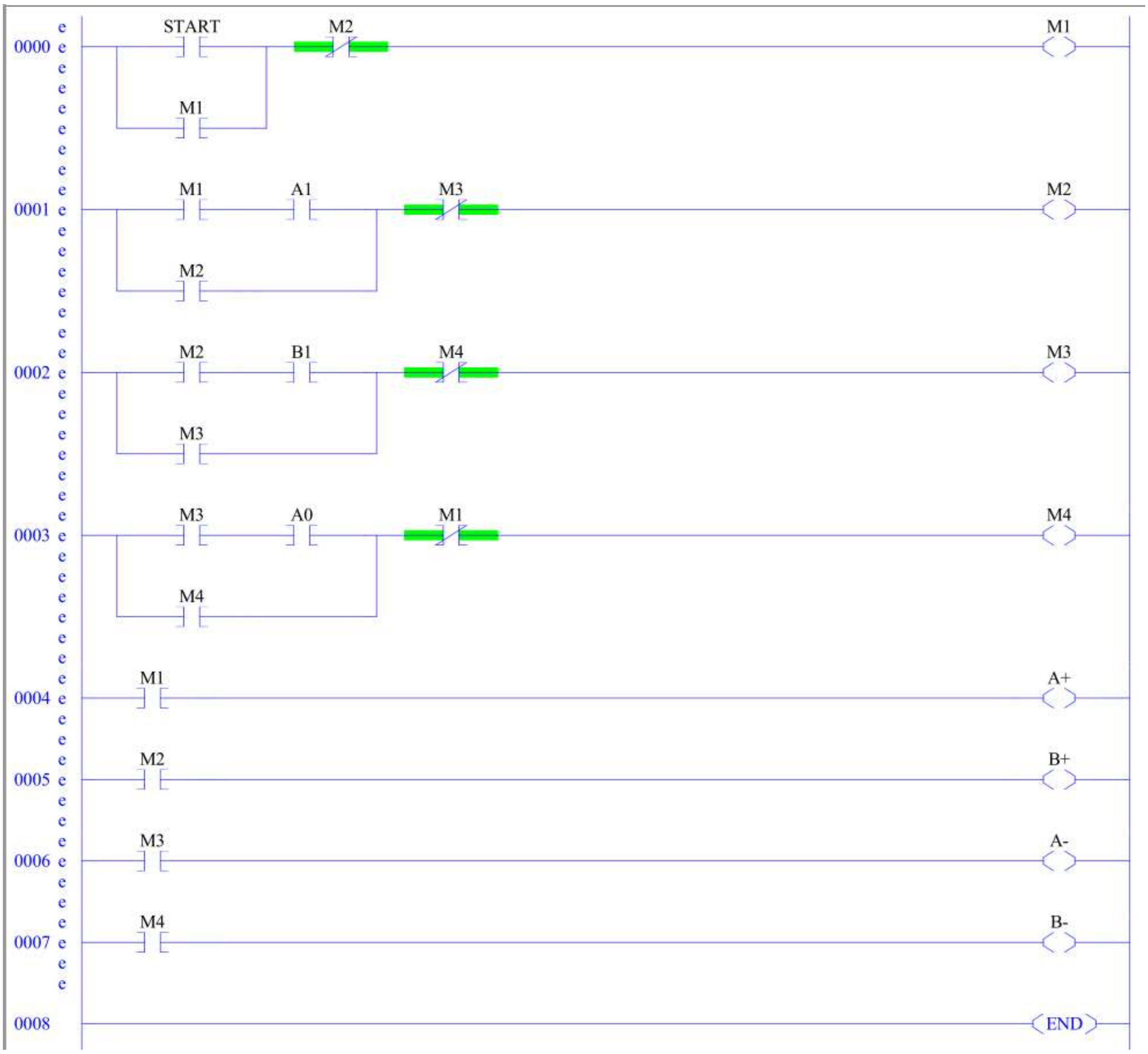


Figure 60: PLC Implementation

The first 4 rungs represent the setting and resetting equations of the Batch Technique. The next 4 rungs represent the activation/deactivation of the valve associated with each Memory.

The reset equation is represented by the normally closed switches in the ladder logic. While the normally open switches represent the set equation.

9.3 GRAFCET for DIMEAS Machine

Two different GRAFCETS need to be written for our DIMEAS Machine:

- Main Cycle
- Reset Cycle

The Main Cycle GRAFCET will deal with the normal working of the DIMEAS Machine.

The Reset Cycle GRAFCET will deal with the cycle that needs to occur whenever the Machine is turned On(from normal condition or from an emergency condition).

Then Batch Technique will be applied to each of the GRAFCETS and their equations written. After that these equations will be implemented in the Ladder Logic for the PLC.

The Ladder Logic Code written for both the GRAFCETS will exist in the same program of the PLC.

9.3.1 Naming the signals and pneumatic devices associated with DIMEAS Machines

Before creating the GRAFCETs all the inputs, outputs, sensor signals, pneumatic devices need to be defined and named. This way it will be easy to distinguish everything from each other.

- There are a total of 29 possible input signals
- There are a total of 40 possible output signals
- There are a total of 15 pneumatic elements (each with 2 possible movements)
- Since we have to give delays for gripper to close and blower to act there will be 7 timers implemented

The tables associated with each are following:

Pneumatic Elements	
Name	**Association/Description**
AA	Rootstock Pneumatic Arm Horizontal Cylinder
BB	Rootstock Pneumatic Arm Vertical Cylinder
CC	Rootstock Pneumatic Arm Rotation Cylinder
DD	Rootstock Pneumatic Arm Gripper
EE	Rootstock Blade Horizontal Xylinder
FF	Rootstock Support Rotation Cylinder
GG	Clip Arm Rotation Cylinder
HH	Clip Arm Horizontal Cylinder
II	Clip Arm Gripper
LL	Scion Pneumatic Arm Rotation Cylinder
NN	Scion Pneumatic Arm Horizontal Cylinder
OO	Scion Pneumatic Arm Gripper
PP	Scion Blade Horizontal Cylinder
QQ	Scion Support Rotation Cylinder
RR	Scion Pneumatic Arm Vertical Cylinder
SS	Blower

Output Table	
Name	**Function**
AA_Retraction	Rootstock Horizontal Cylinder Retraction
AA_Extension	Rootstock Horizontal Cylinder Extension
BB_Retraction	Rootstock Vertical Cylinder Retraction
BB_Extension	Rootstock Vertical Cylinder Extension
CC_Retraction	Rootstock cylinder outwards rotation
CC_Extension	Rootstock cylinder inwards rotation
DD_Close	Rootstock Gripper Close
DD_Open	Rootstock Gripper Open
EE_Retraction	Rootstock Blade Return
EE_Extension	Rootstock Blade Extension
FF_Retraction	Rootstock Cutting Support rotation towards blade
FF_Extension	Rootstock Cutting support rotation away from blade
GG_Retraction	Clip Arm rotation inwards
GG_Extension	Clip Arm rotation outwards
HH_Retraction	Clip Arm horizontal Cylinder Retraction
HH_Extension	Clip Arm horizontal Cylinder Extension
II_Close	Clip Arm Gripper Close
II_Open	Clip Arm Gripper Open
LL_Retraction	Scion Cylinder External Rotation
LL_Extension	Scion Cylinder Internal Rotation

NN_Retraction	Scion Horizontal Cylinder Retraction
NN_Extension	Scion Horizontal Cylinder Extension
OO_Close	Scion Gripper Close
OO_Open	Scion Gripper Open
PP_Retraction	Scion Blade retraction
PP_Extension	Scion Blade extension
QQ_Retraction	Scion Blade Support rotation towards Blade
QQ_Extension	Scion Blade Support rotation away from Blade
RR_Retraction	Scion Vertical Cylinder Retraction
RR_Extension	Scion Vertical Cylinder Extension
SS_ON	Blower On
SS_OFF	Blower OFF
OUT_1	Scion Cart can move
OUT_2	Rootstock Cart can move
OUT_3	Request Scion
OUT_4	Request Rootstock
OUT_5	Request Grafted Plant Cart
OUT_6	Grafted Plant Cart can move
OUT_7	
OUT_8	

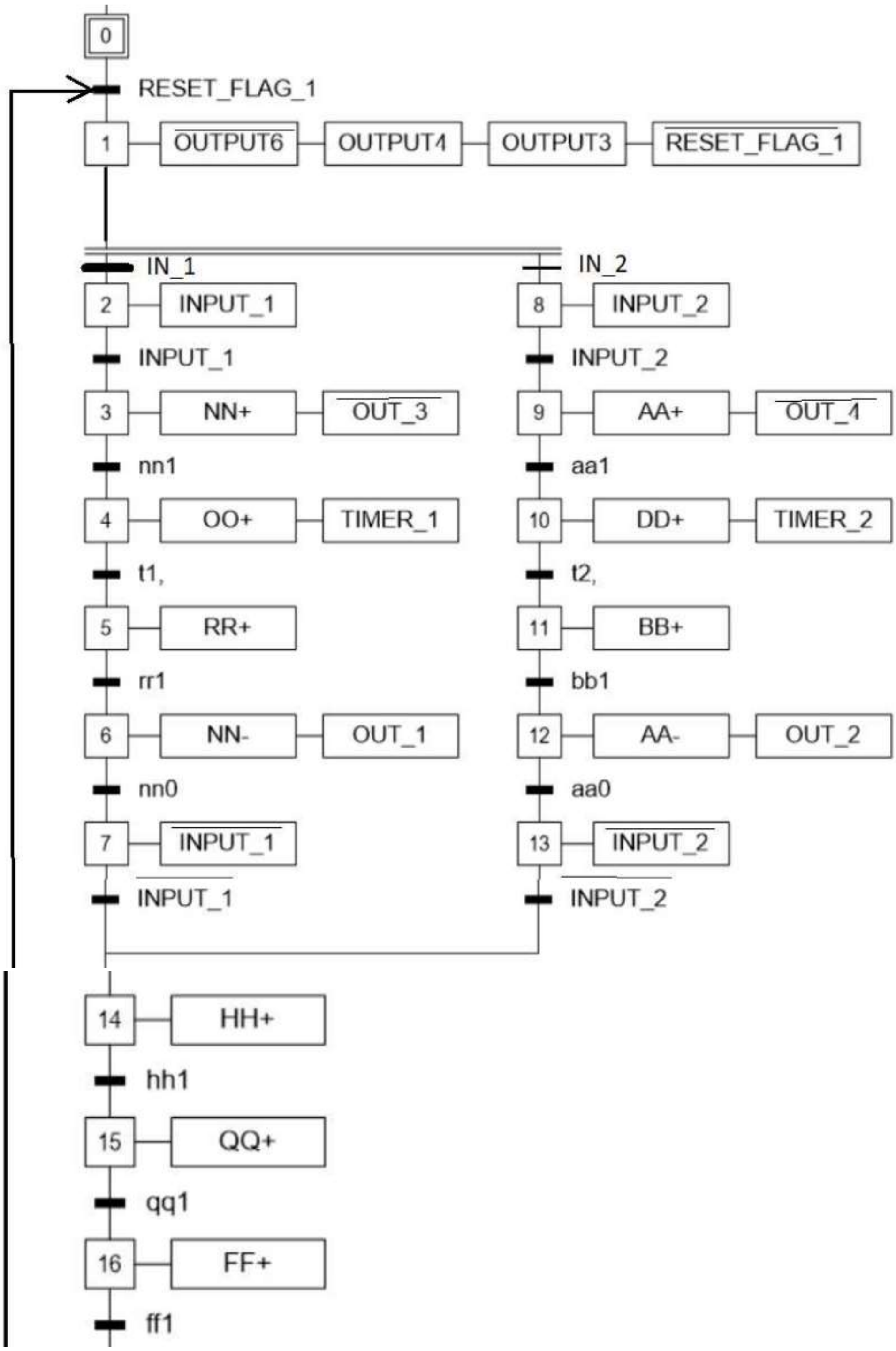
Input Table	
Name	**Function**
AA0	Retraction complete of Cylinder A
AA1	Extension complete of Cylinder A
BB0	Retraction complete of Cylinder B
BB1	Extension complete of Cylinder B
CC0	Retraction complete of Cylinder C
CC1	Extension complete of Cylinder C
EE0	Retraction complete of Cylinder E
EE1	Extension complete of Cylinder E
FF0	Retraction complete of Cylinder F
FF1	Extension complete of Cylinder F
GG0	Retraction complete of Cylinder G
GG1	Extension complete of Cylinder G
HH0	Retraction complete of Cylinder H
HH1	Extension complete of Cylinder H
LL0	Retraction complete of Cylinder L
LL1	Extension complete of Cylinder L

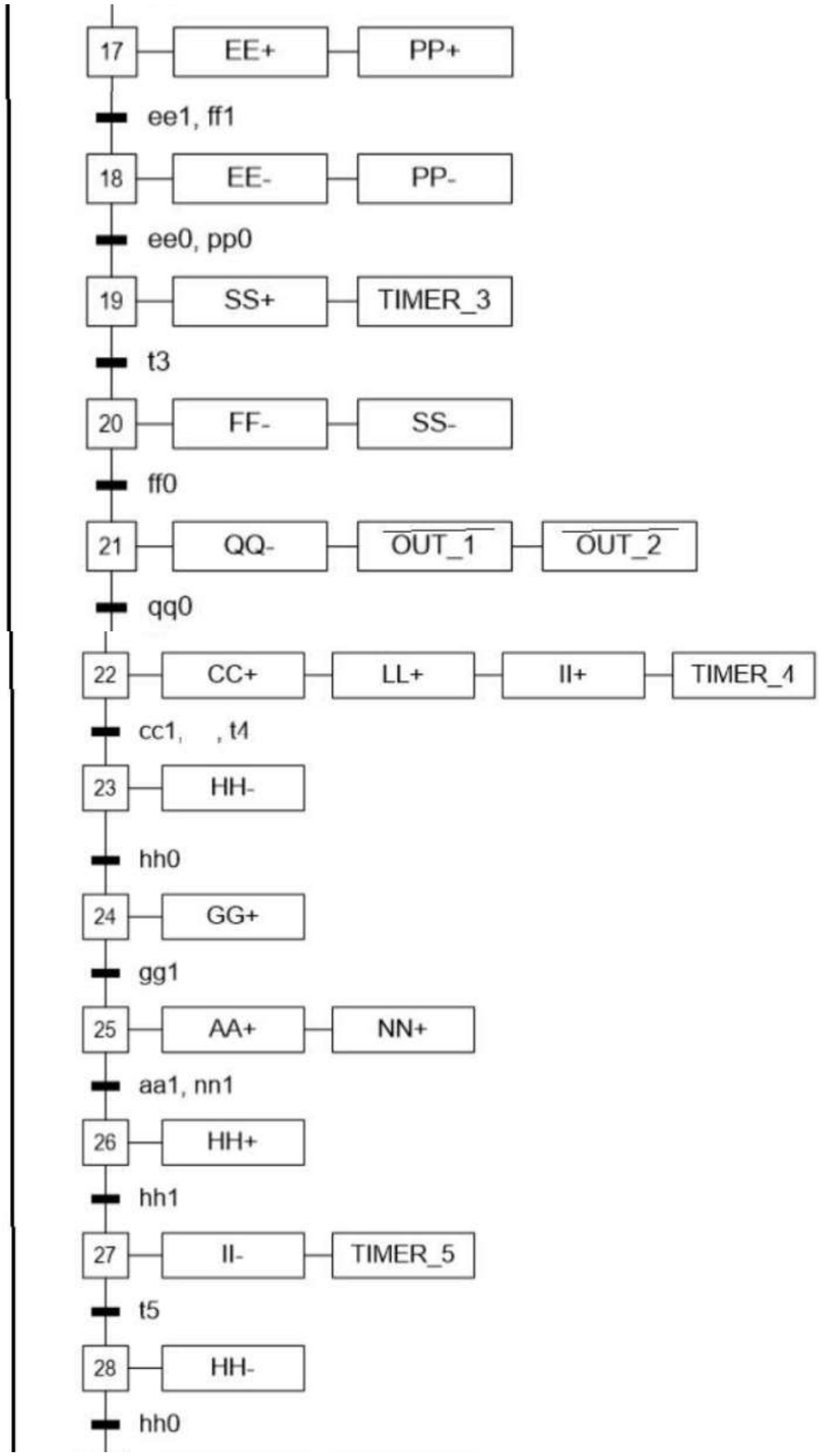
NN0	Retraction complete of Cylinder N
NN1	Extension complete of Cylinder N
PP0	Retraction complete of Cylinder P
PP1	Extension complete of Cylinder P
QQ0	Retraction complete of Cylinder Q
QQ1	Extension complete of Cylinder Q
RR0	Retraction complete of Cylinder R
RR1	Extension complete of Cylinder R
IN_1	Scion has arrived
IN_2	Rootstock has arrived
IN_3	Cart for Grafted Plant has arrived
IN_4	
M	Cycle Complete

TIMER TABLE	
Name	**Function**
Timer_1	Gripper OO Close Timer
Timer_2	Gripper DD Close Timer
Timer_3	Blower Timer
Timer_4	Gripper II Close Timer
Timer_5	Gripper II Open Timer
Timer_6	Gripper OO Open Timer
Timer_7	Gripper DD Open Timer
Delay_1_Complete	Delay Completion Flag of Timer 1
Delay_2_Complete	Delay Completion Flag of Timer 2
Delay_3_Complete	Delay Completion Flag of Timer 3
Delay_4_Complete	Delay Completion Flag of Timer 4
Delay_5_Complete	Delay Completion Flag of Timer 5
Delay_6_Complete	Delay Completion Flag of Timer 6
Delay_7_Complete	Delay Completion Flag of Timer 7

9.3.2 The Main Cycle

The main cycle GRAFCET is given below:




17
EE+
PP+
ee1, ff1
18
EE-
PP-
ee0, pp0
19
SS+
TIMER_3
t3
20
FF-
SS-
ff0
21
QQ-
OUT_1
OUT_2
qq0
22
CC+
LL+
II+
TIMER_4
cc1, , t4
23
HH-
hh0
24
GG+
gg1
25
AA+
NN+
aa1, nn1
26
HH+
hh1
27
II-
TIMER_5
t5
28
HH-
hh0

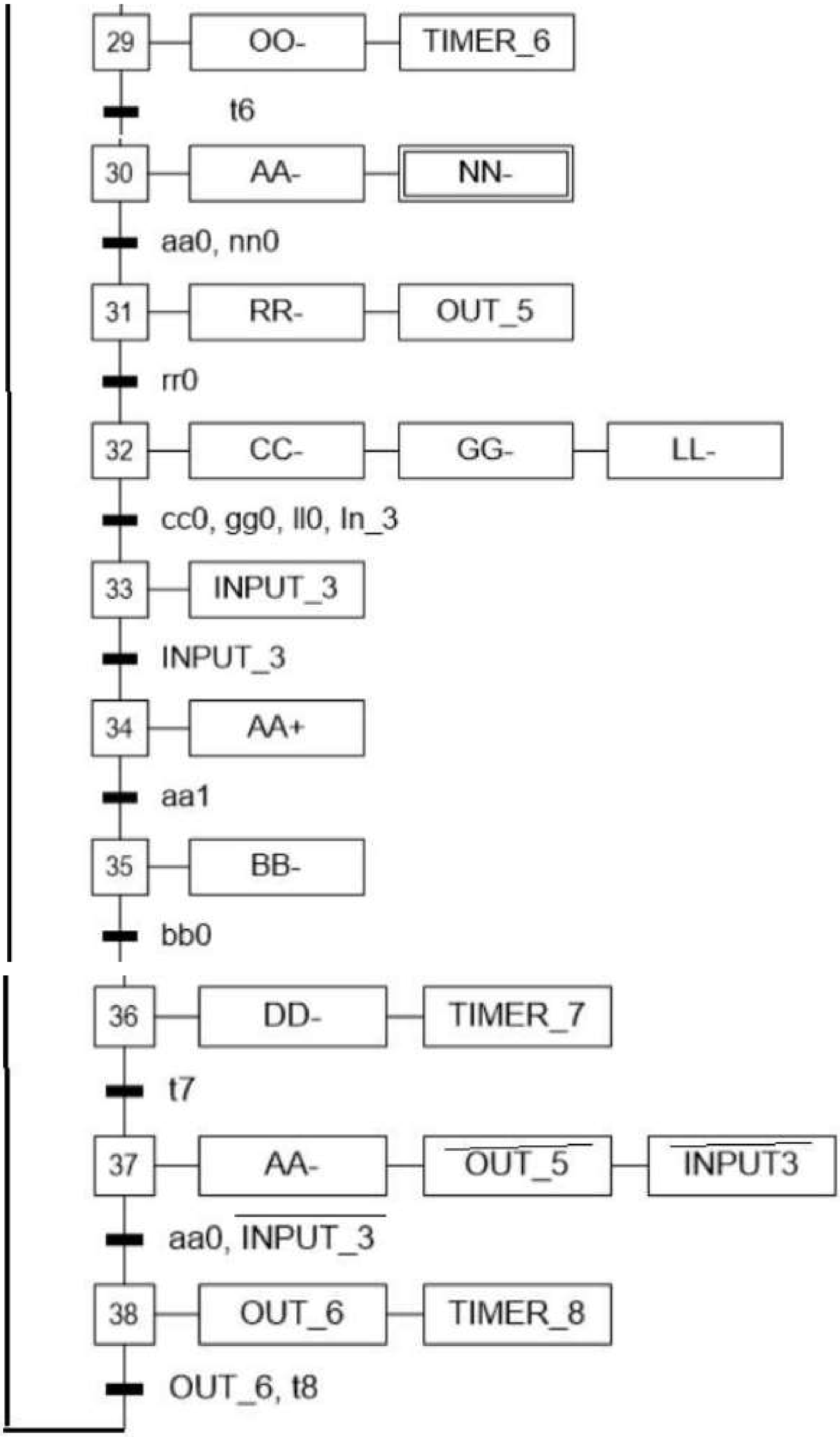


Figure 61: Main Cycle GRAFCET

9.3.3 Reset Cycle GRAFCET

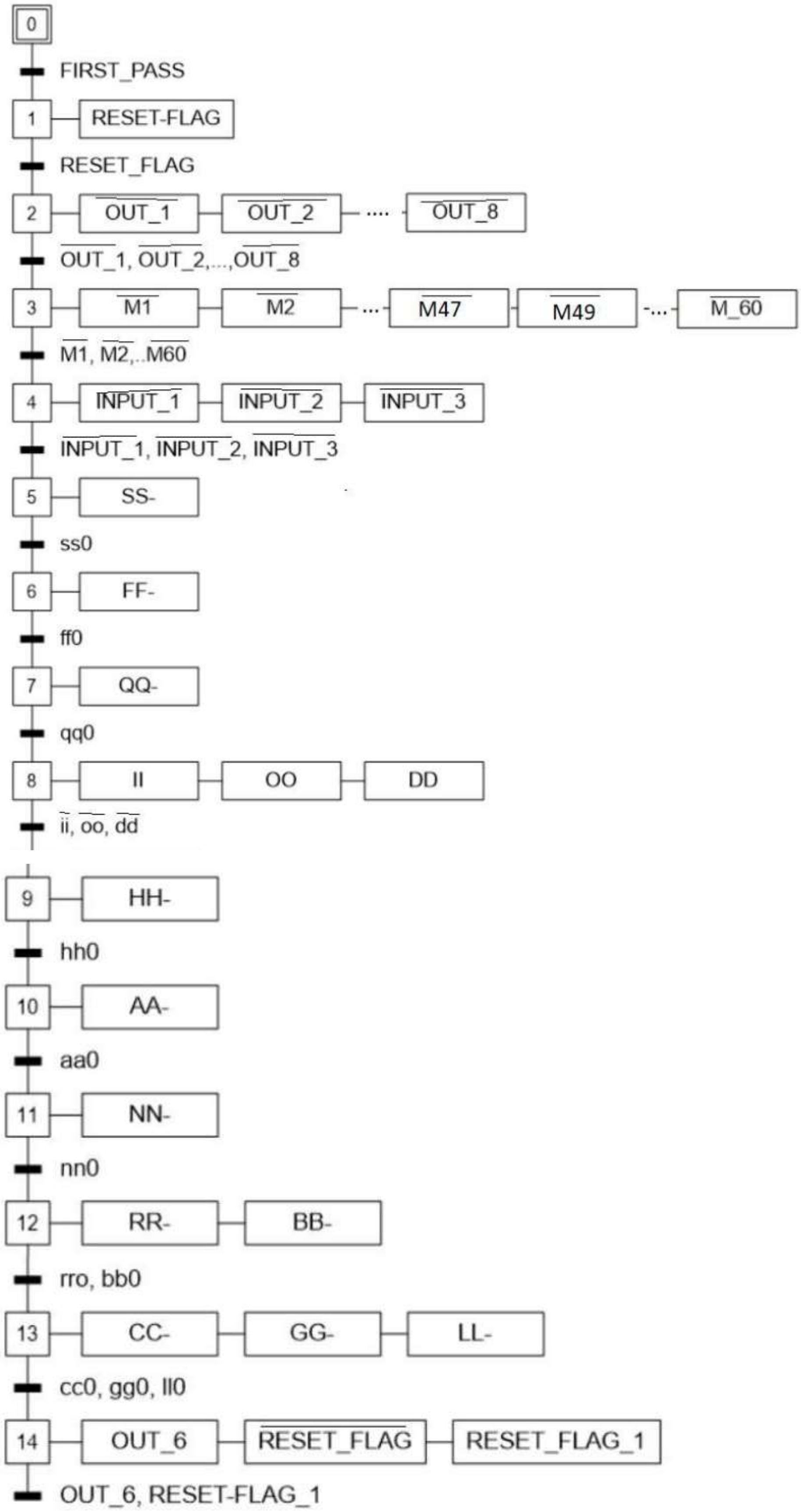


Figure 62: Reset Cycle GRAFCET

9.3.4 Memories Associated with Main Cycle

Step Number	**Associated Memory**
1	M_1
2	M_3
3	M_4
4	M_6
5	M_7
6	M_8
7	M_10
8	M_11
9	M_12
10	M_14
11	M_15
12	M_16
13	M_18
14	M_19
15	M_20
16	M_21
17	M_22
18	M_23
19	M_24
20	M_25
21	M_26
22	M_28

23	M_29
24	M_30
25	M_31
26	M_32
27	M_33
28	M_34
29	M_35
30	M_36
31	M_37
32	M_38
33	M_40
34	M_41
35	M_42
36	M_43
37	M_44
38	M_45

9.3.5 Memories Associated with Reset Cycle

Step Number	Associated Memory
1	M_46
2	M_47
3	M_48
4	M_49
5	M_51
6	M_52
7	M_53
8	M_54
9	M_55
10	M_56
11	M_57
12	M_58
13	M_59
14	M_60

9.3.6 Main Cycle GRAFCET Equations

Memory	**Equation**
M_1	SET M_1=M_45.Out_6.T8+RESET_FLAG_1 RESET M_1=M_3.M_11
M_3	SET M_3=M_1.IN_1 RESET M_3=M_6
M_4	SET M_4=M_3.INPUT_1 RESET M_4=M_6
M_6	SET M_6=nn1.M_4 RESET M_6=M_7
M_7	SET M_7=M_6.T_1 RESET M_7=M_8
M_8	SET M_8=M_7.rr1 RESET M_8=M_10
M_10	SET M_10=M_8.nn0 RESET M_10=M_19
M_11	SET M_11=M_1.IN_2 RESET M_11=M_12
M_12	SET M_12=M_11.INPUT_2 RESET M_12=M14
M_14	SET M_14=M12.aa1 RESET M_14=M_15
M_15	SET M_15=M_14.T_2 RESET M_15=M16
M_16	SET M_16=M_15.bb1

	RESET M_16=M_18
M_18	SET M_18=M_16.aa0 RESET M_18=M_19
M_19	SET M_19=M_10.M_18.INPUT_1.INPUT_2 RESET M19=M_20
M_20	SET M_20=M_19.hh1 RESET M_20=M_21
M_21	SET M_21=M_20.qq1 RESET M_21=M_22
M_22	SET M_22=M_21.ff1 RESET M_22=M_23
M_23	SET M_23=M_22.ee1.pp1 RESET M_23=M_24
M_24	SET M_24=M_23.ee0.pp0 RESET M_24=M_25
M_25	SET M_25=M_24.T_3 RESET M_25=M_26
M_26	SET M_26=M_25.ff0 RESET M_26=M_28
M_28	SET M_28=M_26.qq0 RESET M_28=M_29
M_29	SET M_29=M_28.cc1.ll1.T_4 RESET M_29=M_30
M_30	SET M_30=M_29.hh0

	RESET M_30=M_31
M_31	SET M_31=M_30.gg1 RESET M_31=M_32
M_32	SET M_32=M_31.aa1.nn1 RESET M_32=M_33
M_33	SET M_33=M_32.hh1 RESET M_33=M_34
M_34	SET M_34=M_33.T_5 RESET M_34=M_35
M_35	SET M_35=M_34.hh0 RESET M_35=M_36
M_36	SET M_36=M_35.T_6 RESET M_36=M_37
M_37	SET M_37=M_36.aa0.nn0 RESET M_37=M_38
M_38	SET M_38=M_37.rr0 RESET M_38=M_40
M_40	SET M_40=M_38.cc0.gg0.ll0.IN_3 RESET M_40=M_41
M_41	SET M_41=M_40.INPUT_3 RESET M_41=M_42
M_42	SET M_42=M_41.aa1 RESET M_42=M_43
M_43	SET M_43=M_42.bb0 RESET M_43=M_44

M_44	SET M_44=M_43.T_7 RESET M_44=M_45
M_45	SET M_45=M_44.aa0.INPUT_3 RESET M_45=M_1

9.3.7 Reset Cycle GRAFCET Equations

Memory	Equations
M_46	SET M_46=First_Pass RESET M_46=M_47
M_47	SET M_47=M_46.Reset_Flag RESET M_47=M_48
M_48	SET M_48=M_47.OUT_1.OUT_2.OUT_3.OUT_4 … .OUT_8 RESET M_48=M_49
M_49	SET M_49=M_48.M_1.M_2 … .M_47.M_49 … .M_60 RESET M_49=M_50
M_51	SET M_51=M_49.INPUT_1.INPUT_2.INPUT_3 RESET M_51=M_52
M_52	SET M_52=M_51.SS_ON RESET M_52=M_53
M_53	SET M_53=M_52.ff0 RESET M_53=M_54
M_54	SET M_54=M_53.qq0 RESET M.54=M_55
M_55	SET M_55=M_54.II_Open.OO_Open.DD_Open RESET M_55=M_56
M_56	SET M_56=M_55.hh0 RESET M_56=M_57
M_57	SET M_57=M_56.aa0 RESET M_57=M_58
M_58	SET M_58=M_57.nn0

	RESET M_58=M_59
M_59	SET M_59=M_58.rr0.bb0 RESET M_59=M_60
M_60	SET M_60=M_59.cc0.gg0.ll0 RESET M_60=M_1

9.3.8 Main Cycle GRAFCET Discussion

The Main Cycle GRAFCET is initiated by two possible conditions:

- RESET_FLAG_1 : This goes high whenever the DIMEAS Machine is turned on. The First Scan turns this memory high & it remains high as long as the machine is working.
- By the Out_6 & timer 8's done bit.

It is not necessary for both these conditions to be present at the same time & only one of these conditions is enough to start the cycle. This is because when the DIMEAS Machine is turned on, firstly the reset cycle will run and this will turn the RESET_FLAG_1 high. This RESET_FLAG_1 will start the main cycle. Hence in the first run of the main cycle Out_6 and Timer 8's done bit aren't present and they become available only when a main cycle completes. As a result the first run is triggered by RESET_FLAG_1 and the subsequent runs are triggered by Out_6 and Timer 8's done bit. RESET_FLAG_1 will be turned low in this step as well so that it doesn't trigger another cycle to start before this cycle is complete.

Now that the Rootstock and Scion have been requested by the DIMEAS Machine in the first step we have to collect them from the DISAFA Machine. To save time these two have to be handled simultaneously. As a result in the GRAFCET parallel rungs have been created. One rung handles the operation of receiving the Scion and other the operation of receiving the Rootstock. Since the In_1 and In_2 from the DISAFA Machine are only high momentarily they are stored in separate memories so that they can be used to trigger subsequent actions.

At step 14 the two parallel rungs converge again and the step 14 action is only triggered if output from both these rungs are received, until then the machine waits.

After that the following operations happen:

- Cutting the Rootstock and Scion
- Turning On the blower
- Grafting together the Rootstock and Scion
- Handing over the grafted plant to DISAFA machine

Note that whenever the gripper needs to be opened or closed timers are associated with this action. This is because it takes some time for the gripper to fully open or close and hence a delay needs to be produced in out code to account for it. This delay is produced by the timers & is 0.5 seconds long.

Another purpose that these timers serve is to provide the output associated with their step. Since grippers provide no output as no sensors are associated with them the timer serves as the sign that the operation has been successfully completed.

The last step of the Main Cycle has two actions, Out_6 & Timer_8.

Out_6 to tell the DISAFA Machine that the Grafted plant has been successfully placed inside it's holder and it is now safe to move it away.

Timer_8 serves the purpose of giving some time to DISAFA Machine to move the plant away before the next cycle is triggered.

9.3.8 Reset Cycle GRAFCET Discussion

The Reset Cycle gets triggered only when the machine is turned on from a state of being Off to On. Otherwise the DIMEAS Machine remains in the Main Cycle & the Reset Cycle is never called.

So the Reset Cycle runs only once when the Machine is On and in working condition. The Reset Cycle gets triggered by a bit known as First Scan. It comes in built inside the PLC and it gets high monetarily whenever the machine is turned On. Otherwise it is low.

Due it being high only momentarily the First Scan is stored inside the Reset-Flag memory so that we can trigger the next steps of the GRAFCET.

The next steps involve not only resetting all the actuators to their initial position but also to reset all the memories & outputs that are being used in both the Main Cycle and Reset Cycle.

Resetting the memories associated with the Main Cycle is simple. However resetting the memories associated with the Reset Cycle is more trickier since it is already running. The resetting the memory step is step 3. The memory associated with it is M_48. While the memory associated with previous step is M_47 & with the next step is M_49. The following sequence of events occur:

- When M_47 goes high and performs its associated actions successfully M_48 goes high
- M_48 resets all memories except itself
- Resetting M_47 won’t turn M_48 off because once it gets On only the memory M_49 can turn it off.
- Once these memories are all off & M_48 high M_49 goes high deactivating M_48 first so that M_48 can’t reset M_49 and then M_49 performs it’s action
- This way the memory reset action is handled responsibly.

After this the next steps reset all t he actuators to their initial positions so a new Main Cycle can be started.

The last step is to ask the DISAFA Machine to take back the holder it might have sent for the Grafted plant and to start the main cycle turn the flag Reset_Flag_1 high which triggers the main cycle to start.

9.3.9 Timers & Grippers

Timers in the GRAFCET & it's PLC Implementation serve a dual purpose. It can be seen in the GRAFCETs that whenever a timer associated with each step a gripper action occurs. The two purposes the timer serves are:

- Delay for Gripper Action
- Trigger the Next Step

The pneumatic system that is used to open and close the grippers has no associated sensors. As a result the PLC gets no feedback from it, meaning it doesn't know if the gripper has finished opening or closing. So to give time for the gripper to close a 0.5s delay is created in the gripper action step via a timer. This way the gripper will have ample time to open or close/

Another drawback of having no feedback from the pneumatic system associated with the Gripper is that no signal exists to start execution of the next step. This feedback is instead provided 'virtually' through the timer. When the timer has completed the delay it sends an output that triggers the execution of the next step.

10. PLC Implementation

The software used to write the code for our PLC is the RSLogix 500. This software was made by the Rockwell Corporation for the PLC's they manufacture and sell.

10.1 PLC Elements/Functions Utilised

Before translating the GRAFCET to Ladder Logic we will describe what element of Ladder Logic Programming will be used to represent each element described in the GRAFCET.

Ladder Logic was created as an alternative to the text-based programming. So Ladder Logic is a graphical programming language. So in Ladder Logic the programming is done using graphical symbols. Additionally Ladder Logic is written vertically, top to down. PLC starts executing the Ladder program from the top and starts making its way down.

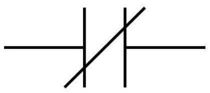
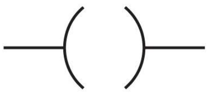
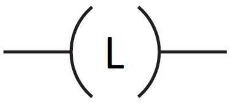
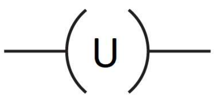
The Ladder Logic program consists of 'rungs'. These rungs are represented by two vertical lines running on each side of the code. These two lines are connected by horizontal lines which contain each line of code represented by symbols within these horizontal lines. with each rung representing a line of code. The rung contains two aspect of code:

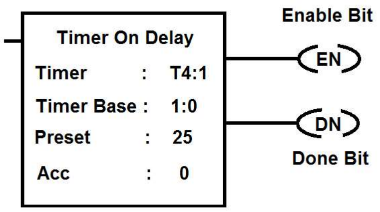
1. The Conditions
2. The result/output

The conditions are represented on the left hand side of the rung. Once these conditions are met the result/ouptut on the right hand side of the rung becomes true. This is displayed in the following figure:

Following are the elements in PLC and what they are used to represent:

Sybmbol	Name	Function
	Examine if Closed	This instruction is conditional type. So what it is being used to represent becomes true this condition becomes true as well. It can represent Memories, Outputs and Inputs

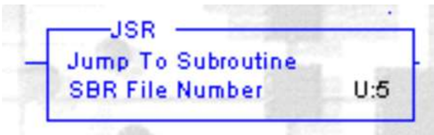
	Examine if Open	This is similar to Examine if Open element except that it’s operation is the opposite. This too is a conditional instruction When what it is being used to represent becomes false then this condition becomes true. It can represent Memories, Outputs and Inputs
	Output Energize	This is the Output When the switches along it’s rung becomes On the Output becomes energized The Output stays energized until the switch on it’s rung is On
	Output Latch	Output Latch is similar to Output Energize When the switches along it’s rung becomes On the this Output Latch becomes energized However Output Latch remains energized even if the switch on it’s rung becomes Off Hence the Output becomes ‘Latched’
	Output UnLatch	Output unLatch de-energises Output Latched switch When the switches along it’s rung becomes On the this Output unLatch switch de-energizes the Output Latched Switch Hence the Output becomes ‘unLatched’

<table>
<tr><td>
</td><td>TON Timer</td><td>TON Timer produces a Timer On Delay.

It becomes activated when the input on it’s rung becomes activated.

Then this timer counts from Timer Base to Preset value.

After Preset value is reached the Done bit goes true

However if the input goes false during the count from 0 to Preset Value the Timer resets and the next time count wil start from 0 again.</td></tr>
<tr><td>
</td><td>Jump To Subroutine</td><td>The jump to subroutine(JSR) instruction, when executed, jumps to the beginning of the designated subroutine file and resumes execution at that point.

It is placed on the right side of the rung

When the left hand condition of the rung becomes true the JSR instruction is executed

JSR instruction jumps to a designated subroutine file stored in the program files folder</td></tr>
<tr><td></td><td>First Pass</td><td>This is a system read-only bit active only in the first scan after power up

It becomes high temporarily and then it goes back to low</td></tr>
<tr><td></td><td>Memory</td><td>This are represented by binary bits in the PLC address register and graphically in ladder logic can be represented by Output Energize or EIC/EIO</td></tr>
</table>

10.2 PLC Initialisation

Once the GRAFCET has been completed the next step is to translate it into ladder logic for the PLC implementation.

However before writing down the Ladder Logic the resources(input, outputs, memories, timers) it utilises need to be described. It needs to be initialised in the code that which output to the pneumatic system & DISAFA Machine is connected with which port of the PLC and which which input from DISAFA Machine & pneumatic system is connected with which port of the PLC. This way we will be able to properly control the DIMEAS Machine & there would be no complications.

Only after doing that can we start writing the Ladder Logic. The addresses, descriptions and names that will be defined here will be used both in our Main Cycle and Reset Cycle.

10.2.1 Initialization in RSLogix 500

The Software that is used to program the PLC we are using our PLC is RSLogix 500. It is designed by Rockwell Automation Company.

Before we start writing the Ladder Logic code we need to initialize and name the outputs, inputs, timers etc in the address library in the software. When we move the Ladder Code to the PLC it will use the same address library.

First when we open RSLogix 500 software we need to inform it which PLC Type we are using. This is because RSLogix 500 can be used by multiple PLC Models so it needs to know for which one we are designing our code. We chose our PLC which is Micrologix 1200 Series C (1 or 2 Comm Ports).

Now a new window will open up containing two sub-windows. The sub-window on the right hand side is where the Ladder Logic Code is written. While the sub-window on the left hand side is where the information related to PLC itself exists like the input, outputs, the subroutines, timers, memories etc. This is shown in image below:

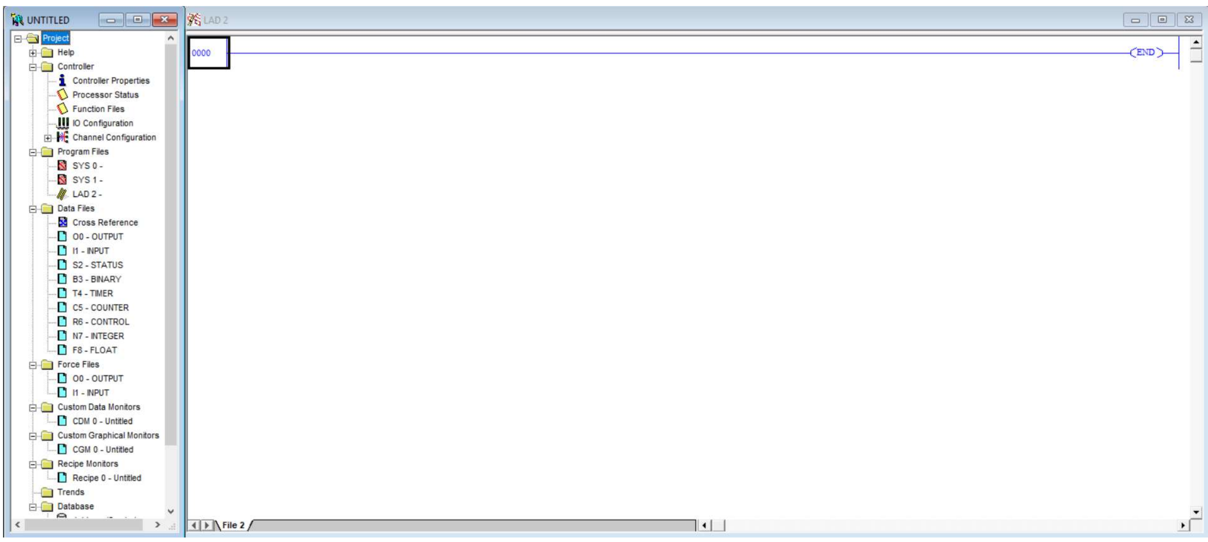


Figure 63: RSLogix Window

To initialize the outputs click the Outputs option on the left hand side sub-window. This will open up a new window containing the register of the Outputs. Here we can select each Output of the PLC and give it the appropriate name & description considering what it is connected to. The example is in the picture below:

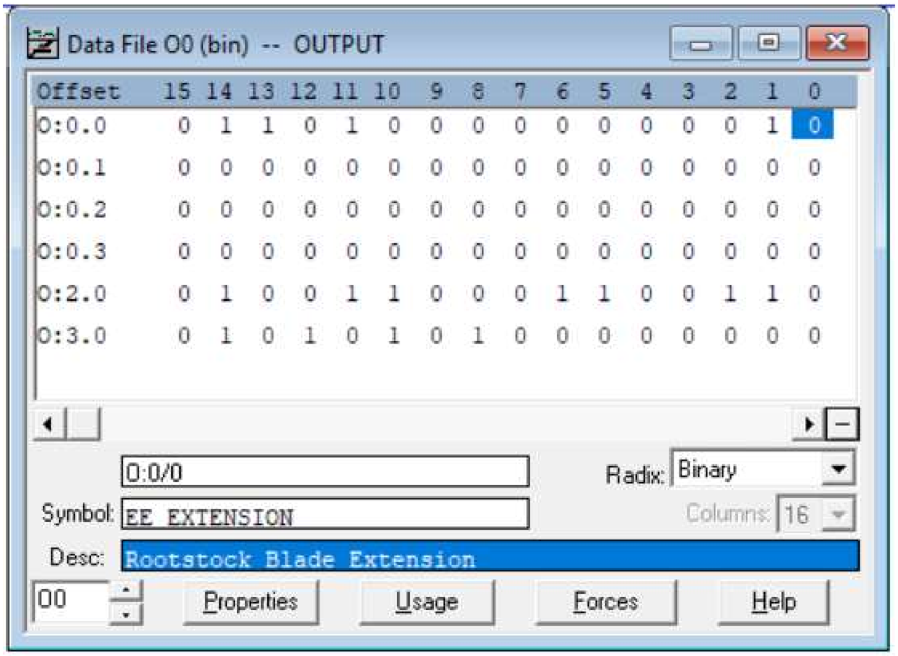


Figure 64: Initialisation Example

Similarly we can do the same for Inputs:

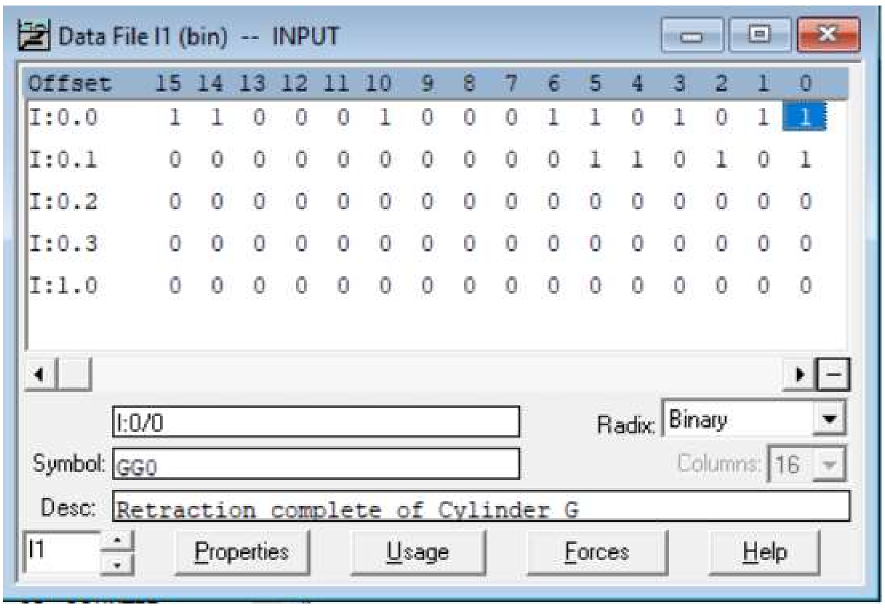


Figure 65: Input Initialisation

The Memories are saved in the Binary register. If more Memories are needed than given by default we can add more Binary values. An example of this is shown in the figure below:

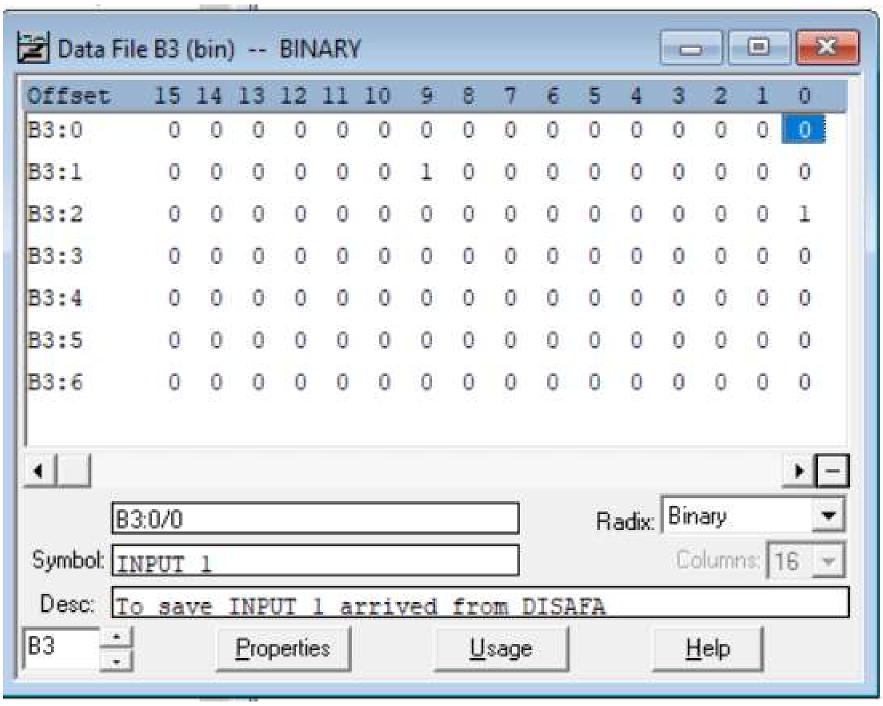


Figure 66: Memory Initialisation

The Timers are initialized using the Timer Register. Not only do we name each timer but we also name each of the DN bits which become high when the timer reaches the required delay value. This is shown in the image below:

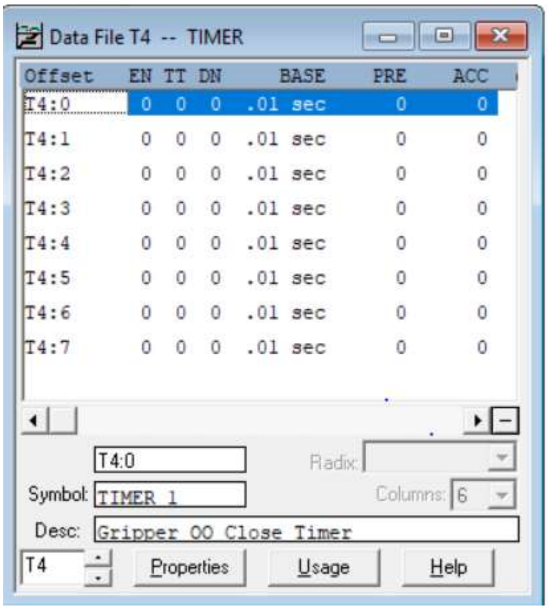


Figure 67: Timer Initialisation

Since we will require two sets of Ladder codes to be run in out program (one for Reset Cycle and one for Main Cycle) we need to add one more Ladder Logic routine in our Program. This is done by right clicking the Program Files option in the left hand side sub-window and clicking new. This will open a new window which will ask us to name the subroutine. The images below show this:

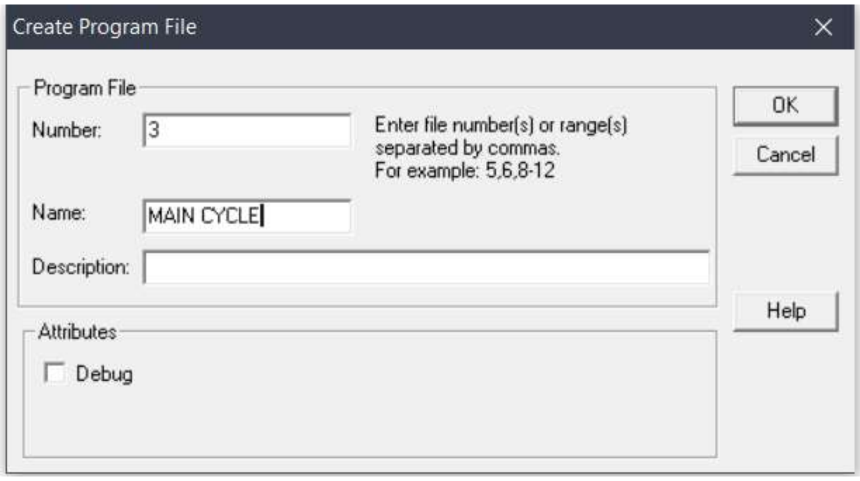


Figure 68: To get a new Ladder Logic Routine

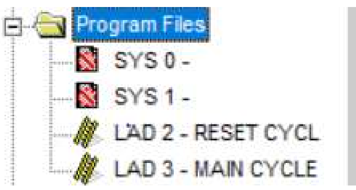


Figure 69: Program with 2 Ladder Logic Routines

10.2.2 PLC Inputs

The following table describes which Port of the PLC is connected with which Input from the DISAFA Machine. This is entered into the Input Address Register in our PLC Program:

INPUT TABLE		
AA0	I:0/1	Retraction complete of Cylinder A
AA1	I:0/4	Extension complete of Cylinder A
BB0	I:0/3	Retraction complete of Cylinder B
BB1	I:0/7	Extension complete of Cylinder B
CC0	I:0/5	Retraction complete of Cylinder C
CC1	I:0/8	Extension complete of Cylinder C
EE0	I:0/6	Retraction complete of Cylinder E
EE1	I:0/9	Extension complete of Cylinder E
FF0	I:0/10	Retraction complete of Cylinder F
FF1	I:0/12	Extension complete of Cylinder F
GG0	I:0/0	Retraction complete of Cylinder G
GG1	I:0/2	Extension complete of Cylinder G
HH0	I:0/15	Retraction complete of Cylinder H
HH1	I:0/13	Extension complete of Cylinder H
LL0	I:0/18	Retraction complete of Cylinder L
LL1	I:0/11	Extension complete of Cylinder L
NN0	I:0/14	Retraction complete of Cylinder N
NN1	I:0/22	Extension complete of Cylinder N
PP0	I:0/21	Retraction complete of Cylinder P
PP1	I:0/19	Extension complete of Cylinder P
QQ0	I:0/23	Retraction complete of Cylinder Q

QQ1	I:0/20	Extension complete of Cylinder Q
RR0	I:0/16	Retraction complete of Cylinder R
RR1	I:0/17	Extension complete of Cylinder R
IN_1	I:1/4	Nesto has arrived
IN_2	I:1/2	Porrtanesto has arrived
IN_3	I:1/0	Cart for Grafted Plant has arrived
IN_4	I:1/10	
M	I:1/6	Cycle Complete

10.2.3 PLC Outputs

The following table describes which Port of the PLC is connected with which Output from the DISAFA Machine. This is entered into the Output Address Register in our PLC Program:

Name	**Address**	**Function**
AA_Retraction	O:0/13	Rootstock Horizontal Cylinder Retraction
AA_Extension	O:0/10	Rootstock Horizontal Cylinder Extension
BB_Retraction	O:3/14	Rootstock Vertical Cylinder Retraction
BB_Extension	O:3/15	Rootstock Vertical Cylinder Extension
CC_Retraction	O:0/14	Rootstock cylinder outwards rotation
CC_Extension	O:0/15	Rootstock cylinder inwards rotation
DD_Close	O:3/13	Rootstock Gripper Close
DD_Open	O:3/12	Rootstock Gripper Open
EE_Retraction	O:0/1	Rootstock Blade Return
EE_Extension	O:0/0	Rootstock Blade Extension
FF_Retraction	O:0/11	Rootstock Cutting Support rotation towards blade
FF_Extension	O:0/12	Rootstock Cutting support rotation away from blade

GG_Retraction	O:2/2	Clip Arm rotation inwards
GG_Extension	O:2/0	Clip Arm rotation outwards
HH_Retraction	O:3/10	Clip Arm horizontal Cylinder Retraction
HH_Extension	O:3/11	Clip Arm horizontal Cylinder Extension
II_Close	O:3/8	Clip Arm Gripper Close
II_Open	O:3/9	Clip Arm Gripper Open
LL_Retraction	O:2/1	Scion Cylinder External Rotation
LL_Extension	O:2/7	Scion Cylinder Internal Rotation
NN_Retraction	O:2/10	Scion Horizontal Cylinder Retraction
NN_Extension	O:2/8	Scion Horizontal Cylinder Extension
OO_Close	O:2/14	Scion Gripper Close
OO_Open	O:2/12	Scion Gripper Open
PP_Retraction	O:2/11	Scion Blade retraction
PP_Extension	O:2/9	Scion Blade extension
QQ_Retraction	O:2/6	Scion Blade Support rotation towards Blade
QQ_Extension	O:2/4	Scion Blade Support rotation away from Blade
RR_Retraction	O:2/5	Scion Vertical Cylinder Retraction
RR_Extension	O:2/3	Scion Vertical Cylinder Extension
SS_ON	O:3/6	Blower On
SS_OFF	O:3/7	Blower OFF
OUT_1	O:2/15	Scion Cart can move
OUT_2	O:2/13	Rootstock Cart can move
OUT_3	O:3/5	Request Scion

OUT_4	O:3/3	Request Rootstock
OUT_5	O:3/1	Request Grafted Plant Cart
OUT_6	O:3/0	Grafted Plant Cart can move
OUT_7	O:3/2	
OUT_8	O:3/4	

10.2.4 PLC Timers

The following table describes the Timers used in our PLC. This is entered into the Timers Address Register in our PLC Program:

TIMER TABLE			
Name	**Address**	**Preset**	**Base**
Timer_1	T:4/0	50	0.01
Timer_2	T:4/1	50	0.01
Timer_3	T:4/2	50	0.01
Timer_4	T:4/3	50	0.01
Timer_5	T:4/4	50	0.01
Timer_6	T:4/5	50	0.01
Timer_7	T:4/6	50	0.01
Timer_8	T:4/7	2	1
Delay_1_Complete	T4:0/DN		
Delay_2_Complete	T4:1/DN		
Delay_3_Complete	T4:2/DN		
Delay_4_Complete	T4:3/DN		
Delay_5_Complete	T4:4/DN		
Delay_6_Complete	T4:5/DN		

Delay_7_Complete	T4:6/DN		
Delay_8_Complete	T4:7/DN		

10.2.5 PLC Memories

The following table describes the Memories being used in our PLC for our Program. This is entered into the Binary Address Register in our PLC Program:

MEMORY TABLE		
Name	**Address**	**Function**
First_Pass	S:1/15	Is high when PLC started after stopping
RESET_FLAG	B3:6/12	To save First_Pass when the PLC is started after stopping
RESET_FLAG_1	B3:6/13	To trigger the Main Cycle to Run for the first time
INPUT_1	B3:0/0	To save INPUT 1 arrived from DISAFA
INPUT_2	B3:0/1	To save INPUT 2 arrived from DISAFA
INPUT_3	B3:0/2	To save INPUT 3 arrived from DISAFA
M_1	B3:3/0	Memory to activate Output 3 & 4. Output 6 is unlatched
M_2	B3:3/1	Inactive Memory
M_3	B3:3/2	Memory to activate INPUT_1
M_4	B3:3/3	Memory to activate NN_Extension & deactivate Output 3
M_5	B3:3/4	Inactive Memory
M_6	B3:3/5	Memory to activate OO_Extension & start Timer_1
M_7	B3:3/6	Memory to activate RR_Extension
M_8	B3:3/7	Memory to activate NN_Retraction & activate Output_1
M_9	B3:3/8	Inactive Memory
M_10	B3:3/9	Memory to deactivate Input_1

M_11	B3:3/10	Memory to activate INPUT_2
M_12	B3:3/11	Memory to activate AA_Extension & deactivate Output_4
M_13	B3:3/12	Inactive Memory
M_14	B3:3/13	Memory to activate DD_Extension & Timer_2
M_15	B3:3/14	Memory to activate BB_Extension
M_16	B3:3/15	Memory to activate AA_Retraction & activate Ouput_2
M_17	B3:4/0	Inactive Memory
M_18	B3:4/1	Memory to deactivate Input_2
M_19	B3:4/2	Memory to activate HH_Extension
M_20	B3:4/3	Memory to activate QQ_Extension
M_21	B3:4/4	Memory to activate FF_Extension
M_22	B3:4/5	Memory to activate EE_Extension & PP_Extension
M_23	B3:4/6	Memory to activate EE_Retraction & PP_Retraction
M_24	B3:4/7	Memory to activate SS_ON & Timer_3
M_25	B3:4/8	Memory to activate FF_Retraction & SS_Off
M_26	B3:4/9	Memory to activate QQ_Retraction & deactivate Output_1 & Output_2
M_27	B3:4/10	Inactive Memory
M_28	B3:4/11	Memory to activate CC_Extension, LL_Extension, II_Extension & Timer_4
M_29	B3:4/12	Memory to activate HH_Retraction
M_30	B3:4/13	Memory to activate GG_Extension
M_31	B3:4/14	Memory to activate AA_Extension & NN_Extension
M_32	B3:4/15	Memory to activate HH_Extension
M_33	B3:5/0	Memory to activate II_Retraction & Timer_5

M_34	B3:5/1	Memory to activate HH_Retraction
M_35	B3:5/2	Memory to activate OO_Retraction & Timer_6
M_36	B3:5/3	Memory to activate AA_Retraction & NN_Retraction
M_37	B3:5/4	Memory to activate RR_Retraction & Output_5
M_38	B3:5/5	Memory to tell DISAFA Machine that grafted plant cart can move
M_39	B3:5/6	Inactive Memory
M_40	B3:5/7	Memory to activate Input_3
M_41	B3:5/8	Memory to activate AA_Extension
M_42	B3:5/9	Memory to activate BB_Retraction
M_43	B3:5/10	Memory to activate DD_Retraction & Timer_7
M_44	B3:5/11	Memory to activate AA_Retraction & deactivate Output_5 & Input_3
M_45	B3:5/12	Memory to activate Output_6
M_46	B3:5/13	Memory to activate Reset_Flag to save First_Pass
M_47	B3:5/14	Memory to deactivate Output_1 till Output_8
M_48	B3:5/15	Memory to deactivate M1 till M47 & M49 till M60
M_49	B3:6/0	Memory to deactivate Input_1, Input_2 & Input_3
M_50	B:3/6/1	Inactive Memory
M_51	B3:6/2	Memory to activate SS_Off
M_52	B3:6/3	Memory to activate FF_Retraction

M_53	B3:6/4	Memory to activate QQ_Retraction
M_54	B3:6/5	Memory to activate II_Retraction, OO_Retraction & DD_Retraction
M_55	B3:6/6	Memory to activate HH_Retraction
M_56	B3:6/7	Memory to activate AA_Retraction
M_57	B3:6/8	Memory to activate NN_Retraction
M_58	B3:6/9	Memory to activate RR_Retraction & BB_Retraction
M_59	B3:6/10	Memory to activate CC_Retraction, GG_Retraction & LL_Retraction
M_60	B3:6/11	Memory to activate Out_6, deactivate Reset_Flag & activate Reset_Flag_1

10.5 The Reset and Main Cycle Ladder Logic

The Ladder Logic written for Reset Cycle is attached to the Appendix-1 in the Thesis.

The Ladder Logic written for Main Cycle is attached to the Appendix-2 in the Thesis.

11. Altering Belluco code for blower implementation

Federico Belluco had formulated the new logic for the DIMEAS Machine according to the new requirements put forward by the DISAFA Team. It was tested and worked as required. However this code didn't have a the blower in it as it was added to the machine later.

So it was required that his code be altered and the blower addition be made. His code used the GRAFCET implemented via the Auxiliary Relay Technique.

11.1 Auxiliary Relay Logic

Belluco had created his GRAFCET and Ladder Logic using the Auxiliary Relay Technique.

The Auxiliary relay technique utilised a technique called 'Contracted GRAFCET', this technique is then combined with associating each step of the GRAFCET with a Relay. The word 'Relay' can be interpreted as a 'Memory' in our implementation on the PLC.

Firstly the concept of Contracted GRAFCET will be introduced. Contracted GRAFCET is a technique to represent a GRAFCET with fewer steps. The following information is taken into consideration when contracting a GRAFCET:

- The original GRAFCET is constructed with each element occurring on a separate step
- Then the steps of this GRAFCET are grouped together into multiple groups. Each group is now associated with one step.
- Each group can contains the successive actions of the steps of the original GRAFCET. The group ends at the step where the second stroke of the actuator already in the group occurs.
- So each group can contain only single actions of actuators, not their second action.
- This way multiple steps of the original GRAFCET are reduced to only a few.

An example of this implementation will be demonstrated in this example. Our system consists of 3 actuators A, B and C. Each of these actuators have two movements each: extension and retraction. The extension is represented by a plus sign while the retraction by a minus sign. The GRAFCET is shown below:

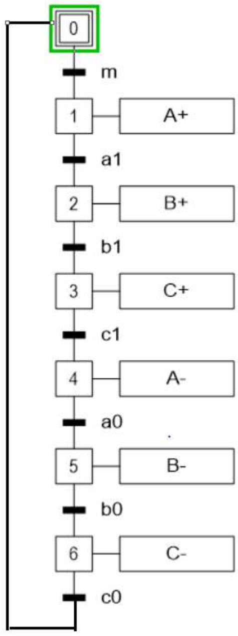


Figure 70: Example

The next step is to make the groups such that they contain only one of the movement of the actuators in the group. So in our case two groups will be created as shown in the figure below:

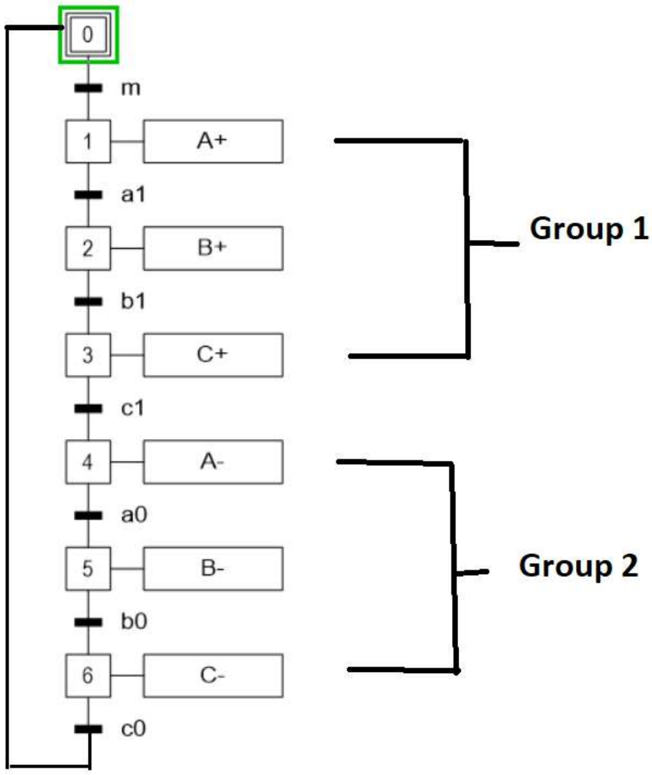


Figure 71: Groups

Now the final step of Contracted GRAFCET technique is to represent each group by a step:

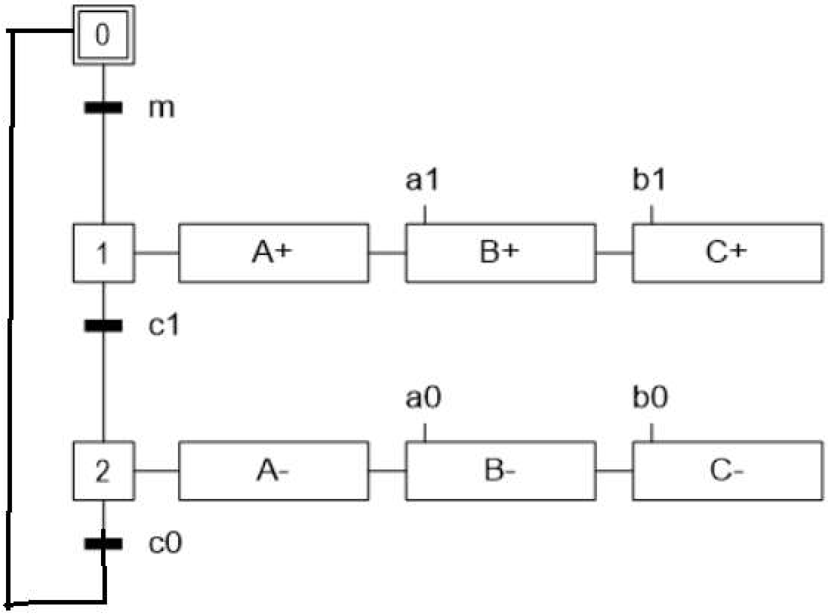


Figure 72: Contracted GRAFCET

After

performing the Contracted GRAFCET Technique the next step in Auxiliary Relay Technique is to associate a Relay/Memory with each step. Each memory has the possibility of having 2 states, activated or not activated. So with N Relays we can have 2^N possible combination of states. So in case of our example only one Relay/Memory is enough:

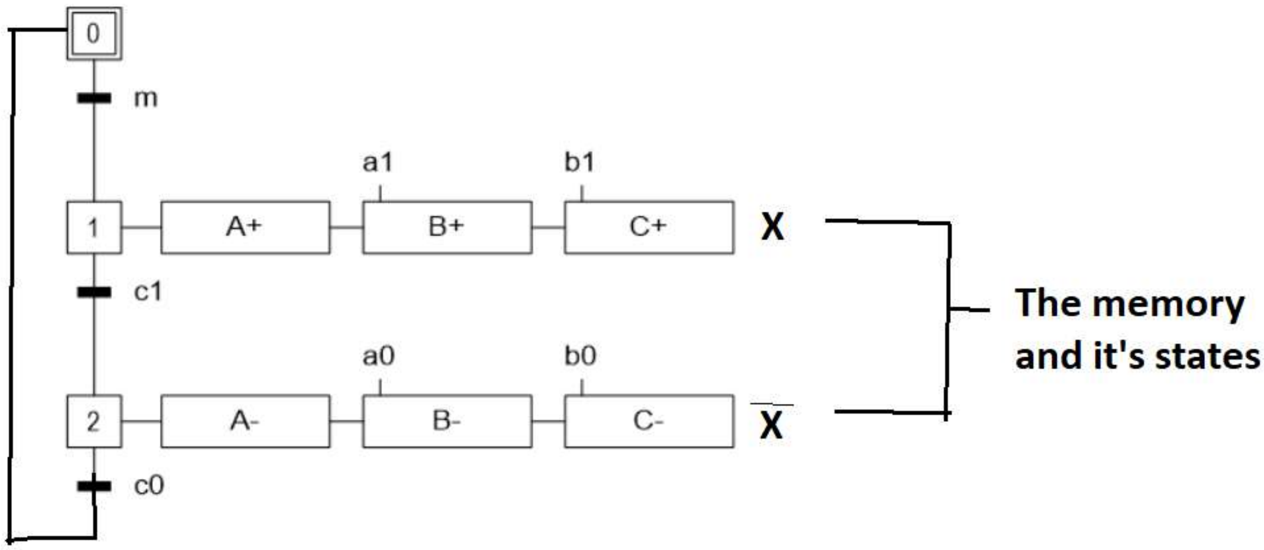


Figure 73: Contracted GRAFCET with associated Relay

Now for each state of the Memory/Relay an equation would be written:

Set X	Set X= m.c0
Reset X	Reset X= c1

This example for simple. In the next example we will use two sets of Relays. Skipping the Contracted GRAFCET step and jumping directly to the Contracted GRAFCET shown below:

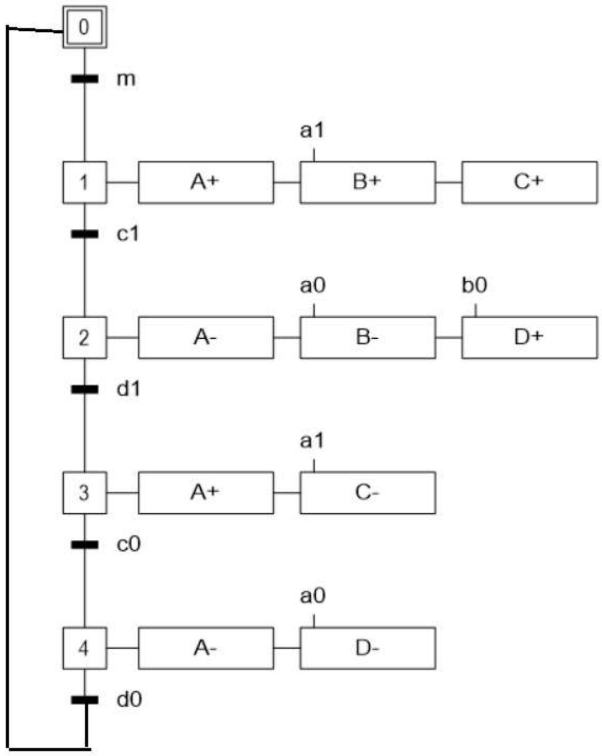


Figure 74: Example

Since there are 4 steps 2 Relays would be enough to represent this GRAFCET. These relays are represented by X and Y:

Step	Memory X State	Memory Y State
1	X	Y
2	X	Y
3	X	Y
4	X	Y

So each Step gets activated when both the memories are in the state associated with it.

Now we write each Memory's set and reset equations:

Memory State	**Equation**
Set X	X = m.d0.Y
Reset X	X = d1.Y
Set Y	Y = b1.c1.X
Reset Y	Y = c0. X

Now we consolidate the equation and write an equation for each memory representing both the reset and set parts. The standard format for such an equation is:

- U=(SET+u).RESET
- U is the corresponding memory
- SET is the Set equation of that memory
- RESET is the Reset equation of that memory

So the consolidated equations are:

Memory	**Consolidated Equation**
X	X=(m.d0.Y+x).(d1+Y)
Y	Y=(b1.c1.X+y).(c0+X)

The equations for each action of the Steps is written using the state of the Memories associated with it and (if present) the preceding signal of actuation.

Step	**Actuation**	**Equation**
1	A+	A+=X.Y
1	B+C+	B+C+=X.Y.a1
2	A-	A-=X.Y
2	B-	B-=X.Y.a0
2	D+	D+=X.Y.b0
3	A+	A+=X.Y
3	C-	C-=X.Y.a1
4	A-	A-=X.Y
4	D-	D=X.Y.a0

The next step is to represent these equation in the Ladder Logic. Each Consolidated Equation & Actuation equation is represented with one rung of Ladder Logict. So the Ladder Logic of these equations is shown in the figure below:

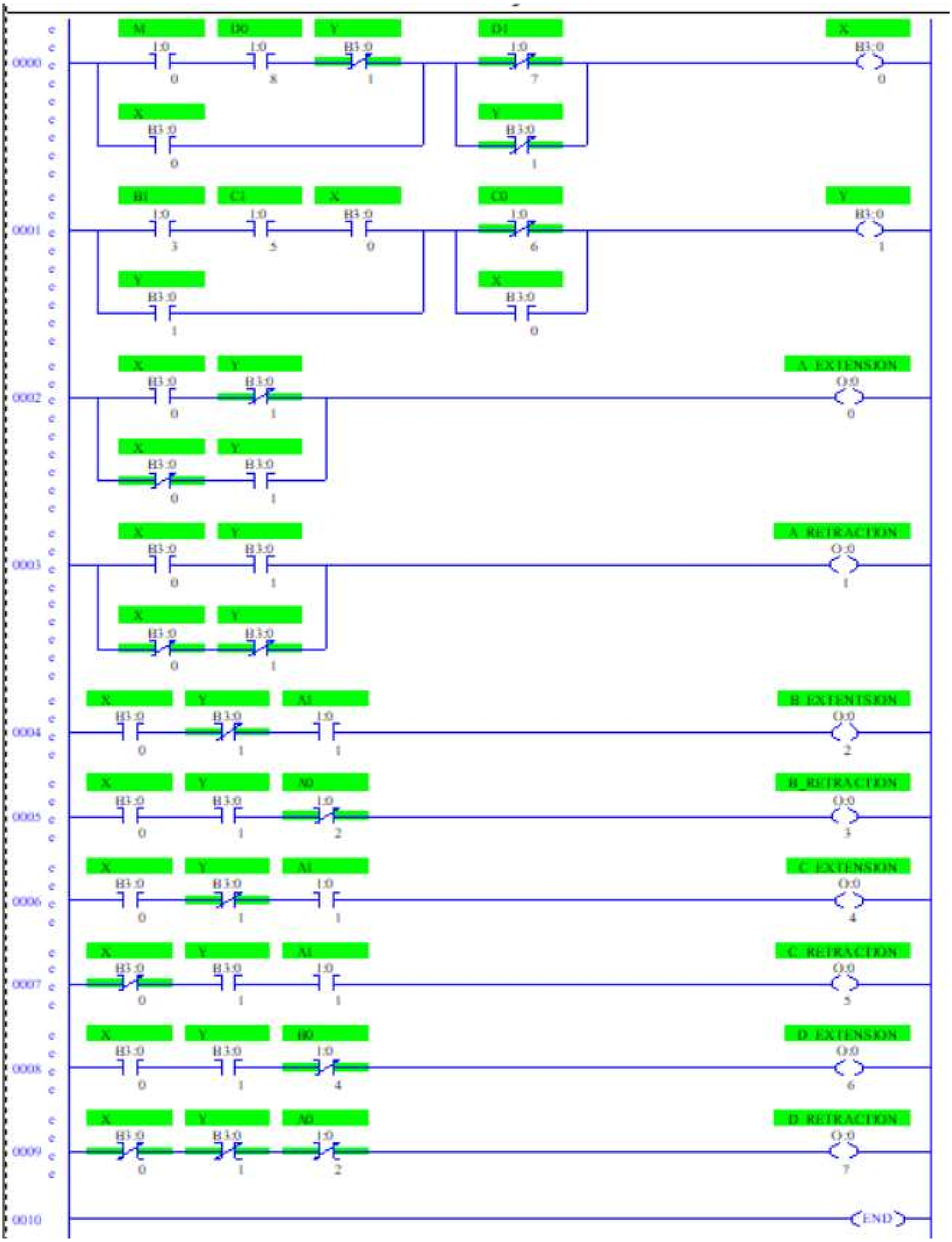


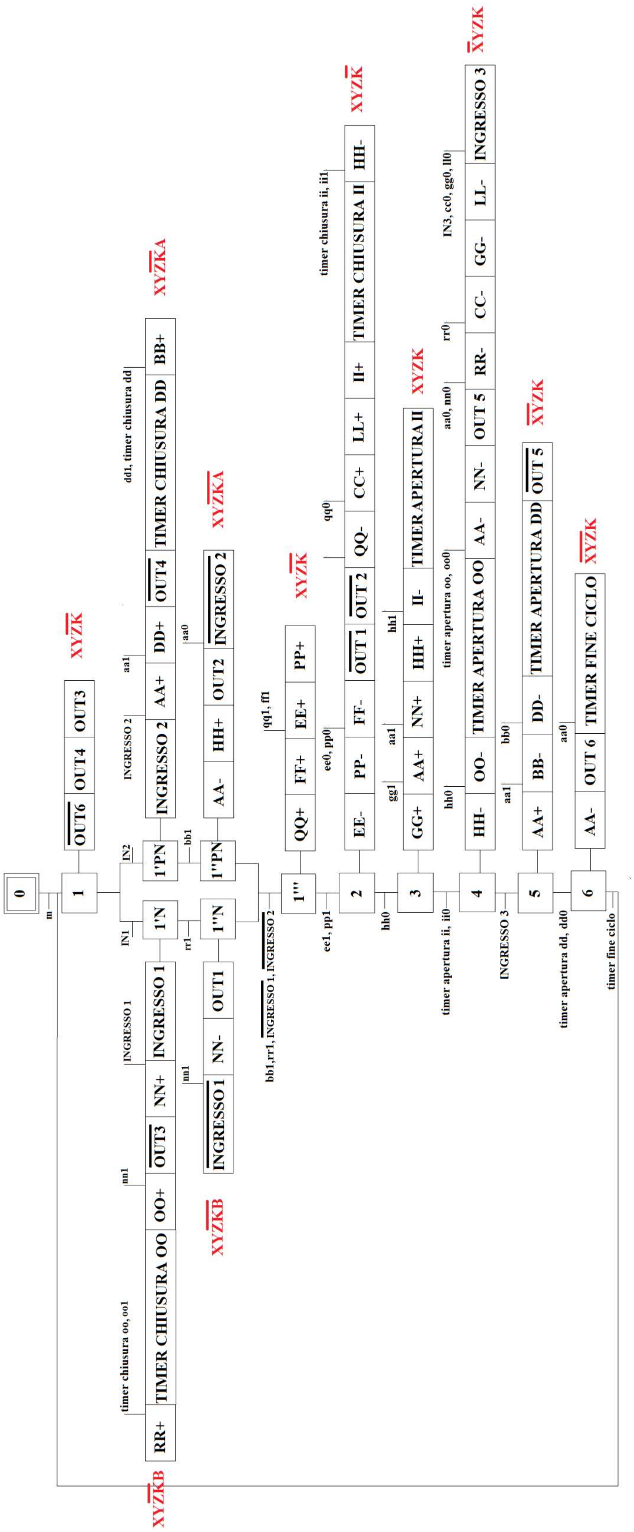
Figure 75: Ladder Logic

11.2 Belluco's GRAFCET

Belluco had created two GRAFCET's using the Auxiliary Relay Technique. One for the Main Cycle and One for the Reset Cycle

11.2.1 Main Cycle GRAFCET

The Main Cycle GRAFCET is shown in the image below:



11.2.2 Reset Cycle GRAFCET

The Reset Cycle GRAFCET is shown in the image below:

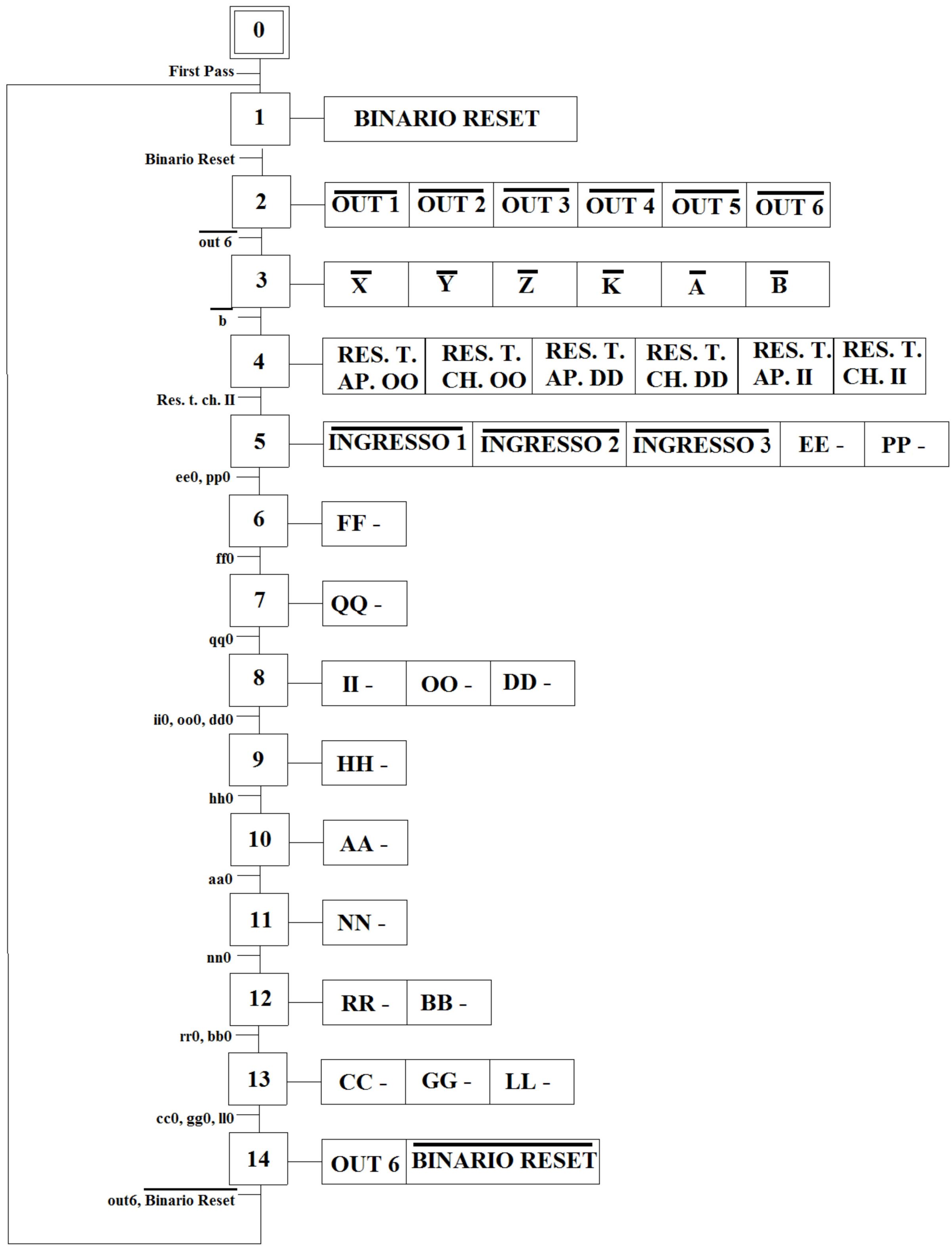


Figure 76: Reset Cycle GRAFCET

11.3 Addition of Blower

There was a need to protect the machine from the by-products/wastage being produced by the DIMEAS Machine. The solution implemented was the addition of a cover over the machine to offer protection. The cover was slanting so as to guide the wastage away from the machine rather than it just lying on top of it.

However despite this slant there is a chance the waste may stick to the surface of the cover or have trouble moving easily away from the machine. To provide the ‘push’ needed to achieve this a blower was attached to the surface of the cover.

This blower is not be constantly on as that would be a waste of energy. Instead it is connected to the PLC which will control when it turns on, how long it stays on and then turns it off

The GRAFCET and Ladder Logic created by Belluco was done without the Blower. After the addition of the blower the GRAFCET and Ladder Logic need to be readjusted for it.

As discussed in Chapter 8 the Blower was attached to the vacant Valve in the Valve Block which was then connected to the vacant ports on the PLC’s Output Expansion block.

The address of these ports is:

- O:3/6 : SS_ON
- O:3/7 : SS_OFF

The pictures below shows the ports that the electrical connection is made to, connecting the expansion block of the PLC with the bistable valve chosen for the blower.

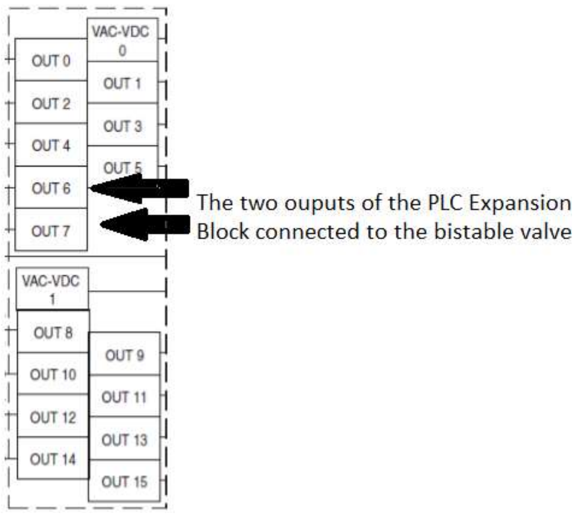


Figure 77: Ports to be used

The picture below shows the actual connection that was made:

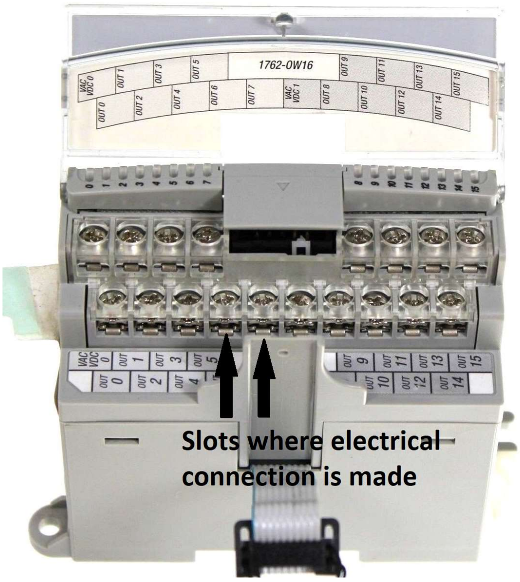


Figure 78: Ports to be connected

Furthermore a new timer is added to create

11.4 The new input, output, timer, auxiliary memory table

11.4.1 New Output Table

Since an addition has been made to the Output, the Output table of Belluco needs to be updated. The updated Output Table is:

Name	Address	Function
AA_ENTRA	O:0/13	Rientro orizzontale cilindro portanesto
AA_ESCE	O:0/10	Uscita orizzontale cilindro portanesto
BB_ENTRA	O:3/14	Rientro verticale cilindro portanesto
BB_ESCE	O:3/15	Uscita verticale cilindro portanesto
CC_ENTRA	O:0/14	Rotazione esterna cilindro portanesto
CC_ESCE	O:0/15	Rotazione interna cilindro portanesto
DD_ENTRA	O:3/13	Apertura pinze portanesto

DD_ESCE	O:3/12	Chiusura pinze portanesto
EE_ENTRA	O:0/1	Rientro lama portanesto
EE_ESCE	O:0/0	Uscita lama portanesto
FF_ENTRA	O:0/11	Rotazione verso posizione riposo riscontro portanesto
FF_ESCE	O:0/12	Rotazione verso posizione lavoro riscontro portanesto
GG_ENTRA	O:2/2	Rotazione interna cilindro clips
GG_ESCE	O:2/0	Rotazione esterna cilindro clips
HH_ENTRA	O:3/10	Rientro orizzontale cilindro clips
HH_ESCE	O:3/11	Uscita orizzontale cilindro clips
II_ENTRA	O:3/8	Apertura pinza clips
II_ESCE	O:3/9	Chiusura pinza clips
LL_ENTRA	O:2/1	Rotazione esterna cilindro nesto
LL_ESCE	O:2/7	Rotazione interna cilindro nesto
NN_ENTRA	O:2/10	Rientro orizzontale cilindro nesto
NN_ESCE	O:2/8	Uscita orizzontale cilindro nesto
OO_ENTRA	O:2/14	Apertura pinze nesto
OO_ESCE	O:2/12	Chiusura pinze nesto
PP_ENTRA	O:2/11	Rientro lame nesto
PP_ESCE	O:2/9	Uscita lame nesto
QQ_ENTRA	O:2/6	Rotazione verso posizione riposo riscontro nesto
QQ_ESCE	O:2/4	Rotazione verso posizione lavoro riscontro nesto
RR_ENTRA	O:2/5	Rientro verticale cilindro nesto
RR_ESCE	O:2/3	Uscita verticale cilindro nesto
OUT1_AGRARIA	O:2/15	Carrello nesto libero di muoversi
OUT2_AGRARIA	O:2/13	Carrello portanesto libero di muoversi
OUT3_AGRARIA	O:3/5	Richiesta nesto
OUT4_AGRARIA	O:3/3	Richiesta portanesto
OUT5_AGRARIA	O:3/1	Richiesta carrello per talea completata

OUT6_AGRARIA	O:3/0	Carrello talea libero di muoversi
OUT7_AGRARIA	O:3/2	
OUT8_AGRARIA	O:3/4	
SS_ON	O:3/6	Turn Blower On/Off
SS_OFF	O:3/7	redundant

11.4.2 Input Table

Following is Belluco's Input table:

Input Name	**Address**	**Function**
AA0	I:0/1	Finecorsa rientro cilindro A
AA1	I:0/4	Finecorsa uscita cilindro A
BB0	I:0/3	Finecorsa rientro cilindro B
BB1	I:0/7	Finecorsa uscita cilindro B
CC0	I:0/5	Finecorsa rientro cilindro C
CC1	I:0/8	Finecorsa uscita cilindro C
EE0	I:0/6	Finecorsa rientro cilindro E
EE1	I:0/9	Finecorsa uscita cilindro E
FF0	I:0/10	Finecorsa rientro cilindro F
FF1	I:0/12	Finecorsa uscita cilindro F
GG0	I:0/0	Finecorsa rientro cilindro G
GG1	I:0/2	Finecorsa uscita cilindro G
HH0	I:0/15	Finecorsa rientro cilindro H
HH1	I:0/13	Finecorsa uscita cilindro H
LL0	I:0/18	Finecorsa rientro cilindro L
LL1	I:0/11	Finecorsa uscita cilindro L
NN0	I:0/14	Finecorsa rientro cilindro N
NN1	I:0/22	Finecorsa uscita cilindro N
PP0	I:0/21	Finecorsa rientro cilindro P
PP1	I:0/19	Finecorsa uscita cilindro P
QQ0	I:0/23	Finecorsa rientro cilindro Q
QQ1	I:0/20	Finecorsa uscita cilindro Q
RR0	I:0/16	Finecorsa rientro cilindro R
RR1	I:0/17	Finecorsa uscita cilindro R
IN1_AGR	I:1/4	Arrivo nesto
IN2_AGR	I:1/2	Arrivo portanesto
IN3_AGR	I:1/0	Arrivo carrello vuoto
IN4_AGR	I:1/10	
M	I:1/6	Tasto inizio ciclo

11.4.3 Memory Table

Following is the Memory Table:

Memory Name	Address	Function
RELE AUSIL X	B3:0/0	Simulatore relè ausiliario X
RELE AUSIL Y	B3:0/1	Simulatore relè ausiliario Y
RELE AUSIL Z	B3:0/2	Simulatore relè ausiliario Z
RELE AUSIL K	B3:0/3	Simulatore relè ausiliario K
RELE AUSIL A	B3:0/4	Simulatore relè ausiliario A
RELE AUSIL B	B3:0/5	Simulatore relè ausiliario B
INGRESSO1	B3:0/6	Memoria di arrivo input 1 macchina DISAFA
INGRESSO2	B3:0/7	Memoria di arrivo input 3 macchina DISAFA
INGRESSO3	B3:0/8	Memoria di arrivo input 3 macchina DISAFA
DD0	B3:0/9	Fine corsa virtuale apertura pinza DD
DD1	B3:0/10	Fine corsa virtuale chiusura pinza DD
OO0	B3:0/11	Fine corsa virtuale apertura pinza OO
OO1	B3:0/12	Fine corsa virtuale chiusura pinza OO
II0	B3:0/13	Fine corsa virtuale apertura pinza II
II1	B3:0/14	Fine corsa virtuale chiusura pinza II
BINARIORESET	B3:0/15	Memoria di input inizio ciclo reset
First Pass	S:1/15	Accensione del PLC, necessario per far partire il RESET

11.4.4 The Timer Table

Following is the timer table. A timer is added to create delay for Blower to operate.

Timer Name	Address	Function	Base	Preset
T_CHIUSURA_PINZA_DD	T:4/0	Temporizzatore chiusura pinza DD	0.01	50
T_CHIUSURA_PINZA_OO	T:4/1	Temporizzatore chiusura pinza 00	0.01	50
T_CHIUSURA_PINZA_II	T:4/2	Temporizzatore chiusura pinza II	0.01	50
T_FINE_CICLO	T:4/3	Temporizzatore fine ciclo per inviare OUT6	0.01	50
T_CHIUSURA_PINZA_DD	T:4/4	Temporizzatore apertura pinza DD	0.01	50
T_APERTURA_PINZA_OO	T:4/5	Temporizzatore apertura pinza OO	0.01	50
T_ APERTURA _PINZA_II	T:4/6	Temporizzatore apertura pinza II	0.01	50
T_Blower	T:4/7	Blower Delay	0.01	200

11.5 The new GRAFCET with Blower

11.5.1 Main Cycle GRAFCET with Blower

Two main additions have to be made in the Main Cycle GRAFCET, they are:

- Addition of Blower
- Addition of timer to create the delay needed for blower to operate

This addition will be made after the cutting operation is completed. So it will be added in step2 of Belluco's GRAFCET (step 7 in the new GRAFCET below). The Blower will be turned ON after the Blades EE and PP have retracted. The new GRAFCET is shown below:

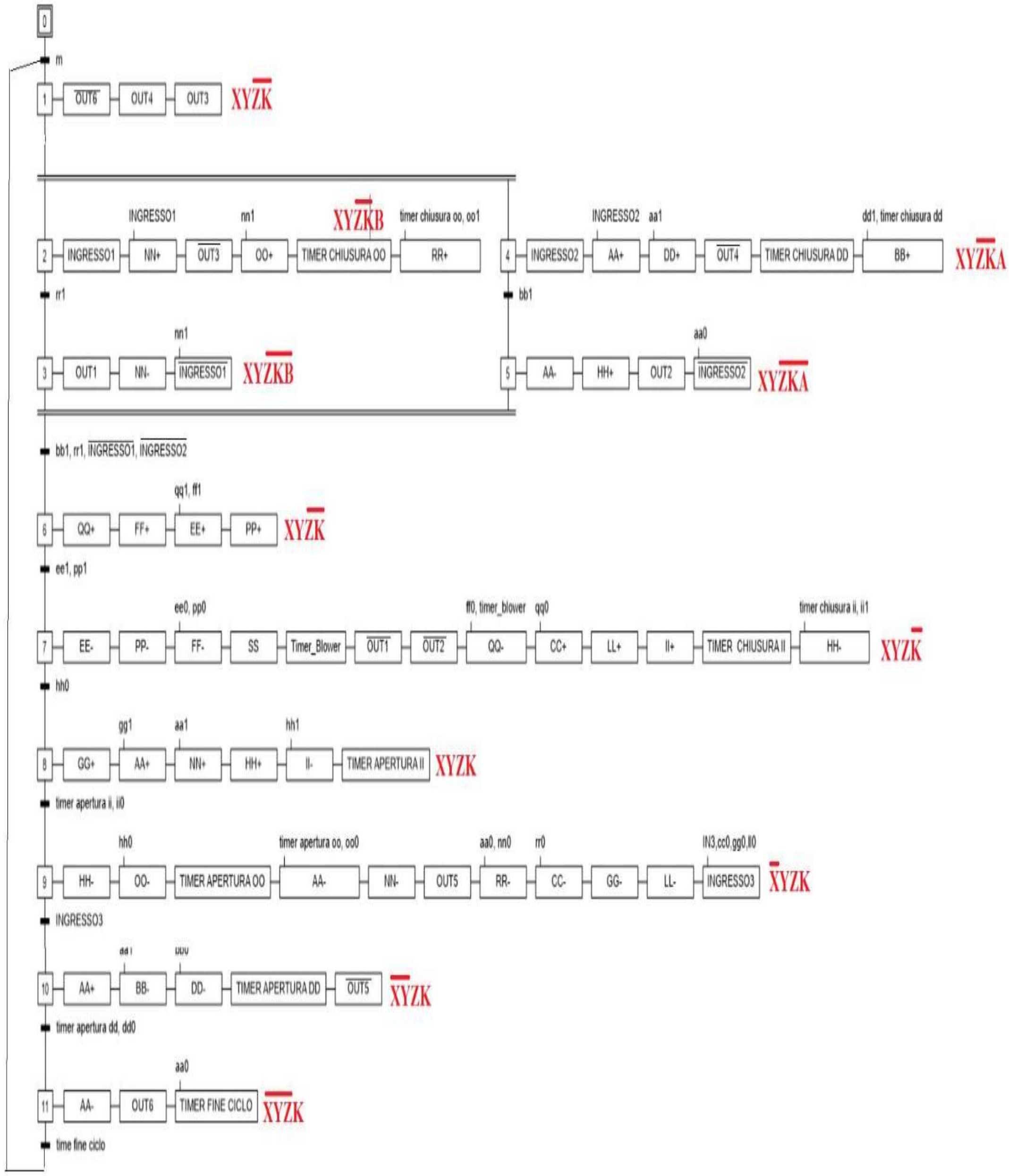


Figure 79: Main Cycle with Blower

11.5.2 Reset Cycle GRAFCET with Blower

In the Reset Cycle two additions have to be made:

- Turn Off the Blower
- Reset the Blower Delay Timer

The Blower Delay Timer will be reset in the step where other timers are being reset. While the Blower will be turned off in the step where the Blade retractions are made. The new GRAFCET is shown below:

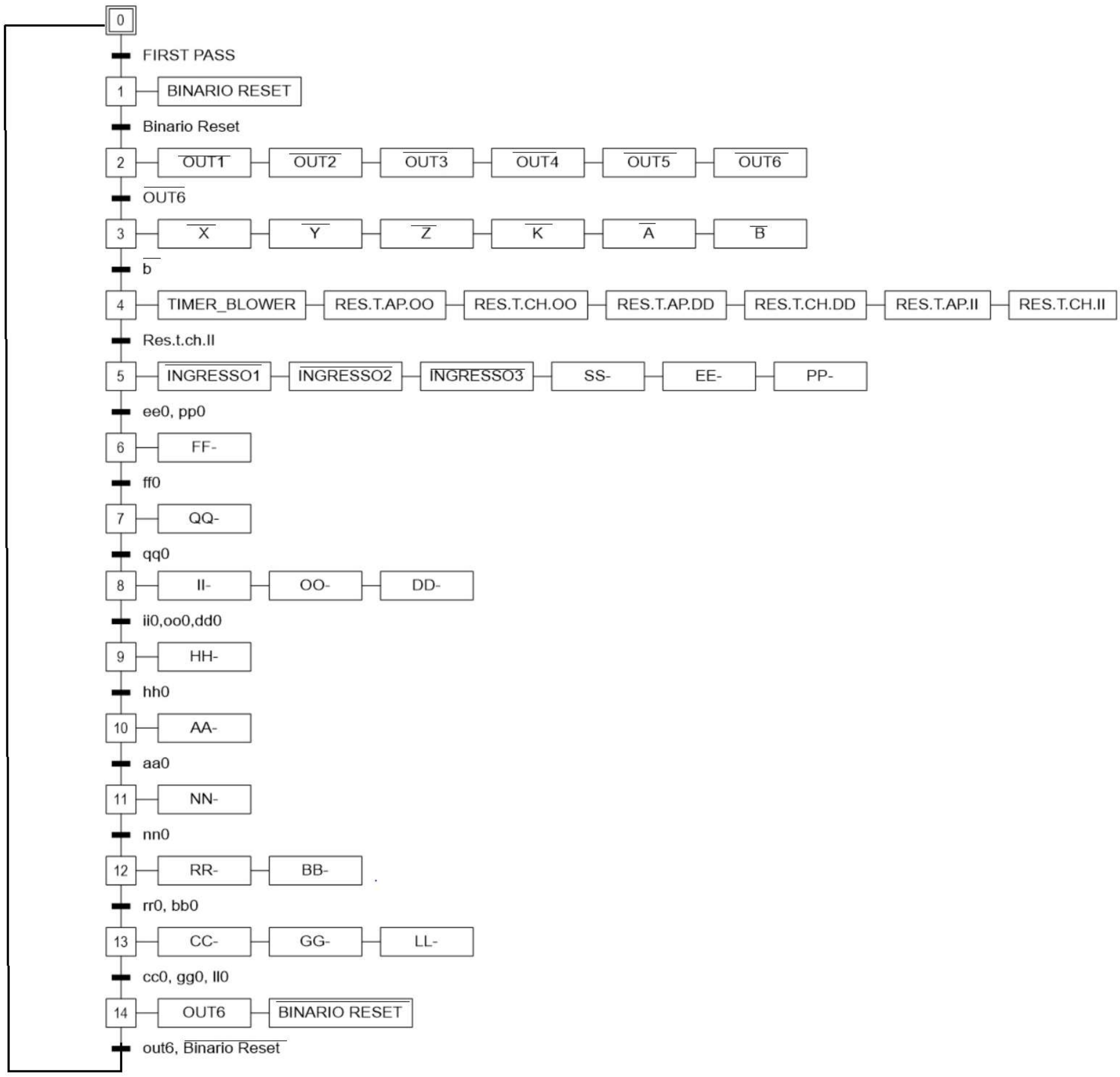


Figure 80: Reset Cycle with Blower

11.6 The Ladder Logic

11.6.1 Main Cycle Ladder Logic

The Main Cycle Ladder Logic GRAFCET is attached to Appendix 3

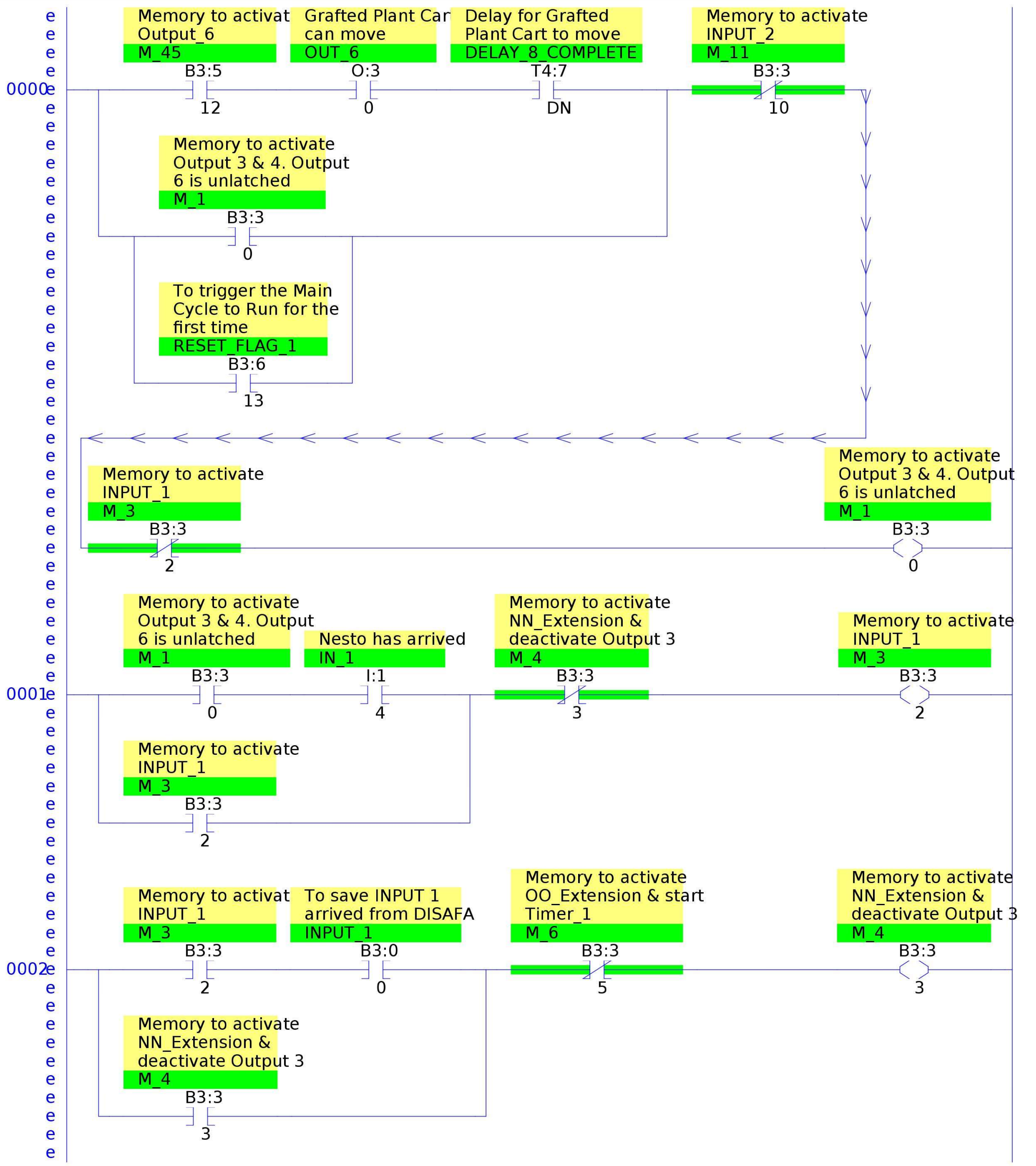
11.6.2 Reset Cycle Ladder Logic

The Reset Cycle Ladder Logic GRAFCET is attached to Appendix 4

Appendix 1 – Main Cycle

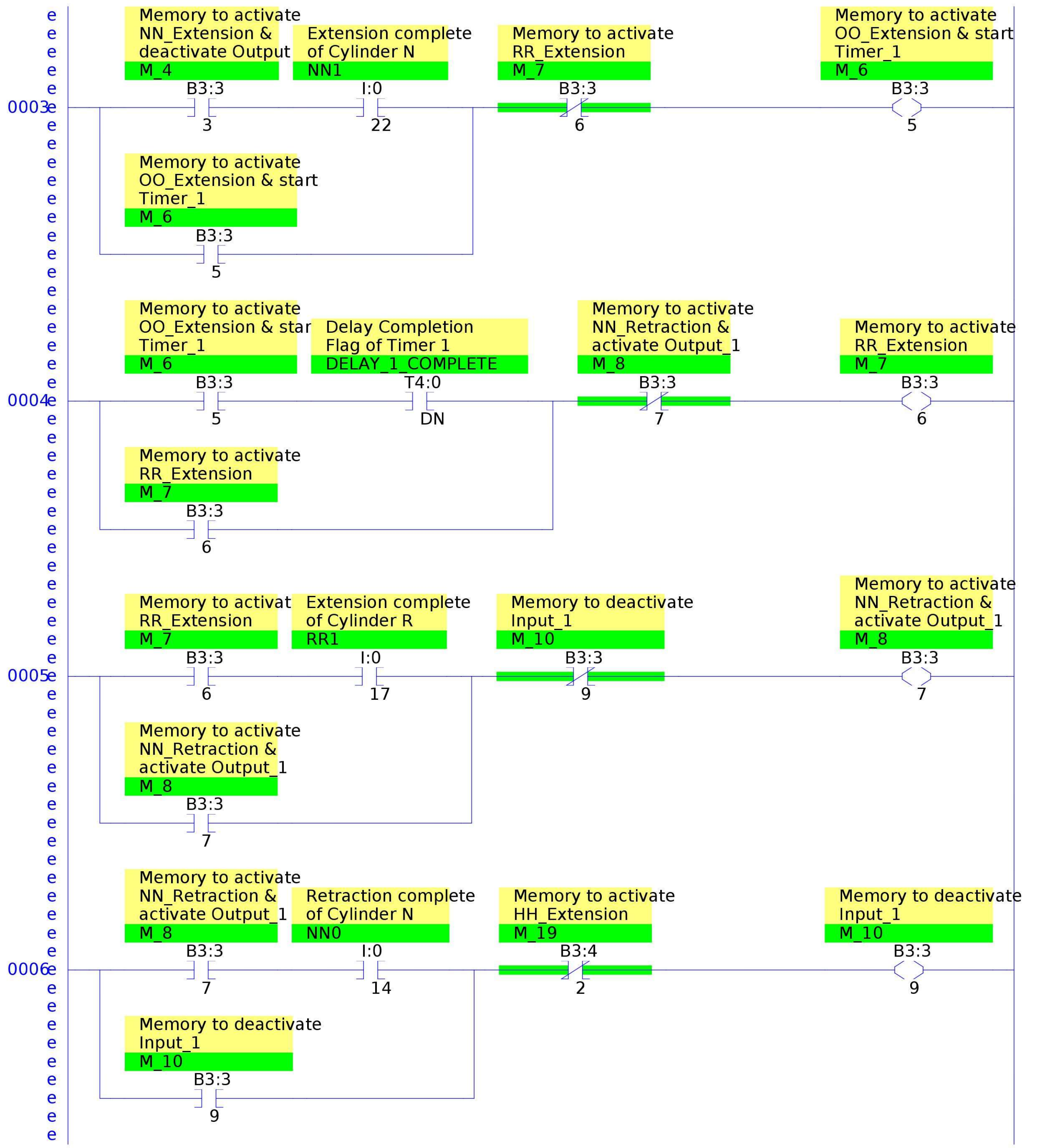
MAIN CYCLE WITH BLOWER

LAD 2 - --- Total Rungs in File = 77



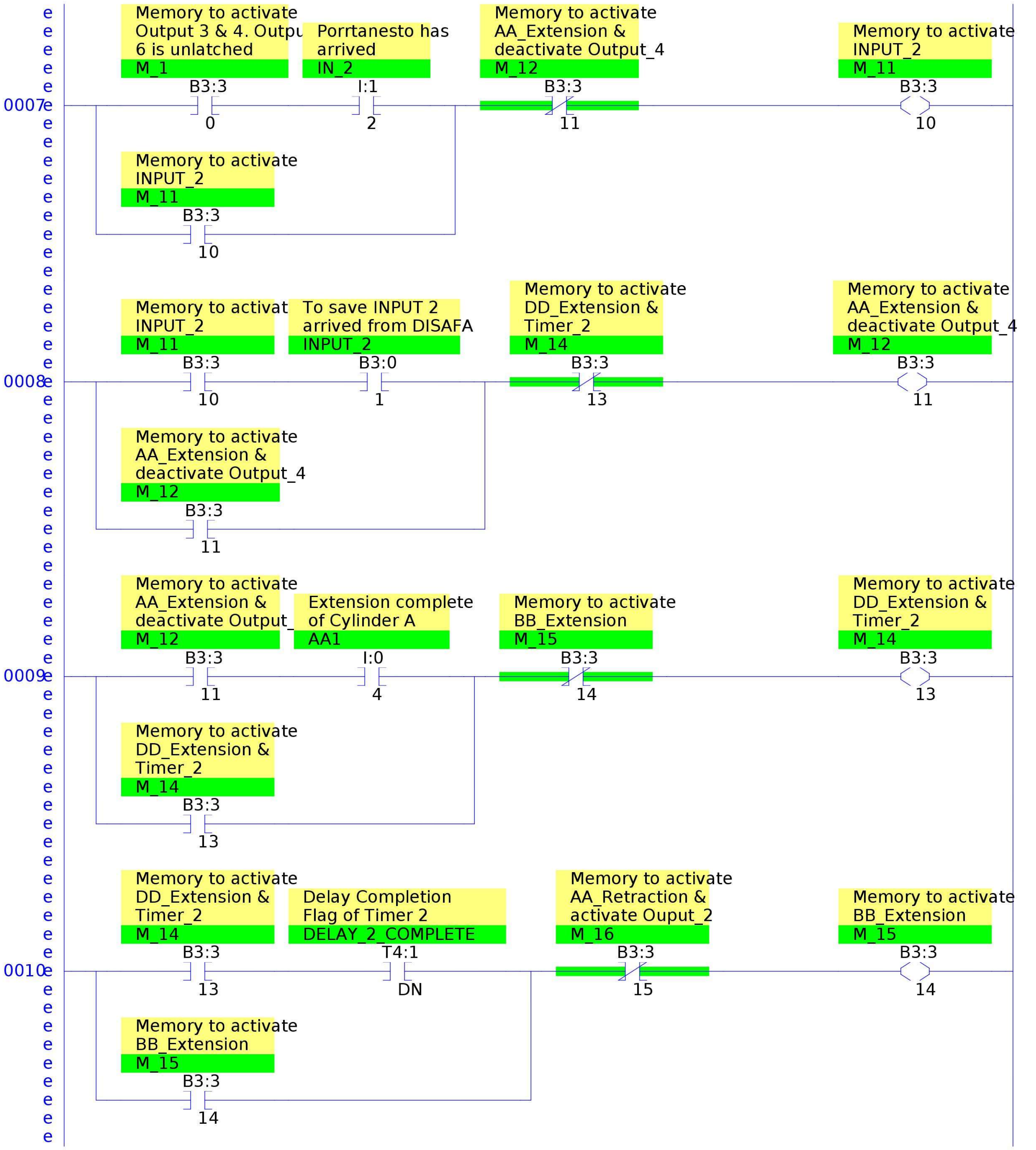
MAIN CYCLE WITH BLOWER

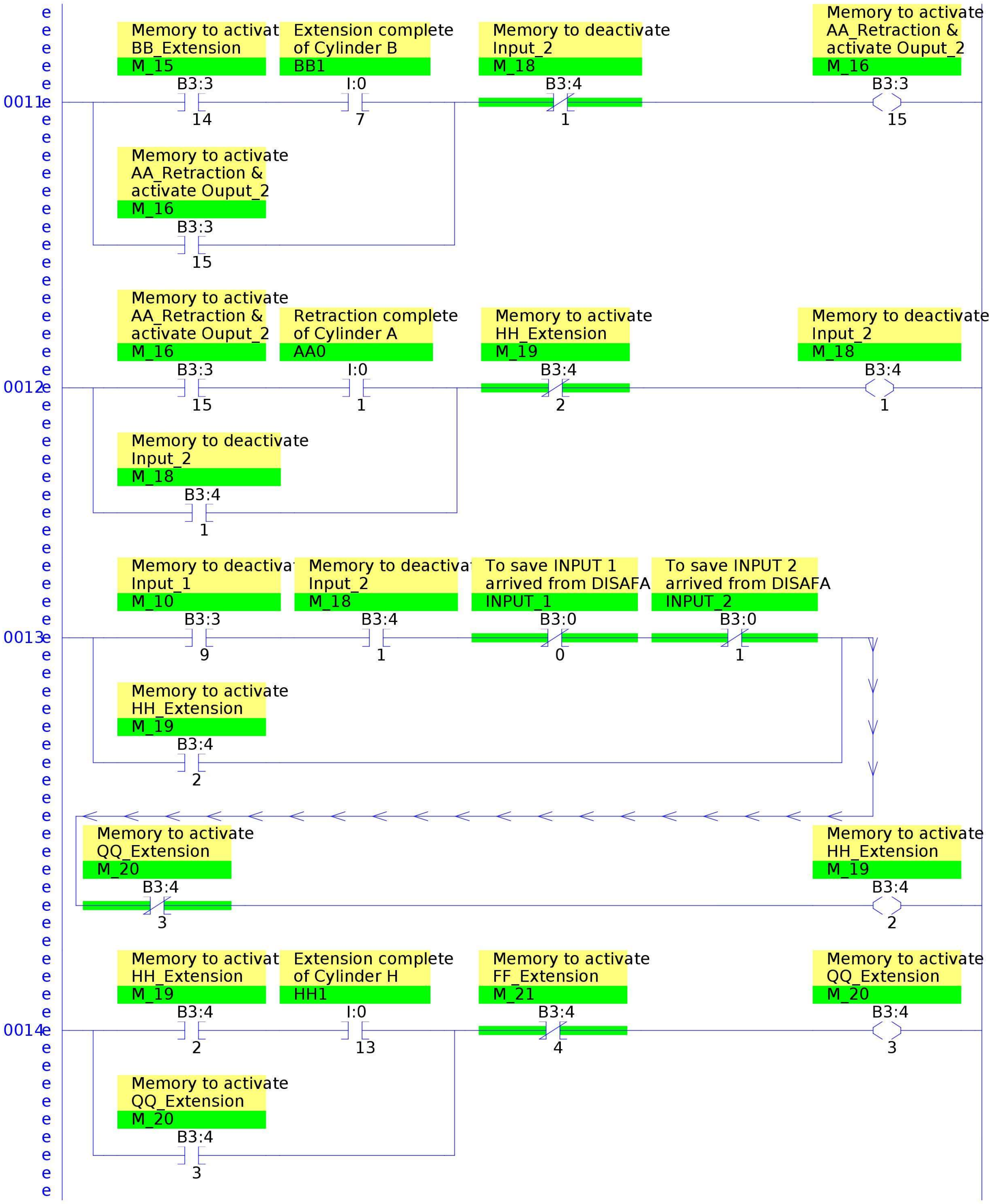
LAD 2 - --- Total Rungs in File = 77



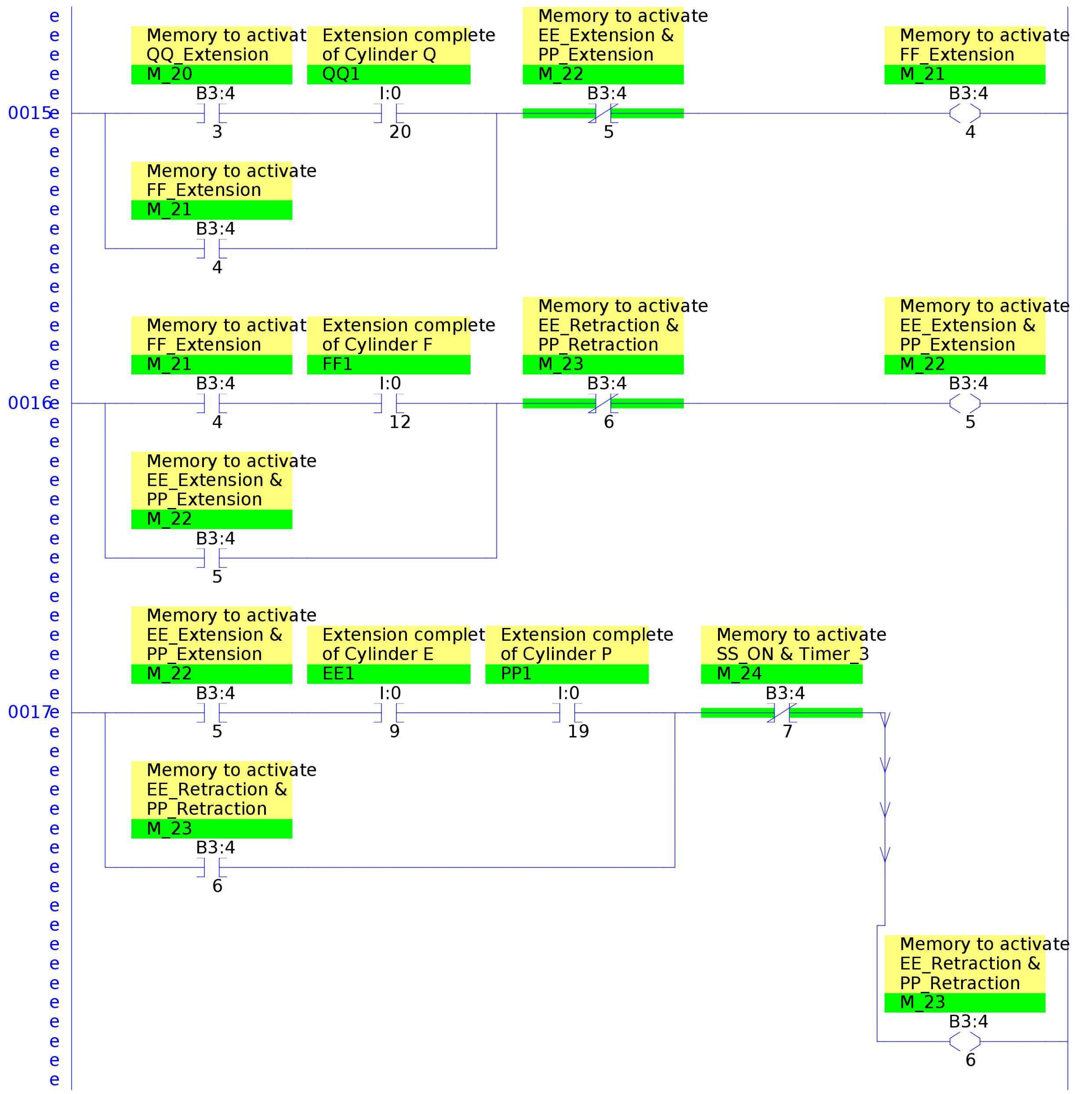
MAIN CYCLE WITH BLOWER

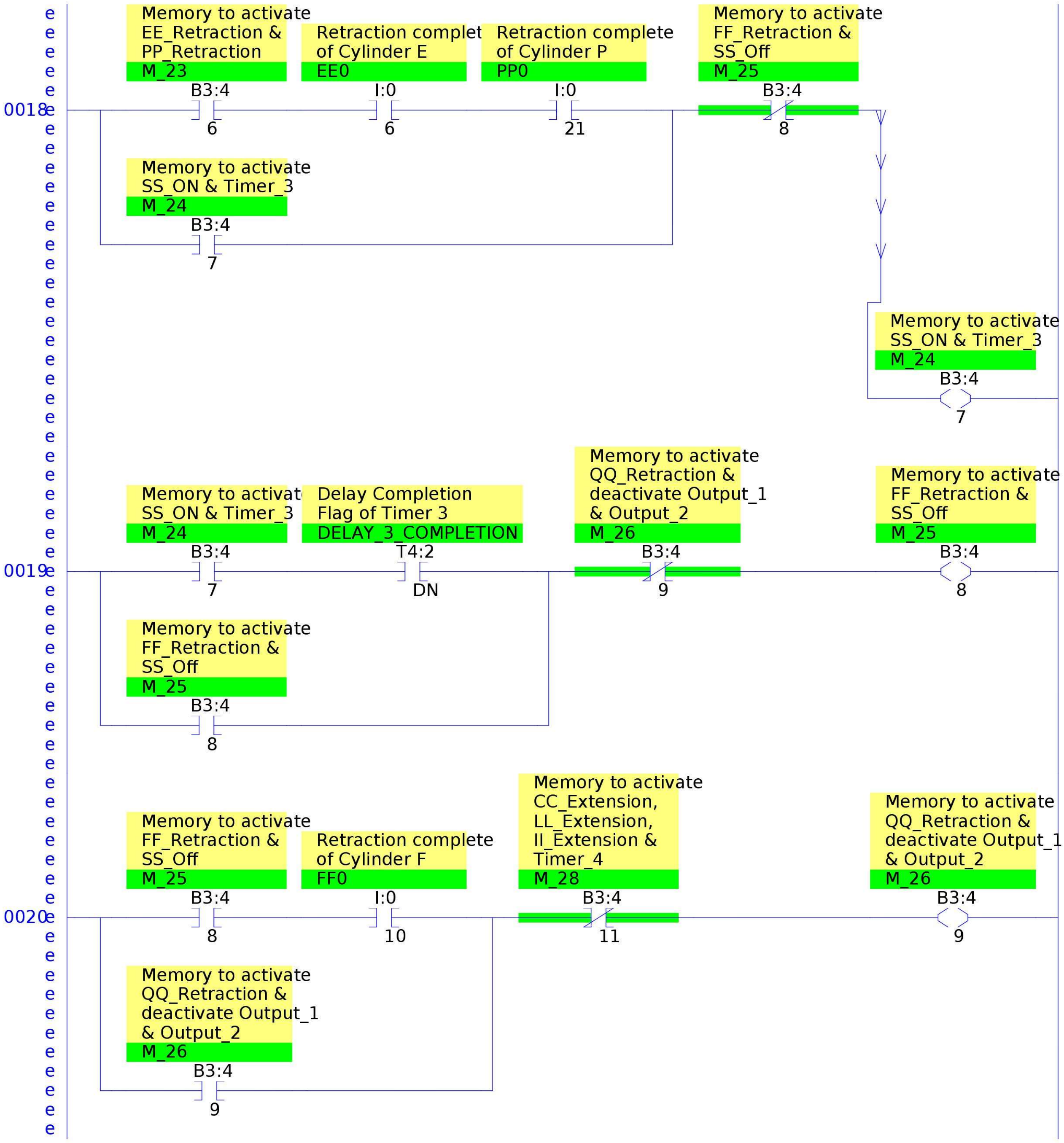
LAD 2 - --- Total Rungs in File = 77

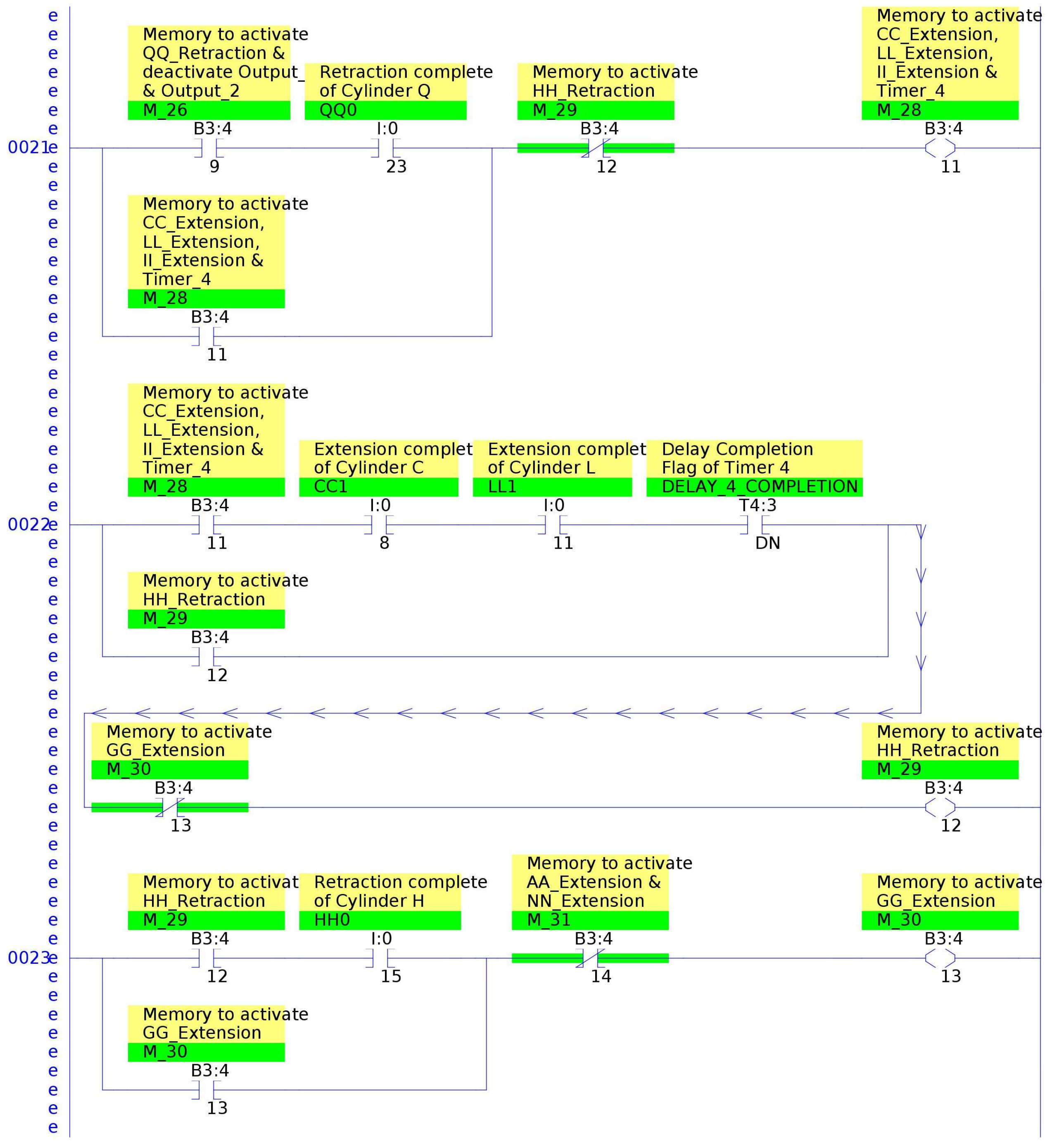



0011
Memory to activat BB_Extension M_15 B3:3 14
Extension complete of Cylinder B BB1 I:0 7
Memory to deactivate Input_2 M_18 B3:4 1
Memory to activate AA_Retraction & activate Ouput_2 M_16 B3:3 15
Memory to activate AA_Retraction & activate Ouput_2 M_16 B3:3 15
0012
Memory to activate AA_Retraction & activate Ouput_2 M_16 B3:3 15
Retraction complete of Cylinder A AA0 I:0 1
Memory to activate HH_Extension M_19 B3:4 2
Memory to deactivate Input_2 M_18 B3:4 1
Memory to deactivate Input_2 M_18 B3:4 1
0013
Memory to deactiva Input_1 M_10 B3:3 9
Memory to deactiva Input_2 M_18 B3:4 1
To save INPUT 1 arrived from DISAFA INPUT_1 B3:0 0
To save INPUT 2 arrived from DISAFA INPUT_2 B3:0 1
Memory to activate HH_Extension M_19 B3:4 2
Memory to activate QQ_Extension M_20 B3:4 3
Memory to activate HH_Extension M_19 B3:4 2
0014
Memory to activat HH_Extension M_19 B3:4 2
Extension complete of Cylinder H HH1 I:0 13
Memory to activate FF_Extension M_21 B3:4 4
Memory to activate QQ_Extension M_20 B3:4 3
Memory to activate QQ_Extension M_20 B3:4 3

LAD 2 - --- Total Rungs in File = 77

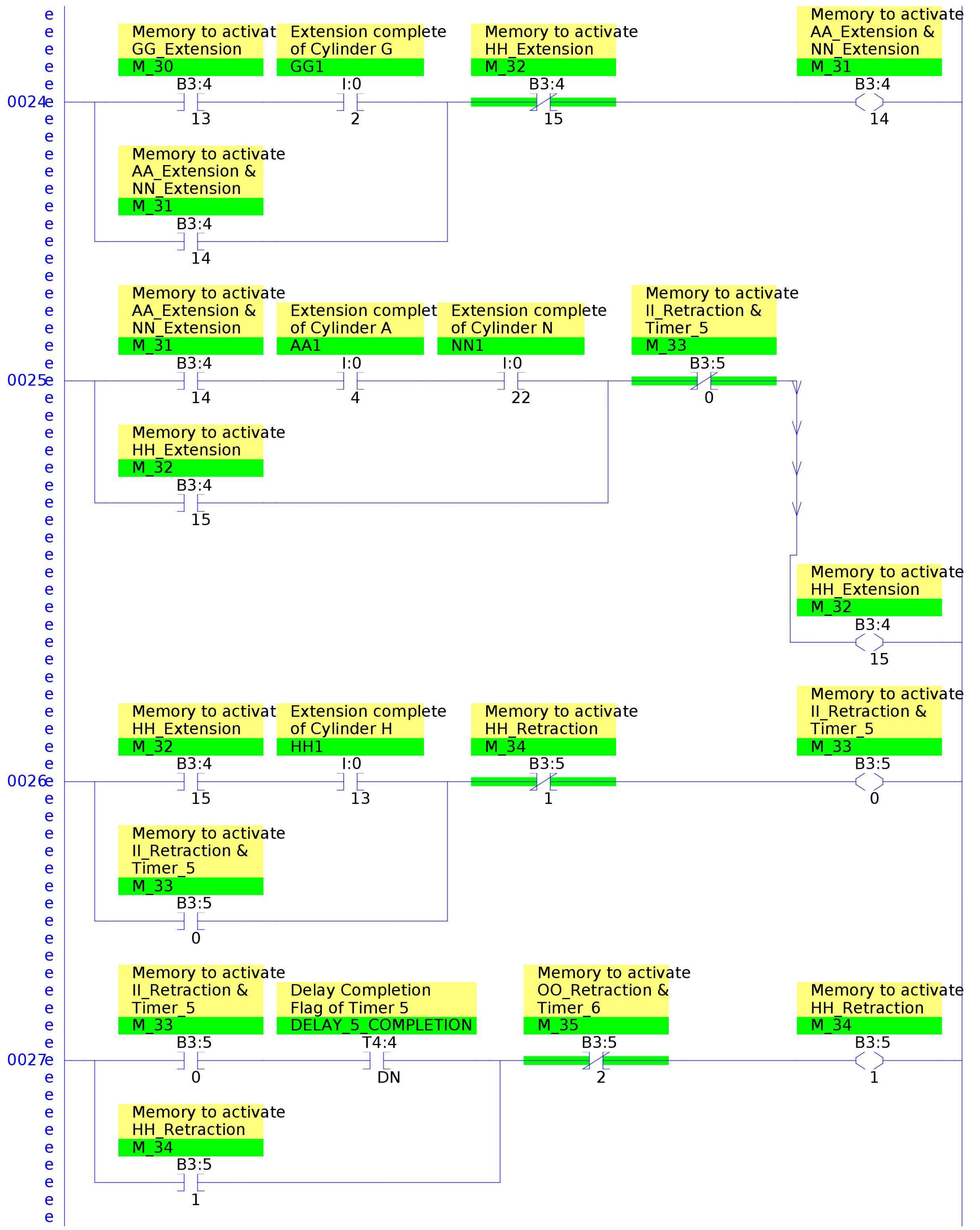



0018
Memory to activate EE_Retraction & PP_Retraction
M_23
B3:4
6
Retraction complet of Cylinder E
EE0
I:0
6
Retraction complete of Cylinder P
PP0
I:0
21
Memory to activate FF_Retraction & SS_Off
M_25
B3:4
8
Memory to activate SS_ON & Timer_3
M_24
B3:4
7
Memory to activate SS_ON & Timer_3
M_24
B3:4
7
0019
Memory to activat SS_ON & Timer_3
M_24
B3:4
7
Delay Completion Flag of Timer 3
DELAY_3_COMPLETION
T4:2
DN
Memory to activate QQ_Retraction & deactivate Output_1 & Output_2
M_26
B3:4
9
Memory to activate FF_Retraction & SS_Off
M_25
B3:4
8
Memory to activate FF_Retraction & SS_Off
M_25
B3:4
8
0020
Memory to activate FF_Retraction & SS_Off
M_25
B3:4
8
Retraction complete of Cylinder F
FF0
I:0
10
Memory to activate CC_Extension, LL_Extension, II_Extension & Timer_4
M_28
B3:4
11
Memory to activate QQ_Retraction & deactivate Output_1 & Output_2
M_26
B3:4
9
Memory to activate QQ_Retraction & deactivate Output_1 & Output_2
M_26
B3:4
9


0021
Memory to activate QQ_Retraction & deactivate Output_ & Output_2
M_26
B3:4
9
Retraction complete of Cylinder Q
QQ0
I:0
23
Memory to activate HH_Retraction
M_29
B3:4
12
Memory to activate CC_Extension, LL_Extension, II_Extension & Timer_4
M_28
B3:4
11
Memory to activate CC_Extension, LL_Extension, II_Extension & Timer_4
M_28
B3:4
11
0022
Memory to activate CC_Extension, LL_Extension, II_Extension & Timer_4
M_28
B3:4
11
Extension complet of Cylinder C
CC1
I:0
8
Extension complet of Cylinder L
LL1
I:0
11
Delay Completion Flag of Timer 4
DELAY_4_COMPLETION
T4:3
DN
Memory to activate HH_Retraction
M_29
B3:4
12
Memory to activate GG_Extension
M_30
B3:4
13
Memory to activate HH_Retraction
M_29
B3:4
12
0023
Memory to activat HH_Retraction
M_29
B3:4
12
Retraction complete of Cylinder H
HH0
I:0
15
Memory to activate AA_Extension & NN_Extension
M_31
B3:4
14
Memory to activate GG_Extension
M_30
B3:4
13
Memory to activate GG_Extension
M_30
B3:4
13

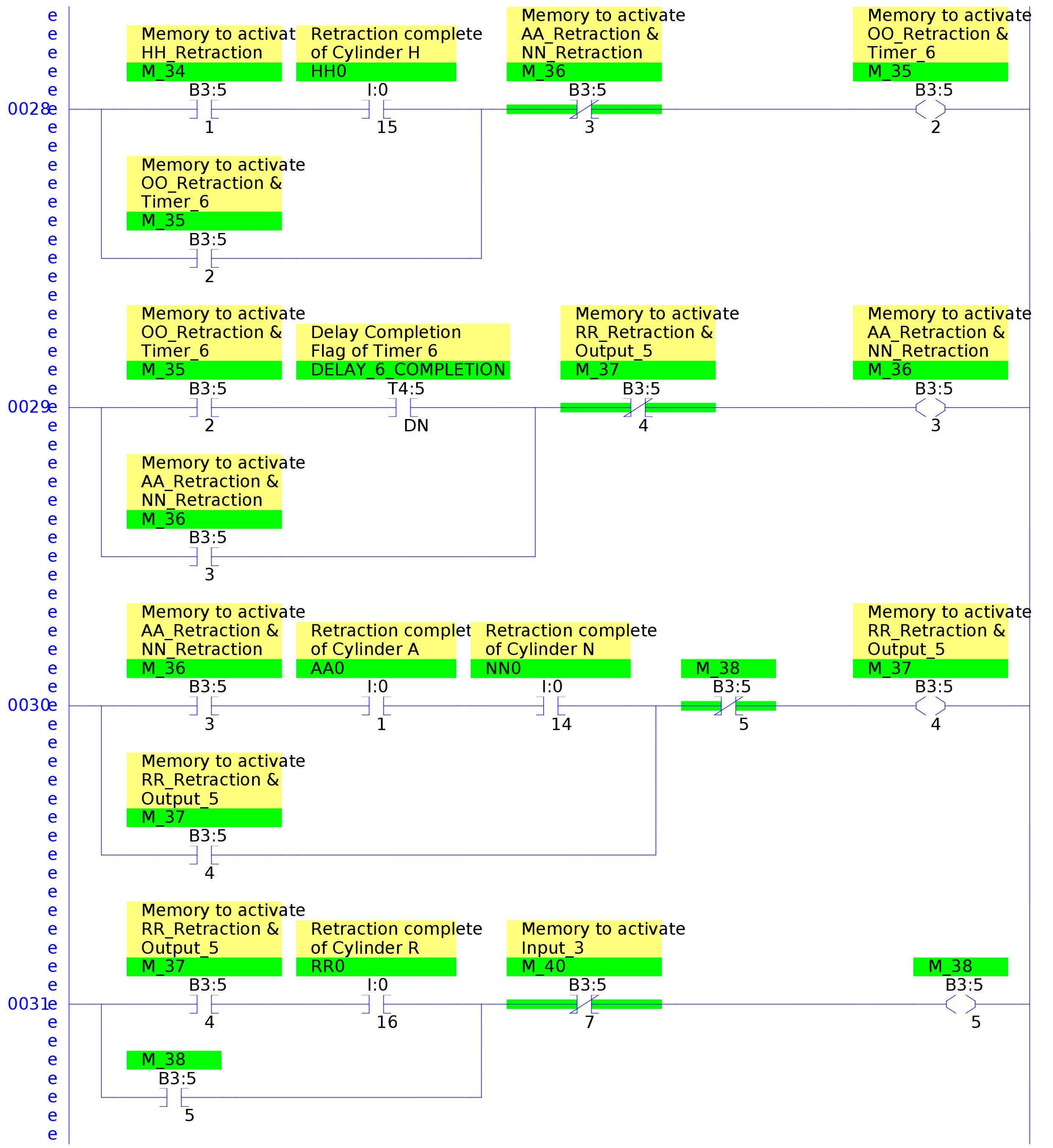
MAIN CYCLE WITH BLOWER

LAD 2 - --- Total Rungs in File = 77



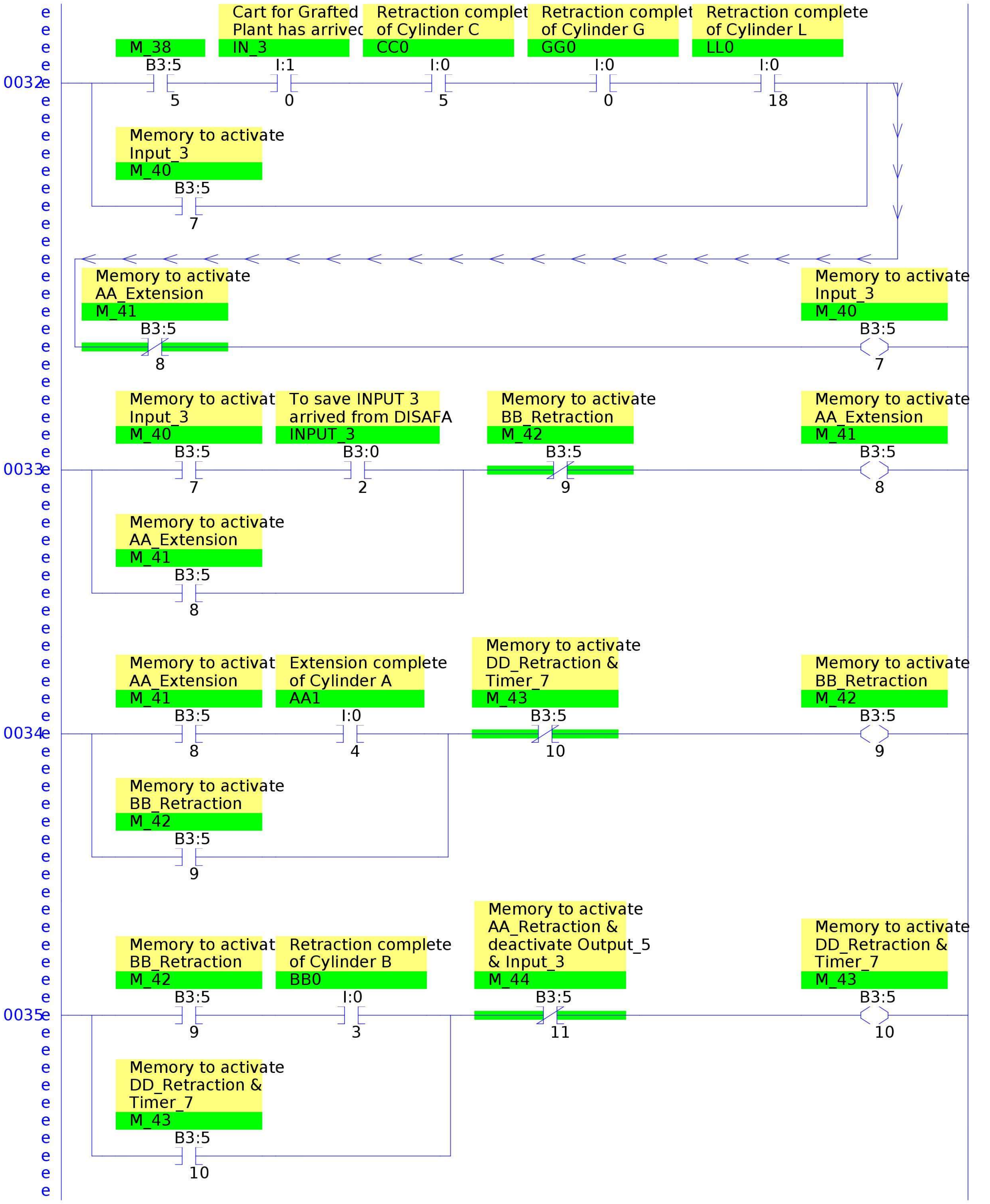
MAIN CYCLE WITH BLOWER

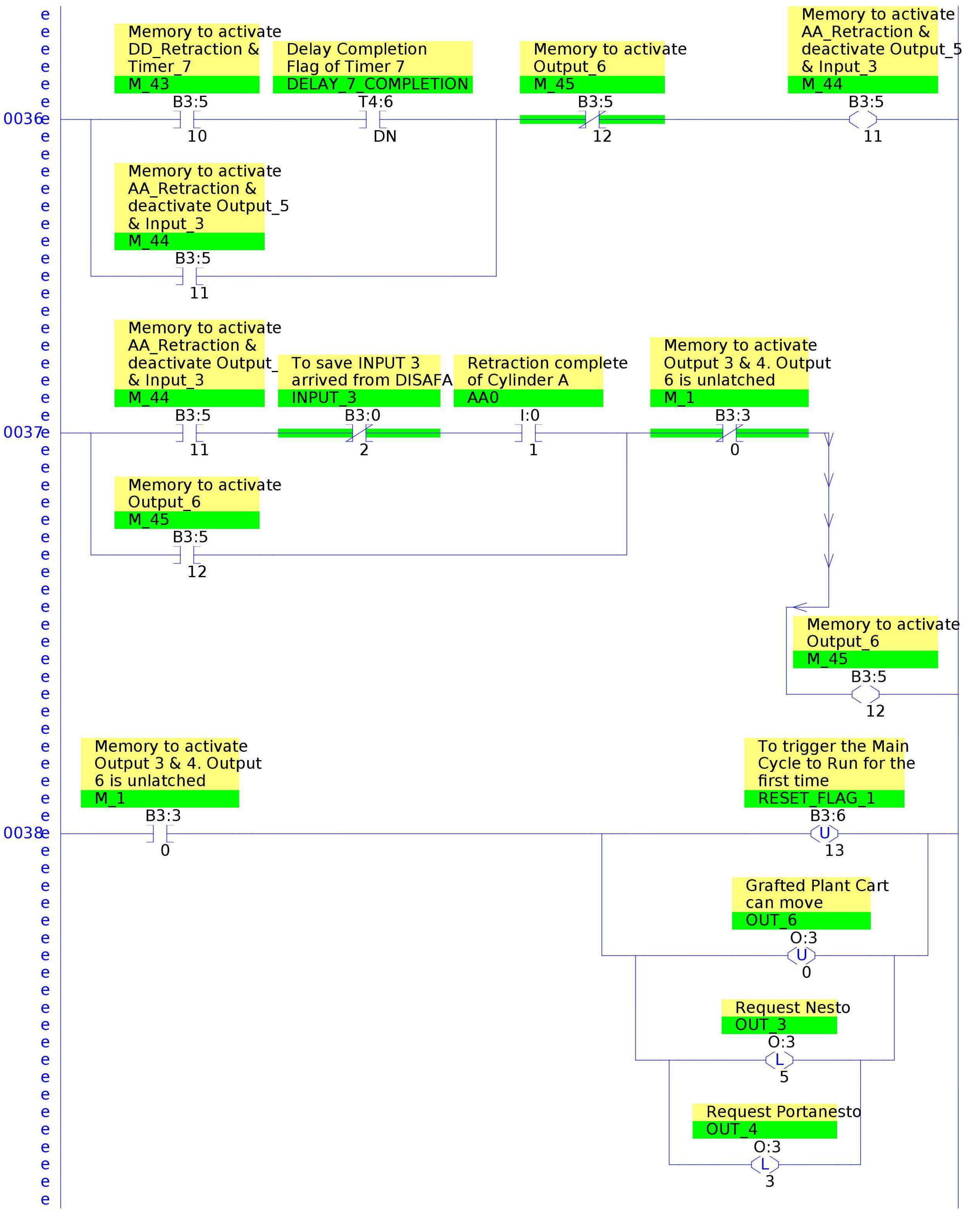
LAD 2 - --- Total Rungs in File = 77

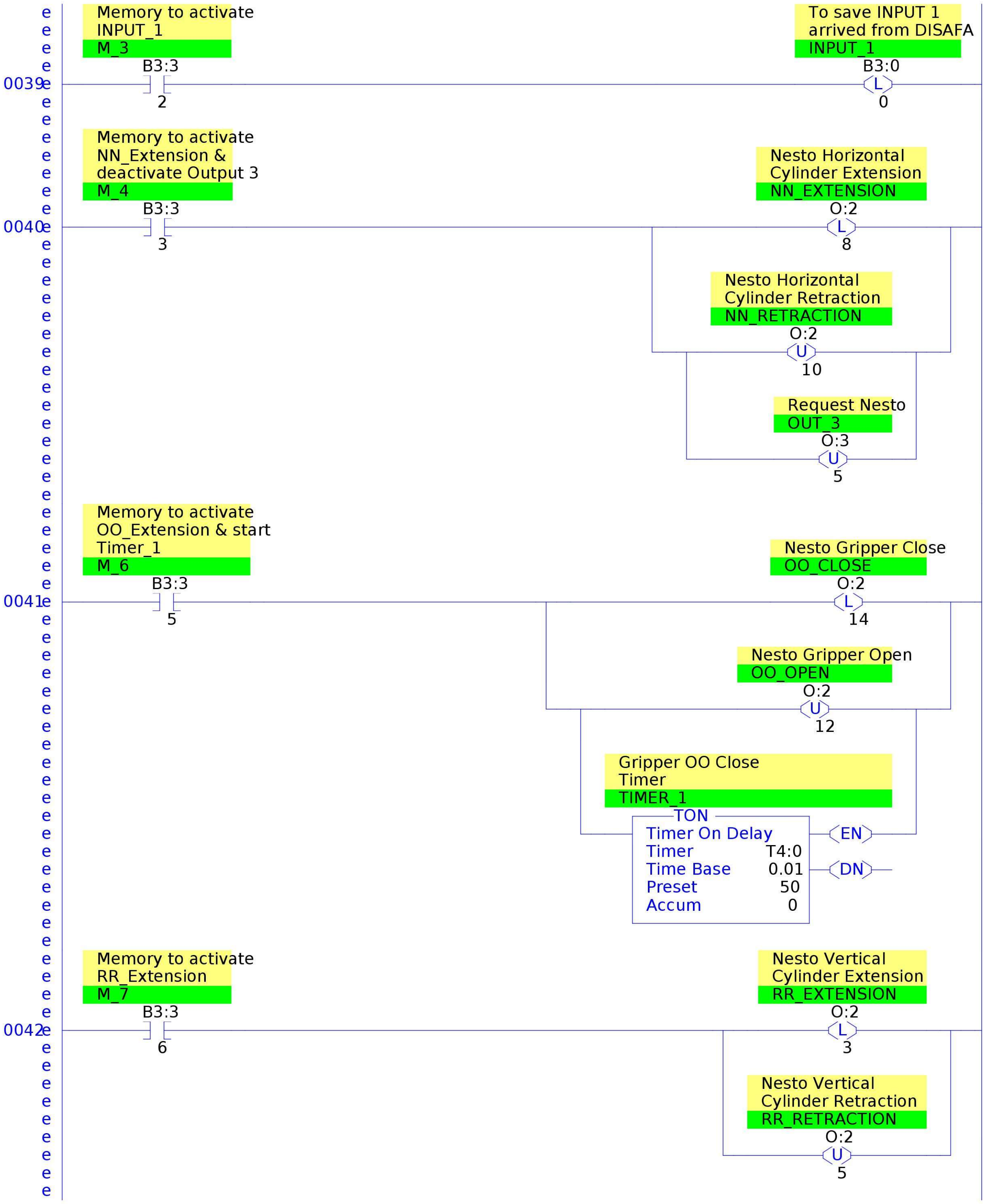


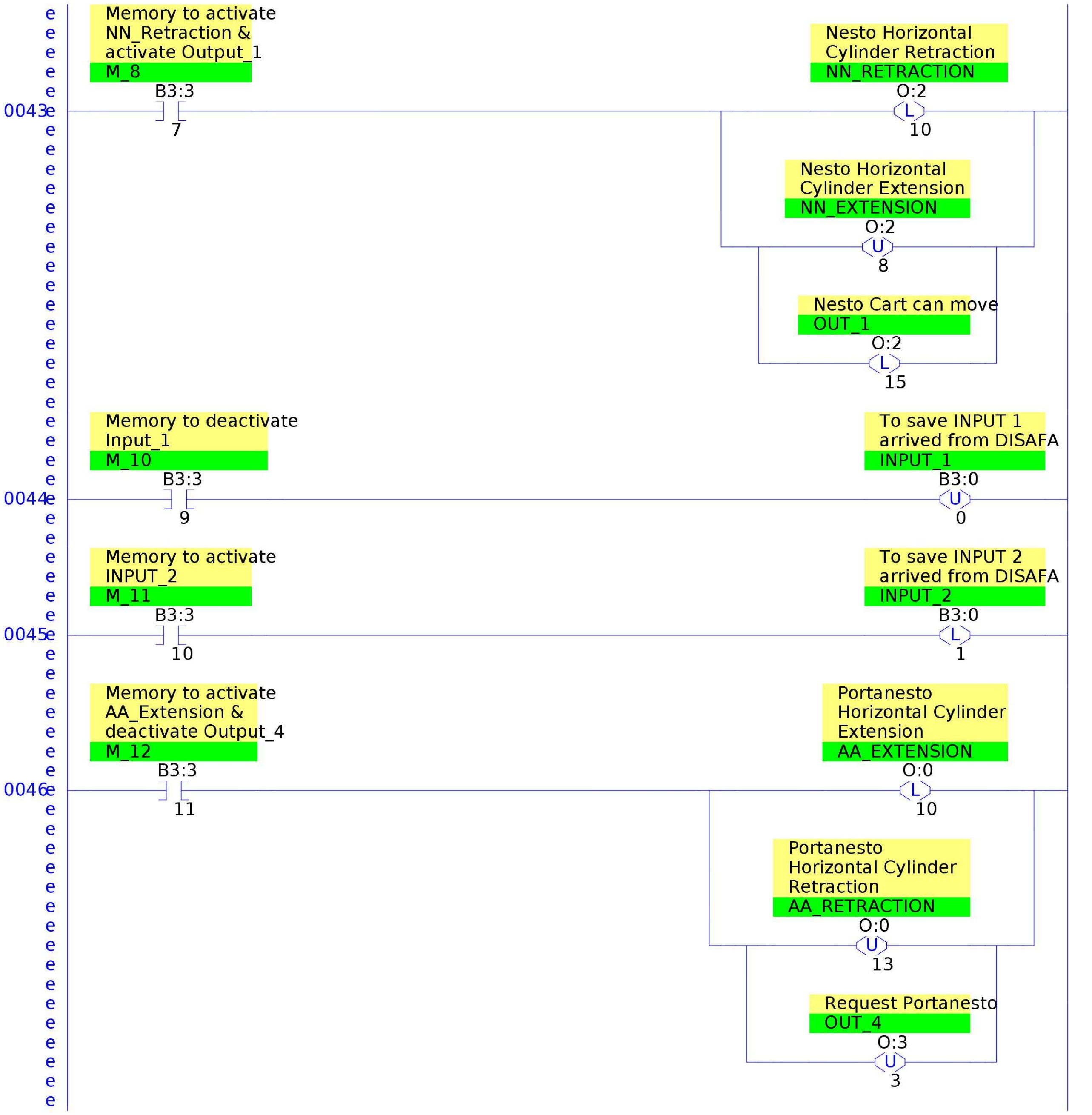
MAIN CYCLE WITH BLOWER

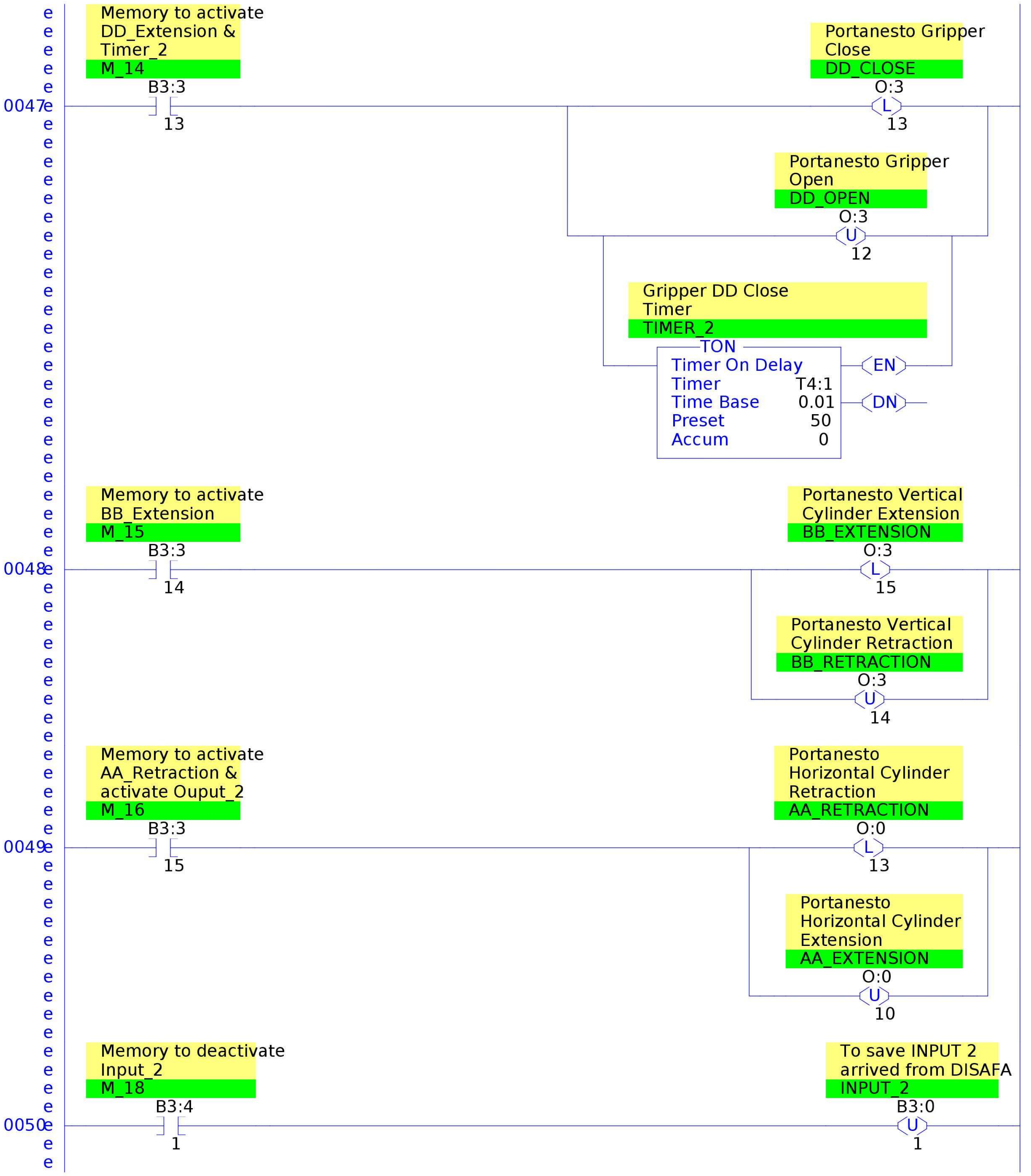
LAD 2 - --- Total Rungs in File = 77

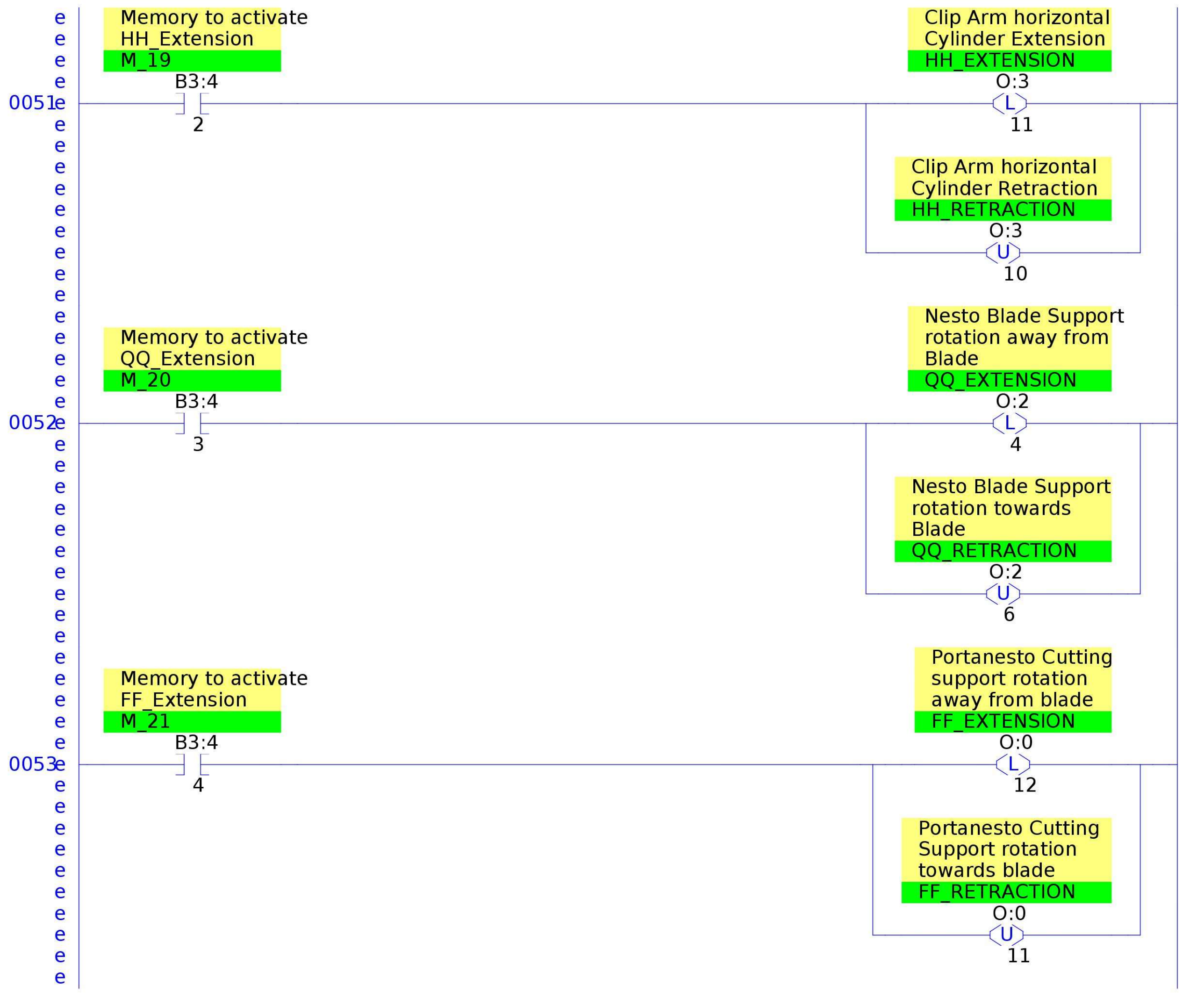


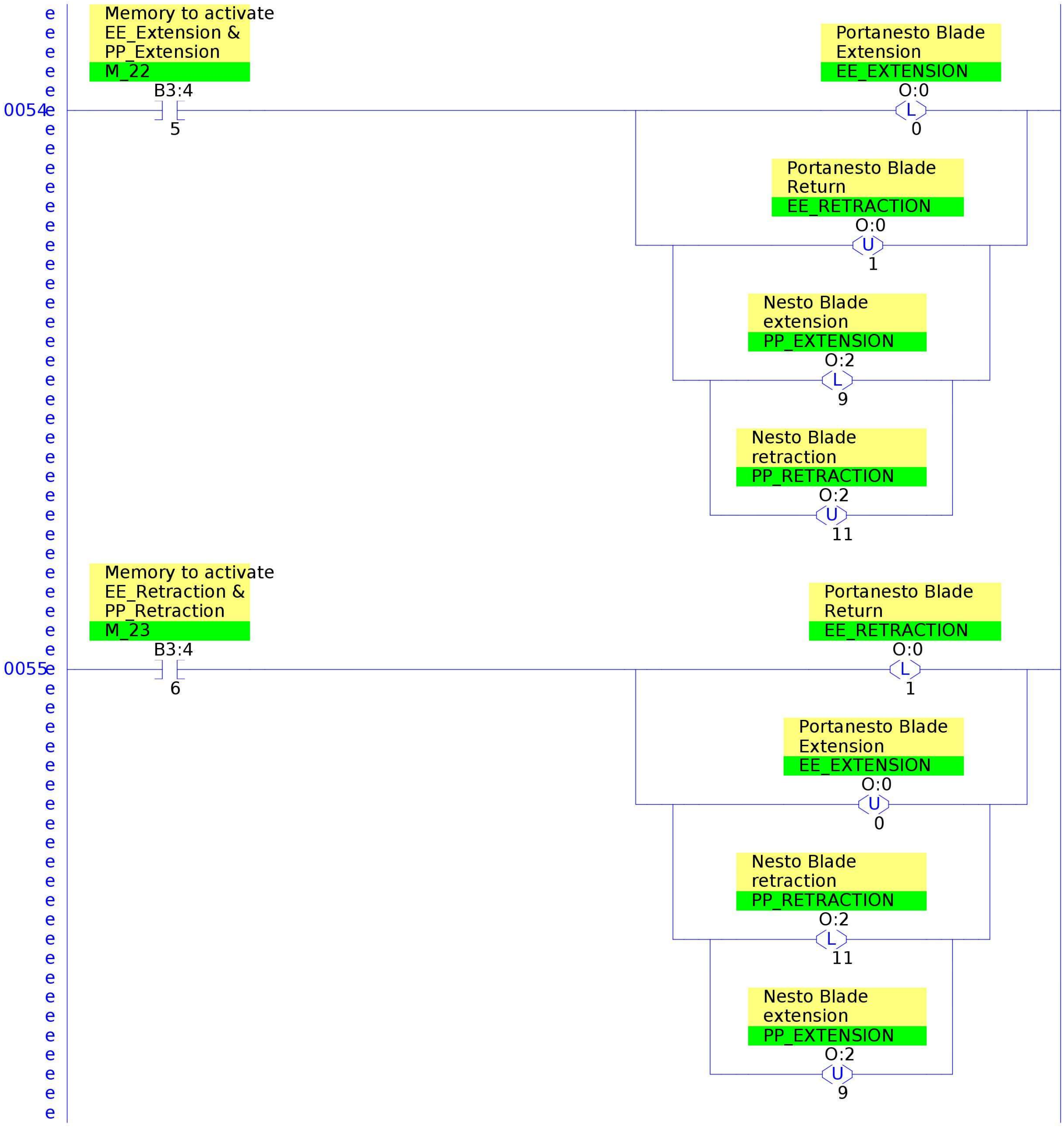

0036
Memory to activate DD_Retraction & Timer_7
M_43
B3:5
10
Delay Completion Flag of Timer 7
DELAY_7_COMPLETION
T4:6
DN
Memory to activate Output_6
M_45
B3:5
12
Memory to activate AA_Retraction & deactivate Output_5 & Input_3
M_44
B3:5
11
Memory to activate AA_Retraction & deactivate Output_5 & Input_3
M_44
B3:5
11
0037
Memory to activate AA_Retraction & deactivate Output_ & Input_3
M_44
B3:5
11
To save INPUT 3 arrived from DISAFA
INPUT_3
B3:0
2
Retraction complete of Cylinder A
AA0
I:0
1
Memory to activate Output 3 & 4. Output 6 is unlatched
M_1
B3:3
0
Memory to activate Output_6
M_45
B3:5
12
Memory to activate Output_6
M_45
B3:5
12
0038
Memory to activate Output 3 & 4. Output 6 is unlatched
M_1
B3:3
0
To trigger the Main Cycle to Run for the first time
RESET_FLAG_1
B3:6
U
13
Grafted Plant Cart can move
OUT_6
O:3
U
0
Request Nesto
OUT_3
O:3
L
5
Request Portanesto
OUT_4
O:3
L
3

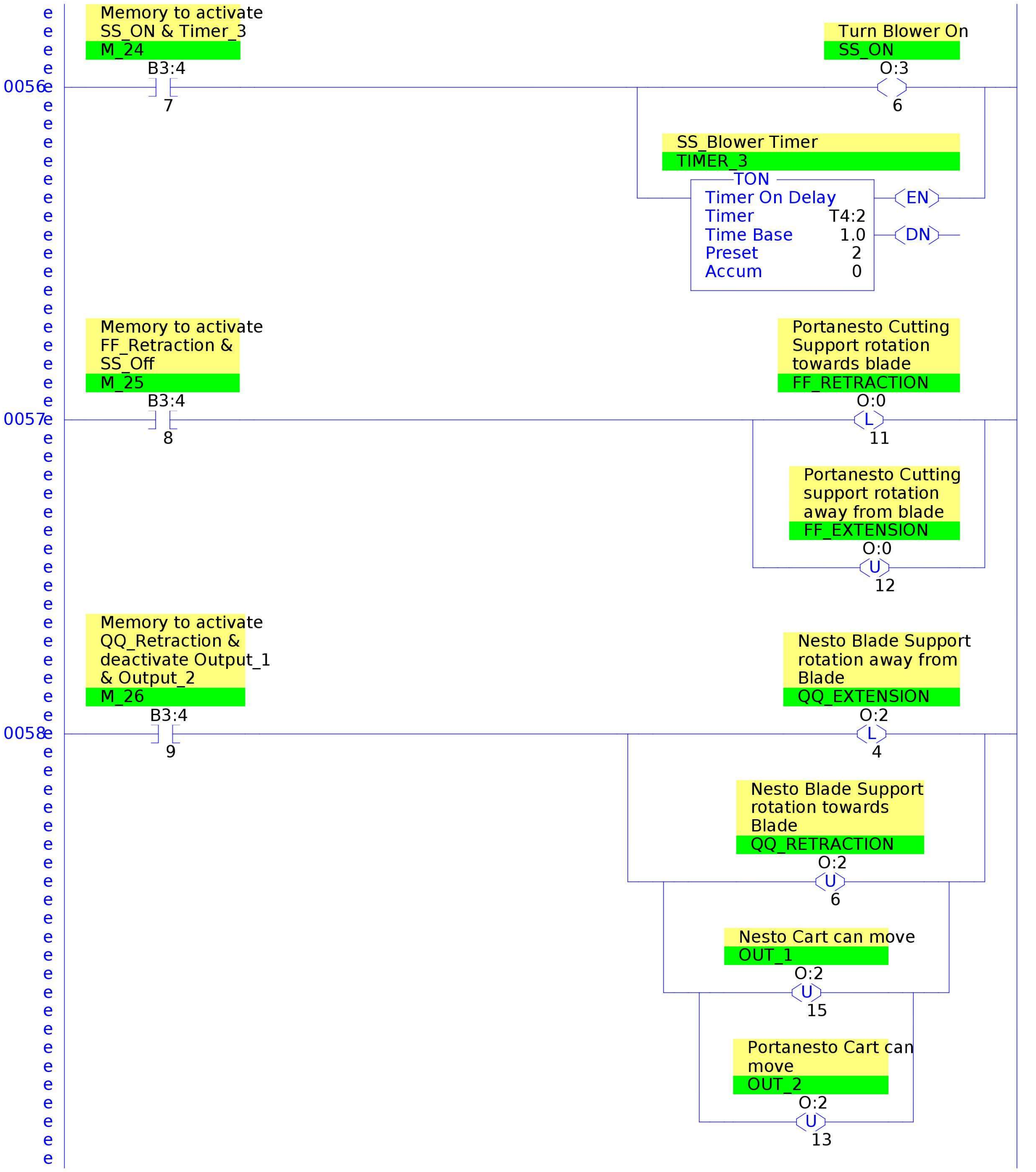

0039
Memory to activate INPUT_1
M_3
B3:3
2
To save INPUT 1 arrived from DISAFA
INPUT_1
B3:0
L
0
0040
Memory to activate NN_Extension & deactivate Output 3
M_4
B3:3
3
Nesto Horizontal Cylinder Extension
NN_EXTENSION
O:2
L
8
Nesto Horizontal Cylinder Retraction
NN_RETRACTION
O:2
U
10
Request Nesto
OUT_3
O:3
U
5
0041
Memory to activate OO_Extension & start Timer_1
M_6
B3:3
5
Nesto Gripper Close
OO_CLOSE
O:2
L
14
Nesto Gripper Open
OO_OPEN
O:2
U
12
Gripper OO Close Timer
TIMER_1
TON
Timer On Delay
Timer T4:0
Time Base 0.01
Preset 50
Accum 0
EN
DN
0042
Memory to activate RR_Extension
M_7
B3:3
6
Nesto Vertical Cylinder Extension
RR_EXTENSION
O:2
L
3
Nesto Vertical Cylinder Retraction
RR_RETRACTION
O:2
U
5

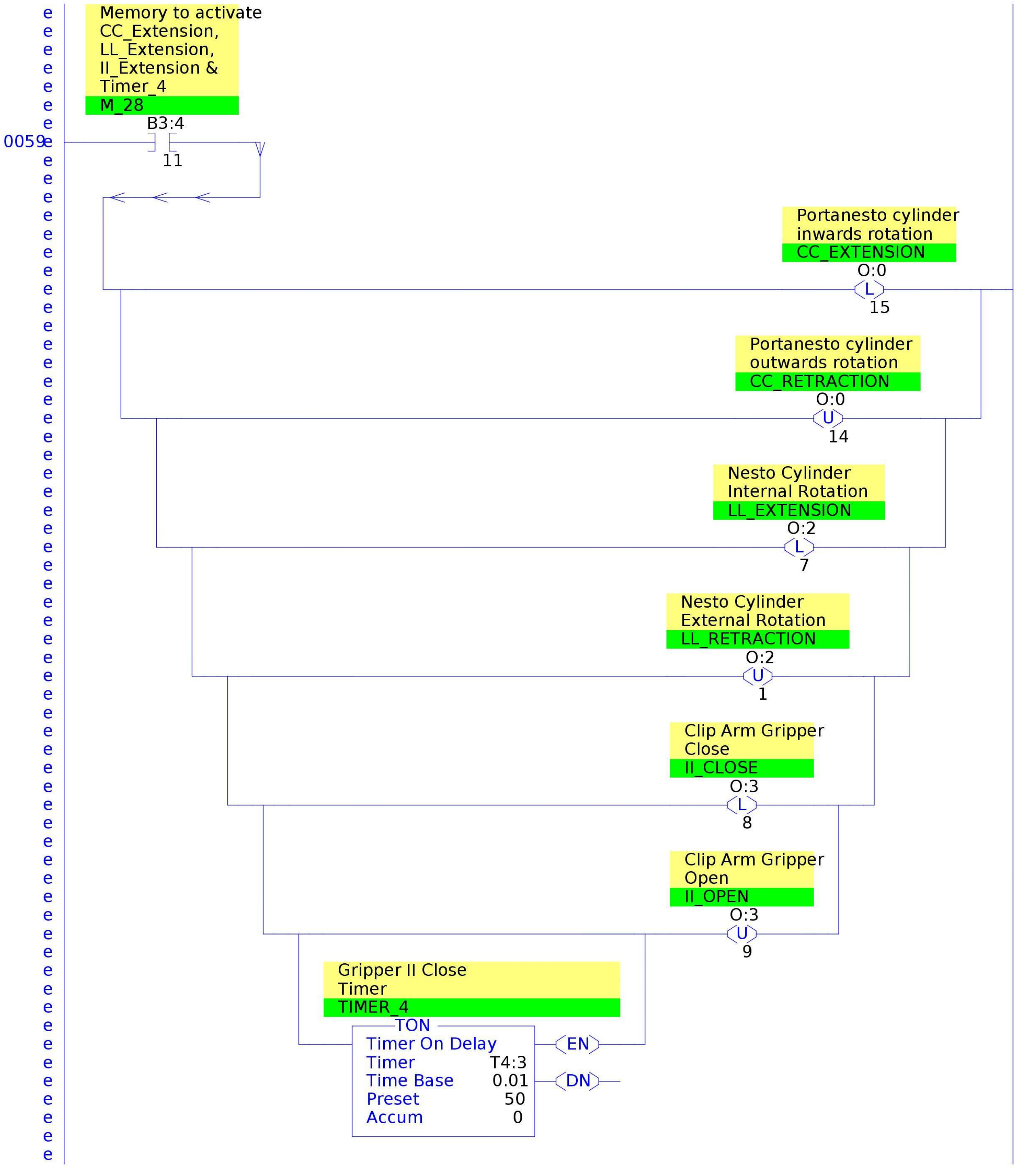

0043
Memory to activate NN_Retraction & activate Output_1
M_8
B3:3
7
Nesto Horizontal Cylinder Retraction
NN_RETRACTION
O:2
L
10
Nesto Horizontal Cylinder Extension
NN_EXTENSION
O:2
U
8
Nesto Cart can move
OUT_1
O:2
L
15
0044
Memory to deactivate Input_1
M_10
B3:3
9
To save INPUT 1 arrived from DISAFA
INPUT_1
B3:0
U
0
0045
Memory to activate INPUT_2
M_11
B3:3
10
To save INPUT 2 arrived from DISAFA
INPUT_2
B3:0
L
1
0046
Memory to activate AA_Extension & deactivate Output_4
M_12
B3:3
11
Portanesto Horizontal Cylinder Extension
AA_EXTENSION
O:0
L
10
Portanesto Horizontal Cylinder Retraction
AA_RETRACTION
O:0
U
13
Request Portanesto
OUT_4
O:3
U
3


0047
Memory to activate DD_Extension & Timer_2
M_14
B3:3
13
Portanesto Gripper Close
DD_CLOSE
O:3
L
13
Portanesto Gripper Open
DD_OPEN
O:3
U
12
Gripper DD Close Timer
TIMER_2
TON
Timer On Delay
Timer T4:1
Time Base 0.01
Preset 50
Accum 0
EN
DN
0048
Memory to activate BB_Extension
M_15
B3:3
14
Portanesto Vertical Cylinder Extension
BB_EXTENSION
O:3
L
15
Portanesto Vertical Cylinder Retraction
BB_RETRACTION
O:3
U
14
0049
Memory to activate AA_Retraction & activate Ouput_2
M_16
B3:3
15
Portanesto Horizontal Cylinder Retraction
AA_RETRACTION
O:0
L
13
Portanesto Horizontal Cylinder Extension
AA_EXTENSION
O:0
U
10
0050
Memory to deactivate Input_2
M_18
B3:4
1
To save INPUT 2 arrived from DISAFA
INPUT_2
B3:0
U
1


0051
Memory to activate HH_Extension
M_19
B3:4
2
Clip Arm horizontal Cylinder Extension
HH_EXTENSION
O:3
L
11
Clip Arm horizontal Cylinder Retraction
HH_RETRACTION
O:3
U
10
0052
Memory to activate QQ_Extension
M_20
B3:4
3
Nesto Blade Support rotation away from Blade
QQ_EXTENSION
O:2
L
4
Nesto Blade Support rotation towards Blade
QQ_RETRACTION
O:2
U
6
0053
Memory to activate FF_Extension
M_21
B3:4
4
Portanesto Cutting support rotation away from blade
FF_EXTENSION
O:0
L
12
Portanesto Cutting Support rotation towards blade
FF_RETRACTION
O:0
U
11

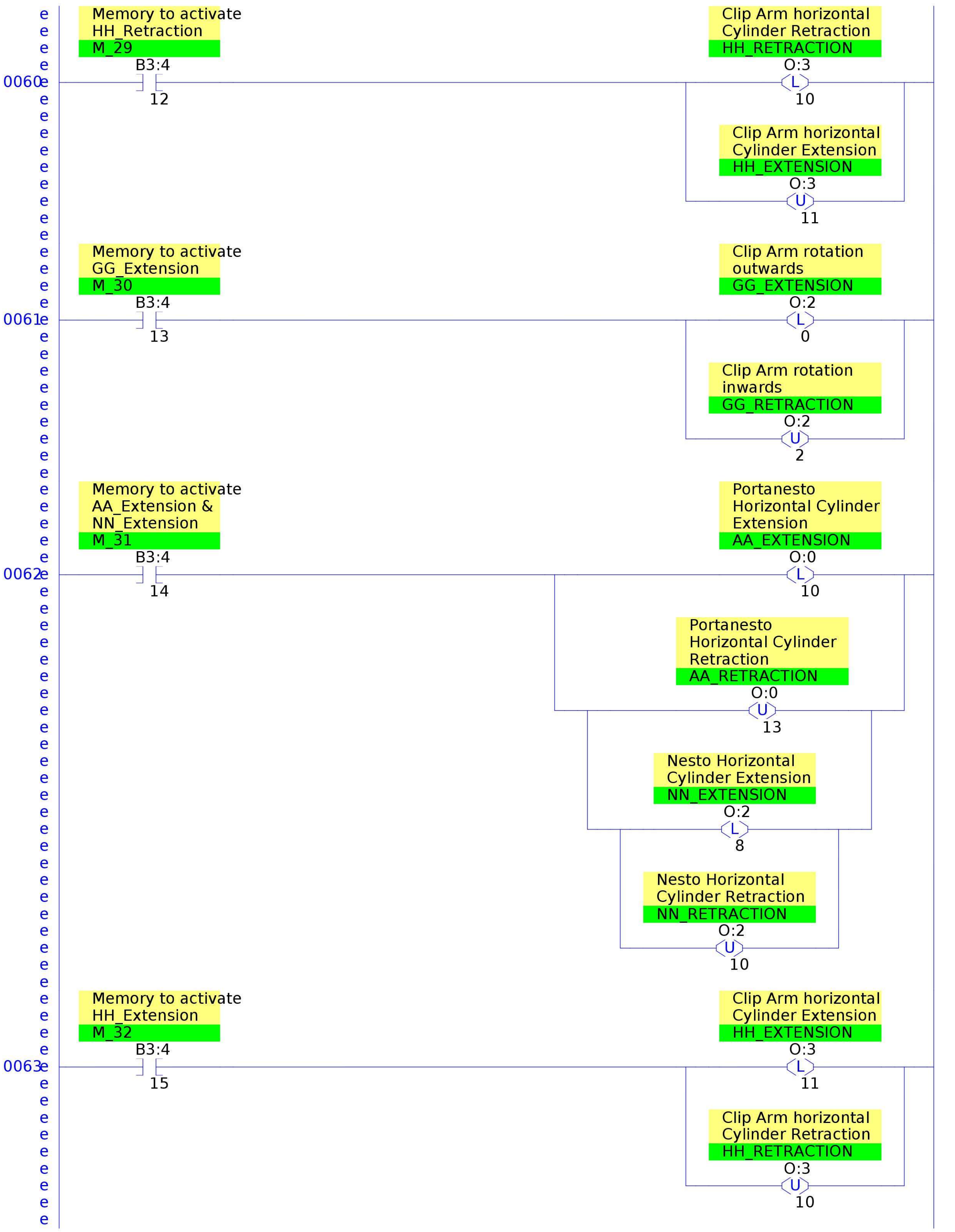

0054
Memory to activate EE_Extension & PP_Extension
M_22
B3:4
5
Portanesto Blade Extension
EE_EXTENSION
O:0
L
0
Portanesto Blade Return
EE_RETRACTION
O:0
U
1
Nesto Blade extension
PP_EXTENSION
O:2
L
9
Nesto Blade retraction
PP_RETRACTION
O:2
U
11
0055
Memory to activate EE_Retraction & PP_Retraction
M_23
B3:4
6
Portanesto Blade Return
EE_RETRACTION
O:0
L
1
Portanesto Blade Extension
EE_EXTENSION
O:0
U
0
Nesto Blade retraction
PP_RETRACTION
O:2
L
11
Nesto Blade extension
PP_EXTENSION
O:2
U
9

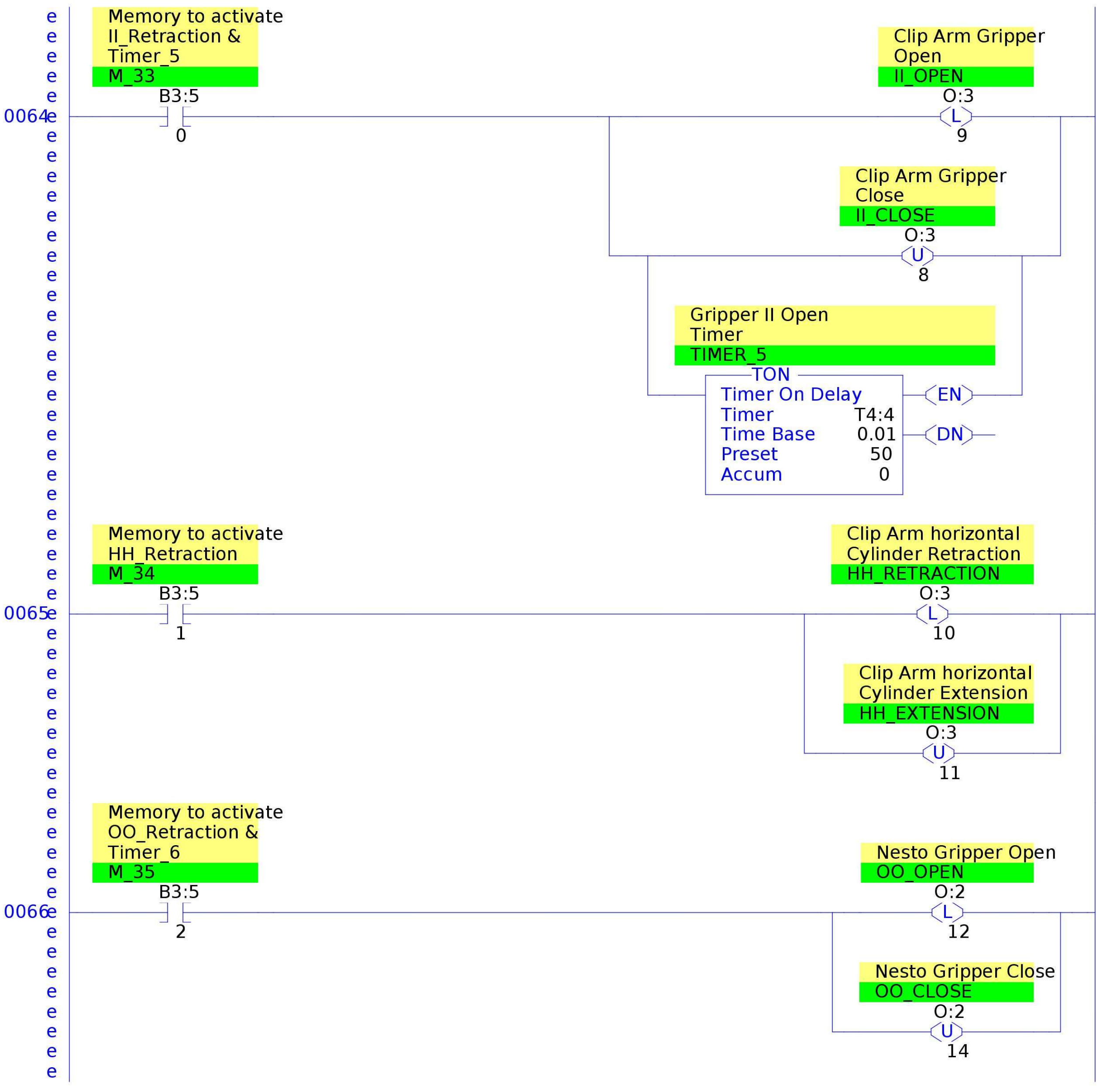

0056
Memory to activate SS_ON & Timer_3
M_24
B3:4
7
Turn Blower On
SS_ON
O:3
6
SS_Blower Timer
TIMER_3
TON
Timer On Delay
Timer T4:2
Time Base 1.0
Preset 2
Accum 0
EN
DN
0057
Memory to activate FF_Retraction & SS_Off
M_25
B3:4
8
Portanesto Cutting Support rotation towards blade
FF_RETRACTION
O:0
L
11
Portanesto Cutting support rotation away from blade
FF_EXTENSION
O:0
U
12
0058
Memory to activate QQ_Retraction & deactivate Output_1 & Output_2
M_26
B3:4
9
Nesto Blade Support rotation away from Blade
QQ_EXTENSION
O:2
L
4
Nesto Blade Support rotation towards Blade
QQ_RETRACTION
O:2
U
6
Nesto Cart can move
OUT_1
O:2
U
15
Portanesto Cart can move
OUT_2
O:2
U
13

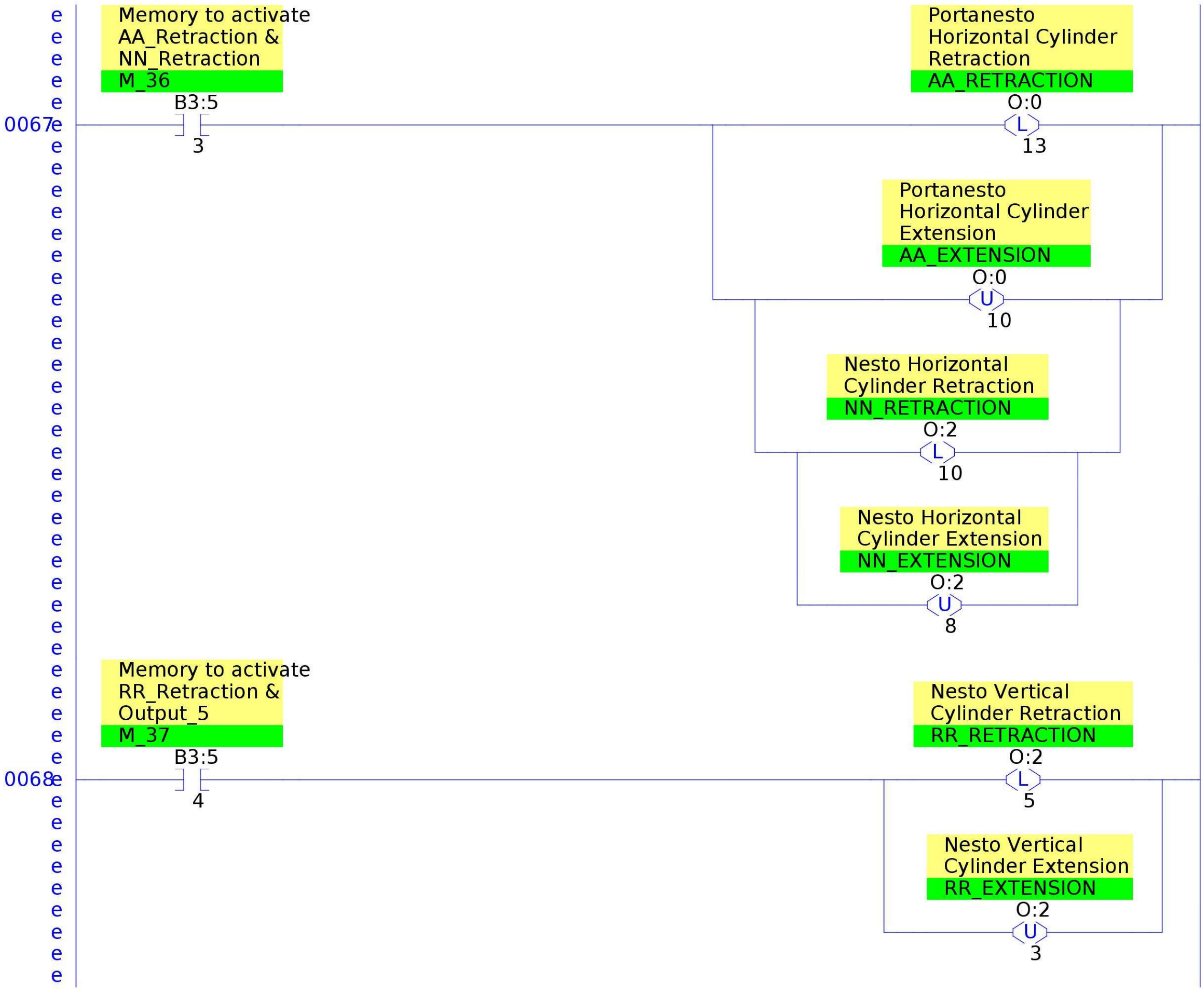

0059
Memory to activate CC_Extension, LL_Extension, II_Extension & Timer_4
M_28
B3:4
11
Portanesto cylinder inwards rotation
CC_EXTENSION
O:0
L
15
Portanesto cylinder outwards rotation
CC_RETRACTION
O:0
U
14
Nesto Cylinder Internal Rotation
LL_EXTENSION
O:2
L
7
Nesto Cylinder External Rotation
LL_RETRACTION
O:2
U
1
Clip Arm Gripper Close
II_CLOSE
O:3
L
8
Clip Arm Gripper Open
II_OPEN
O:3
U
9
Gripper II Close Timer
TIMER_4
TON
Timer On Delay
Timer T4:3
Time Base 0.01
Preset 50
Accum 0
EN
DN

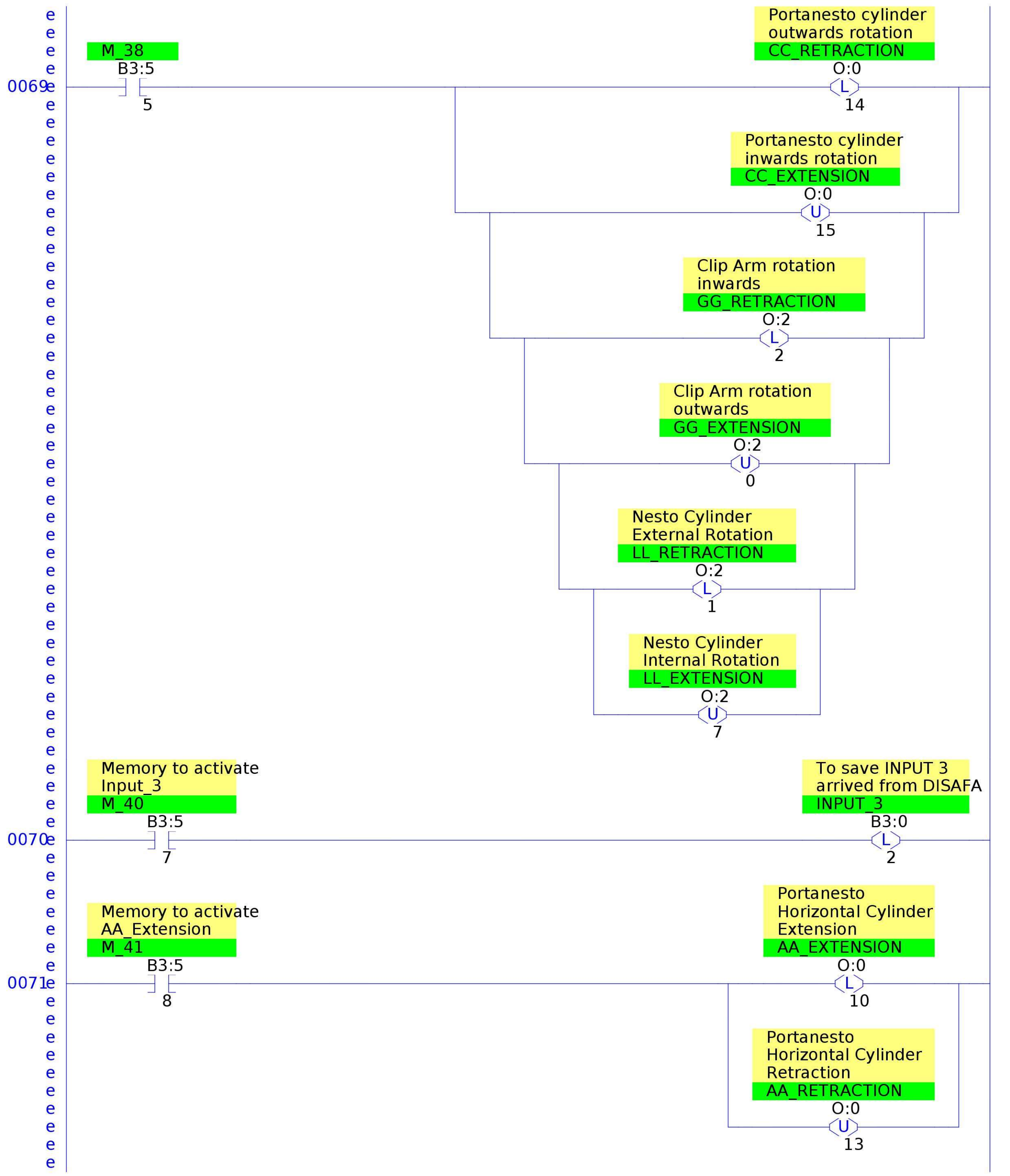
MAIN CYCLE WITH BLOWER

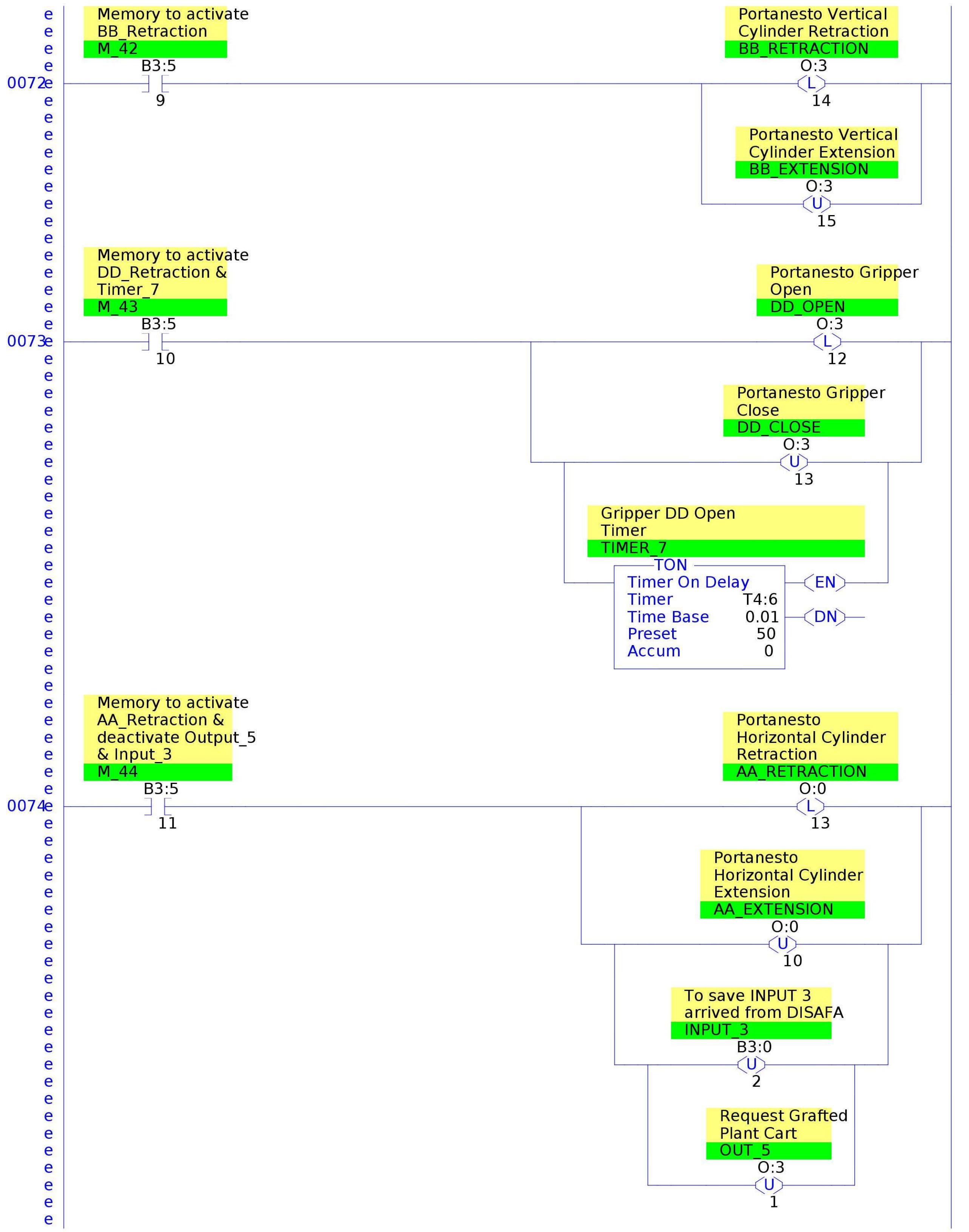
LAD 2 - --- Total Rungs in File = 77

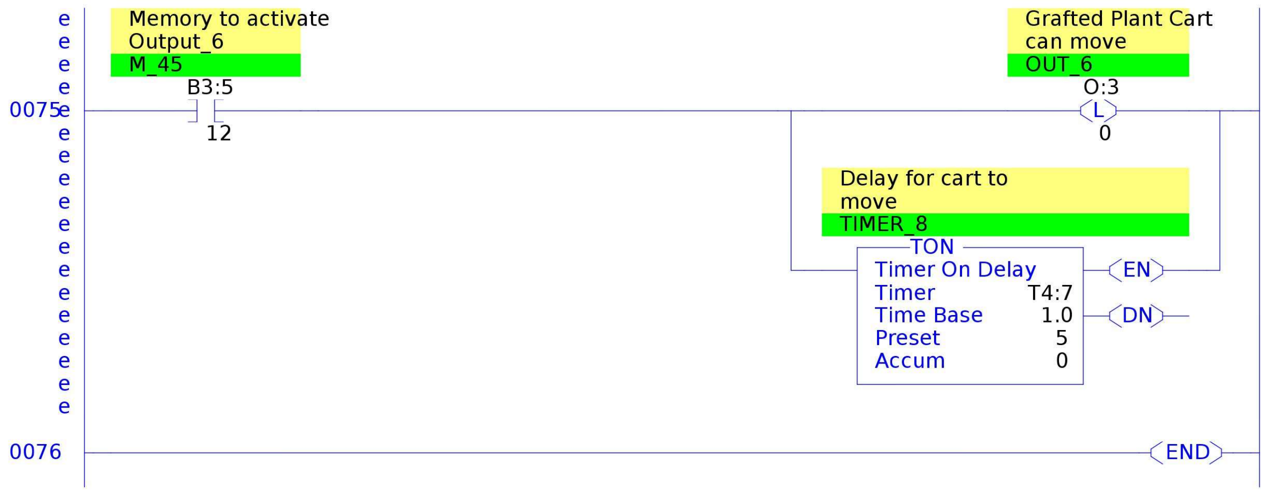



0064
Memory to activate II_Retraction & Timer_5
M_33
B3:5
0
Clip Arm Gripper Open
II_OPEN
O:3
L
9
Clip Arm Gripper Close
II_CLOSE
O:3
U
8
Gripper II Open Timer
TIMER_5
TON
Timer On Delay
Timer T4:4
Time Base 0.01
Preset 50
Accum 0
EN
DN
0065
Memory to activate HH_Retraction
M_34
B3:5
1
Clip Arm horizontal Cylinder Retraction
HH_RETRACTION
O:3
L
10
Clip Arm horizontal Cylinder Extension
HH_EXTENSION
O:3
U
11
0066
Memory to activate OO_Retraction & Timer_6
M_35
B3:5
2
Nesto Gripper Open
OO_OPEN
O:2
L
12
Nesto Gripper Close
OO_CLOSE
O:2
U
14

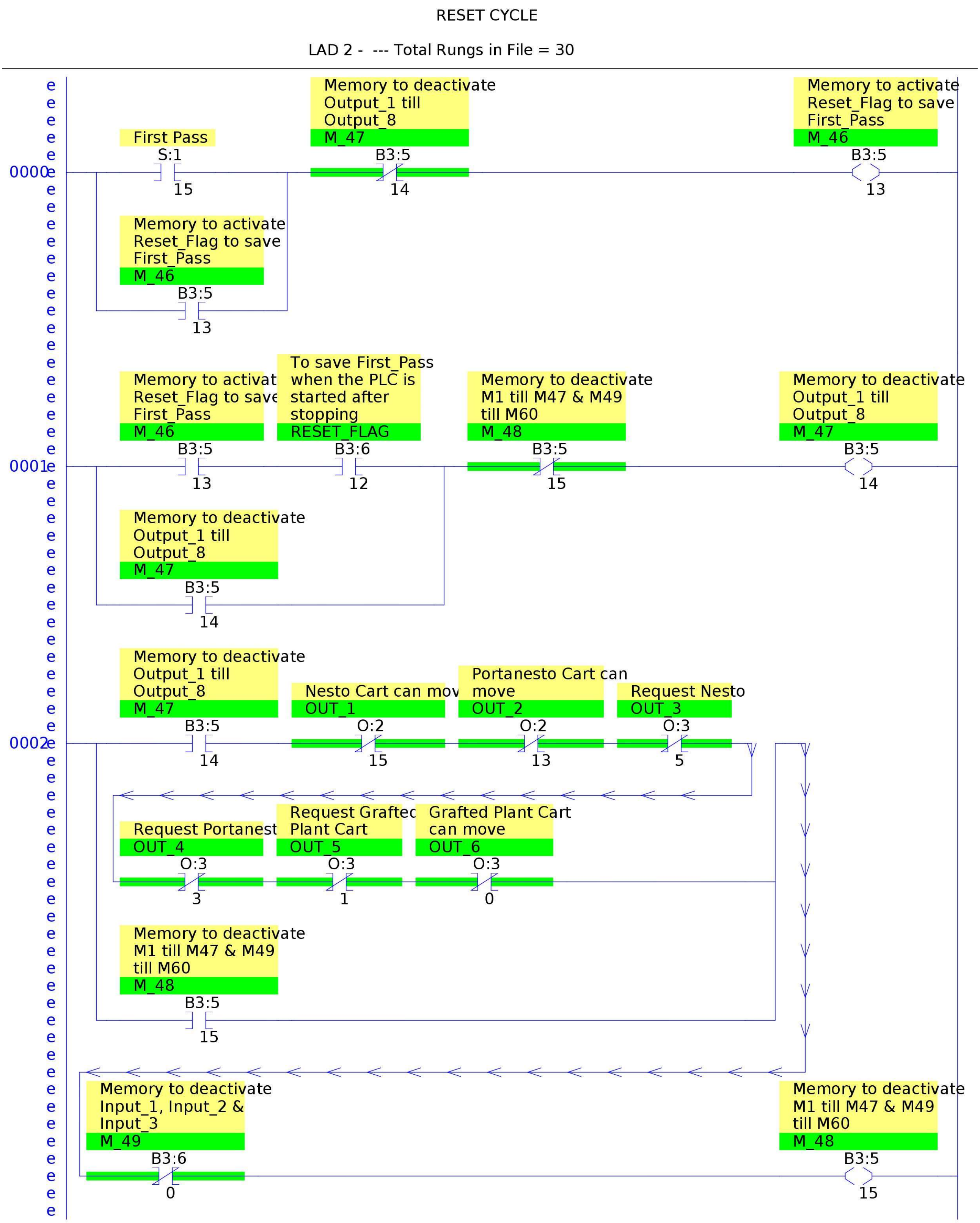

0067
Memory to activate AA_Retraction & NN_Retraction
M_36
B3:5
3
Portanesto Horizontal Cylinder Retraction
AA_RETRACTION
O:0
L
13
Portanesto Horizontal Cylinder Extension
AA_EXTENSION
O:0
U
10
Nesto Horizontal Cylinder Retraction
NN_RETRACTION
O:2
L
10
Nesto Horizontal Cylinder Extension
NN_EXTENSION
O:2
U
8
0068
Memory to activate RR_Retraction & Output_5
M_37
B3:5
4
Nesto Vertical Cylinder Retraction
RR_RETRACTION
O:2
L
5
Nesto Vertical Cylinder Extension
RR_EXTENSION
O:2
U
3


0069
M_38
B3:5
5
Portanesto cylinder outwards rotation
CC_RETRACTION
O:0
L
14
Portanesto cylinder inwards rotation
CC_EXTENSION
O:0
U
15
Clip Arm rotation inwards
GG_RETRACTION
O:2
L
2
Clip Arm rotation outwards
GG_EXTENSION
O:2
U
0
Nesto Cylinder External Rotation
LL_RETRACTION
O:2
L
1
Nesto Cylinder Internal Rotation
LL_EXTENSION
O:2
U
7
0070
Memory to activate Input_3
M_40
B3:5
7
To save INPUT 3 arrived from DISAFA
INPUT_3
B3:0
L
2
0071
Memory to activate AA_Extension
M_41
B3:5
8
Portanesto Horizontal Cylinder Extension
AA_EXTENSION
O:0
L
10
Portanesto Horizontal Cylinder Retraction
AA_RETRACTION
O:0
U
13


0072
Memory to activate BB_Retraction
M_42
B3:5
9
Portanesto Vertical Cylinder Retraction
BB_RETRACTION
O:3
L
14
Portanesto Vertical Cylinder Extension
BB_EXTENSION
O:3
U
15
0073
Memory to activate DD_Retraction & Timer_7
M_43
B3:5
10
Portanesto Gripper Open
DD_OPEN
O:3
L
12
Portanesto Gripper Close
DD_CLOSE
O:3
U
13
Gripper DD Open Timer
TIMER_7
TON
Timer On Delay
Timer T4:6
Time Base 0.01
Preset 50
Accum 0
EN
DN
0074
Memory to activate AA_Retraction & deactivate Output_5 & Input_3
M_44
B3:5
11
Portanesto Horizontal Cylinder Retraction
AA_RETRACTION
O:0
L
13
Portanesto Horizontal Cylinder Extension
AA_EXTENSION
O:0
U
10
To save INPUT 3 arrived from DISAFA
INPUT_3
B3:0
U
2
Request Grafted Plant Cart
OUT_5
O:3
U
1

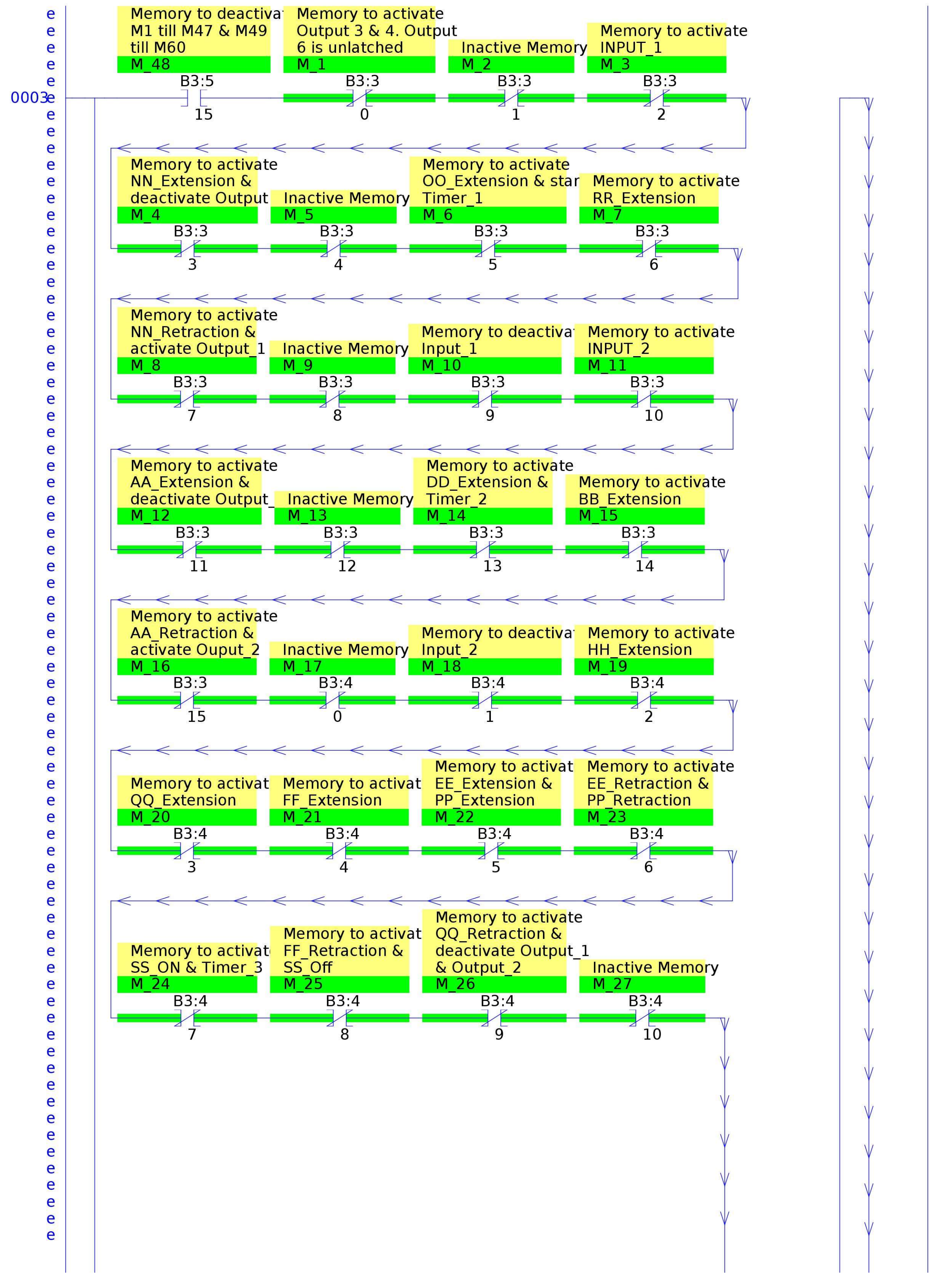

0075
Memory to activate Output_6
M_45
B3:5
12
Grafted Plant Cart can move
OUT_6
O:3
L
0
Delay for cart to move
TIMER_8
TON
Timer On Delay
Timer T4:7
Time Base 1.0
Preset 5
Accum 0
EN
DN
0076
END

Appendix 2 -Reset Cycle



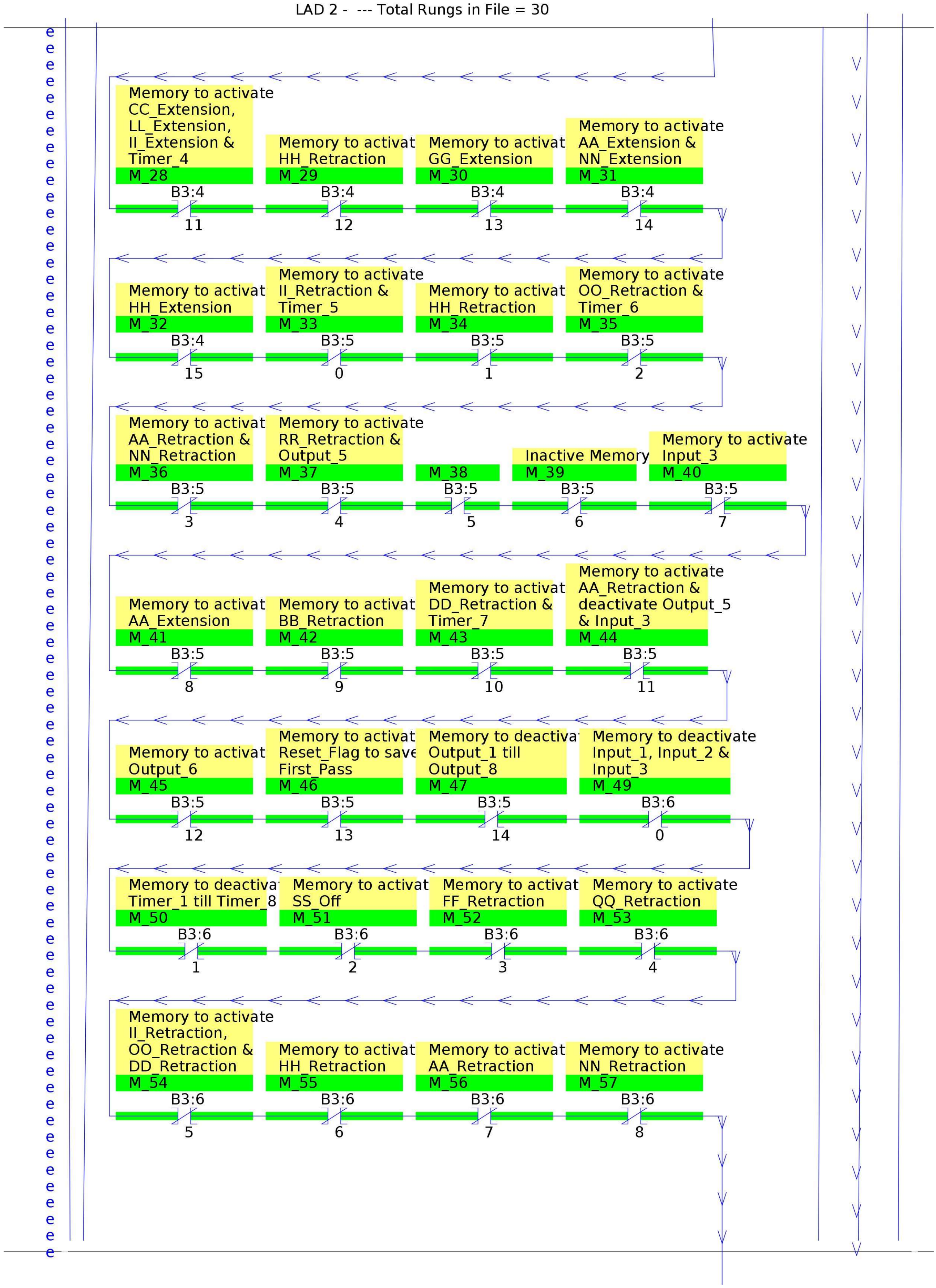
RESET CYCLE

LAD 2 - --- Total Rungs in File = 30



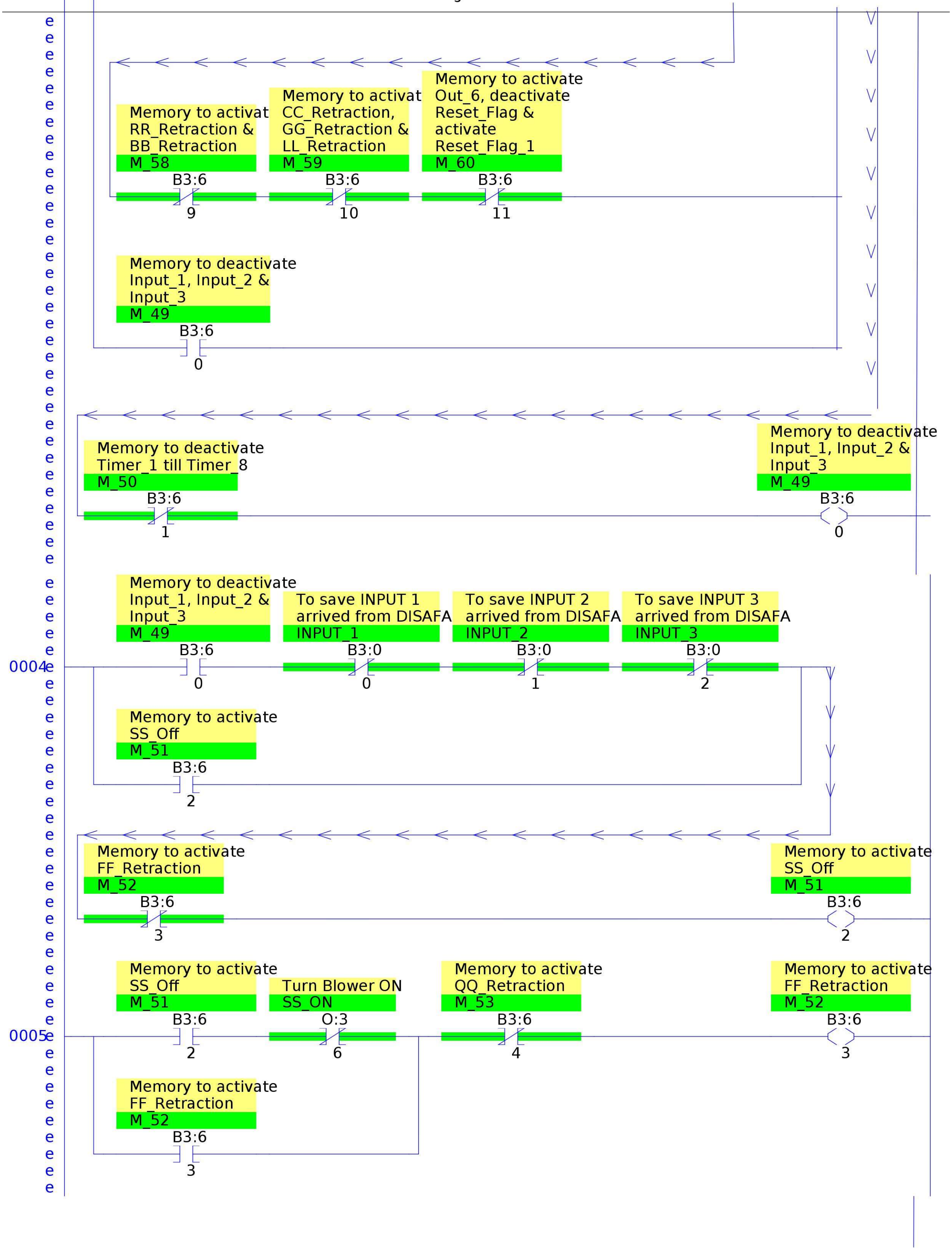
RESET CYCLE

LAD 2 - --- Total Rungs in File = 30



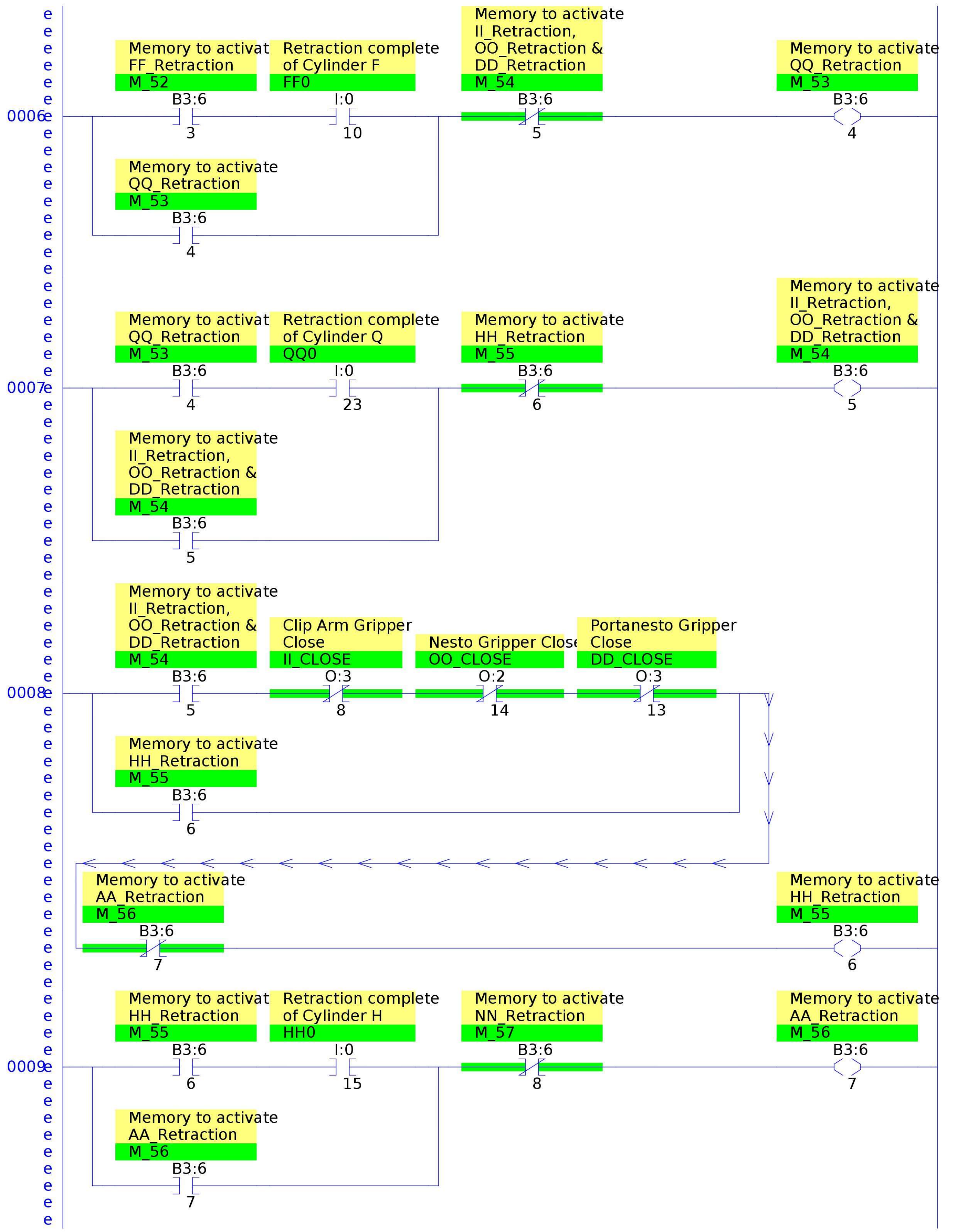
RESET CYCLE

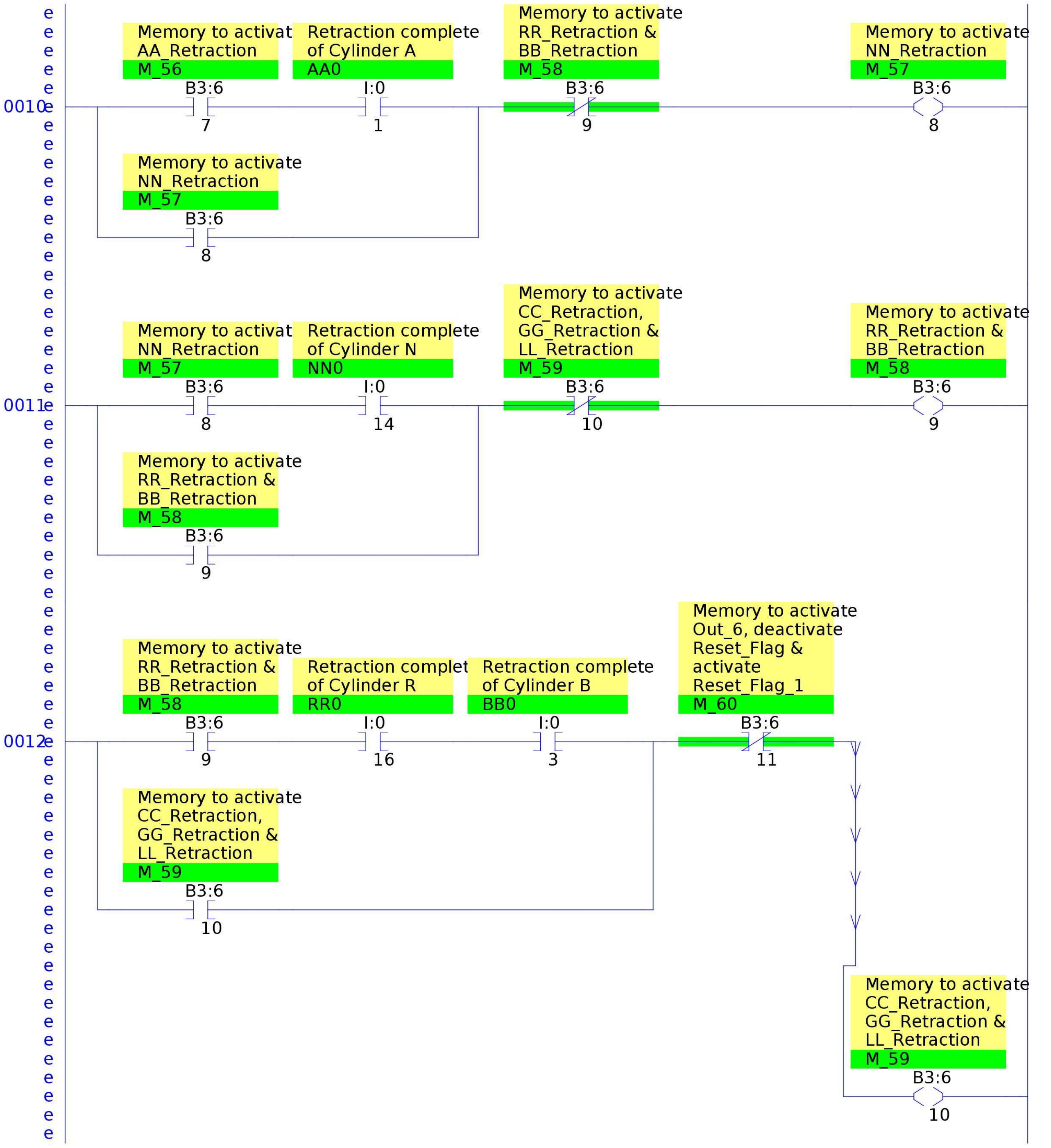
LAD 2 - --- Total Rungs in File = 30

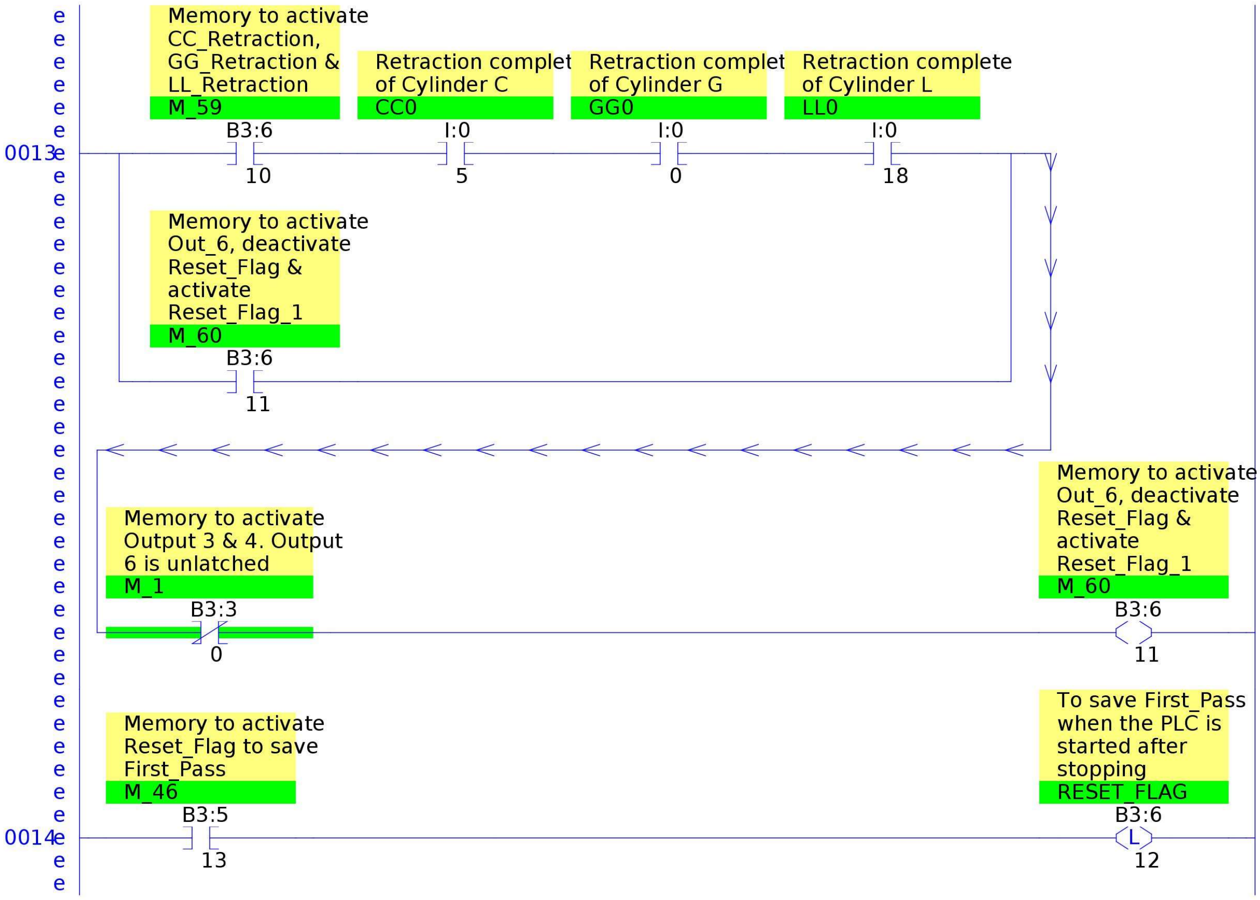


RESET CYCLE

LAD 2 - --- Total Rungs in File = 30

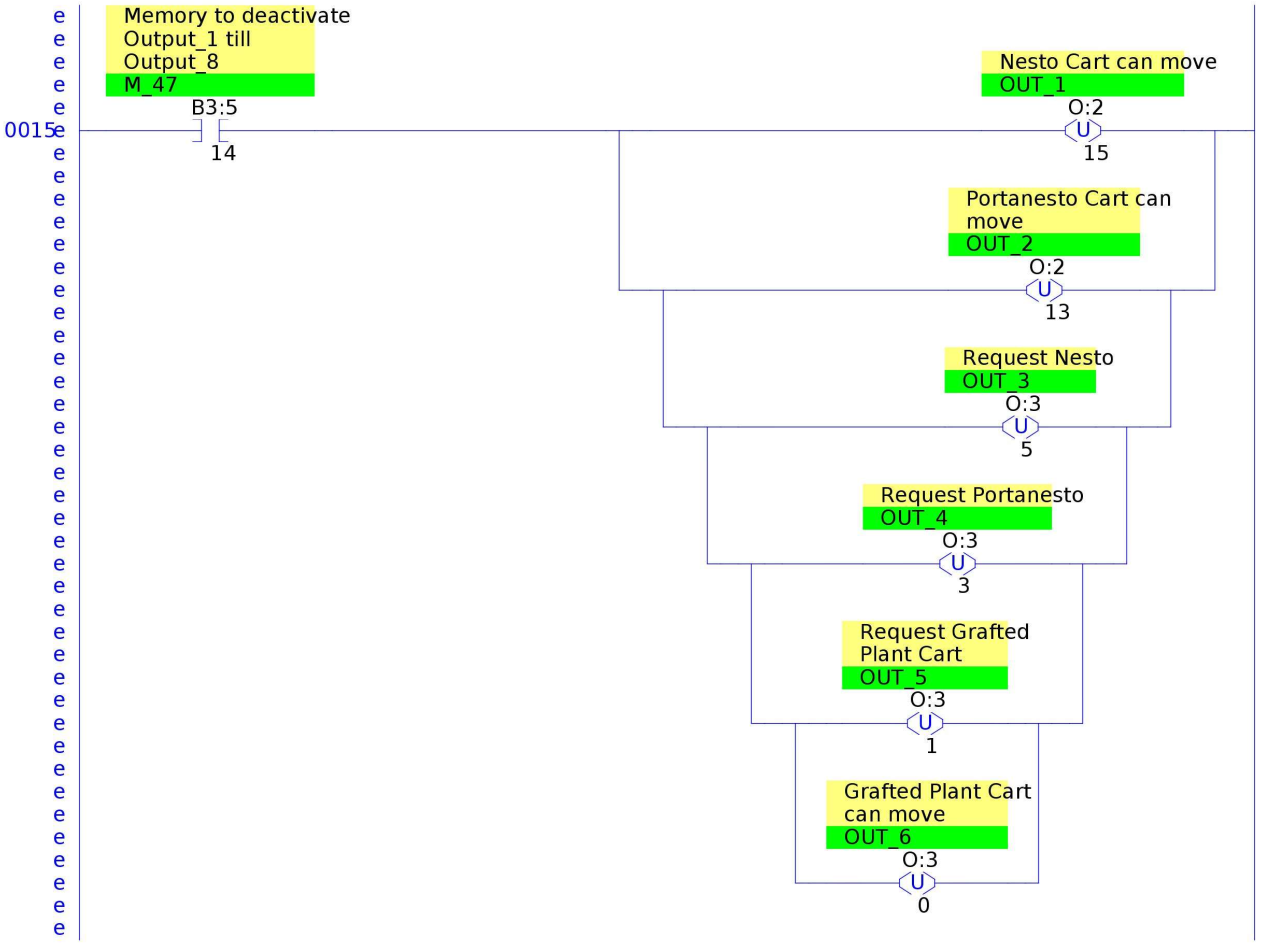


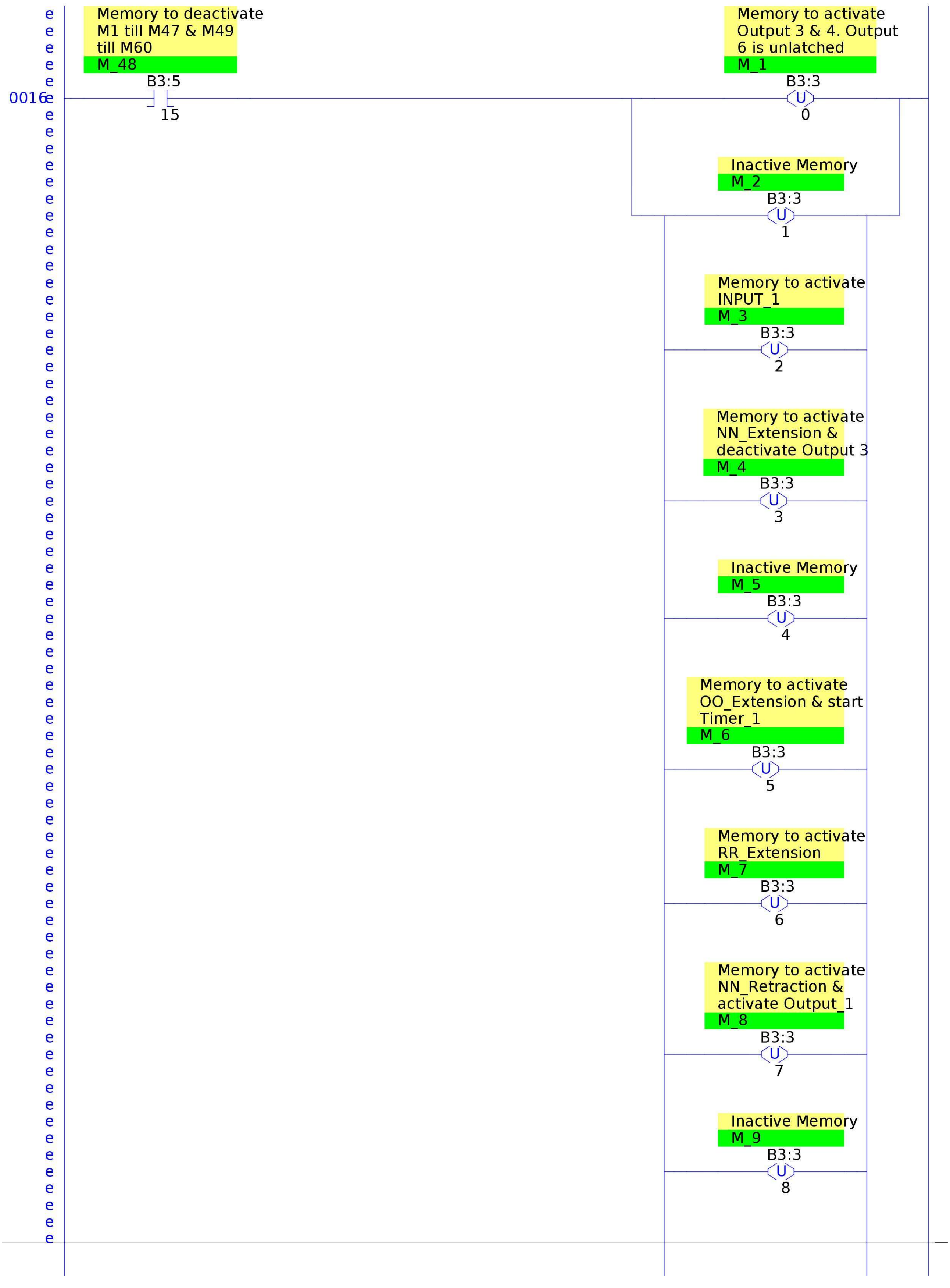

0010
Memory to activat
AA_Retraction
M_56
B3:6
7
Retraction complete
of Cylinder A
AA0
I:0
1
Memory to activate
NN_Retraction
M_57
B3:6
8
Memory to activate
RR_Retraction &
BB_Retraction
M_58
B3:6
9
Memory to activate
NN_Retraction
M_57
B3:6
8
0011
Memory to activat
NN_Retraction
M_57
B3:6
8
Retraction complete
of Cylinder N
NN0
I:0
14
Memory to activate
RR_Retraction &
BB_Retraction
M_58
B3:6
9
Memory to activate
CC_Retraction,
GG_Retraction &
LL_Retraction
M_59
B3:6
10
Memory to activate
RR_Retraction &
BB_Retraction
M_58
B3:6
9
0012
Memory to activate
RR_Retraction &
BB_Retraction
M_58
B3:6
9
Retraction complet
of Cylinder R
RR0
I:0
16
Retraction complete
of Cylinder B
BB0
I:0
3
Memory to activate
CC_Retraction,
GG_Retraction &
LL_Retraction
M_59
B3:6
10
Memory to activate
Out_6, deactivate
Reset_Flag &
activate
Reset_Flag_1
M_60
B3:6
11
Memory to activate
CC_Retraction,
GG_Retraction &
LL_Retraction
M_59
B3:6
10


Memory to activate CC_Retraction, GG_Retraction & LL_Retraction
M_59
B3:6
10
Retraction complet of Cylinder C
CC0
I:0
5
Retraction complet of Cylinder G
GG0
I:0
0
Retraction complete of Cylinder L
LL0
I:0
18
0013
Memory to activate Out_6, deactivate Reset_Flag & activate Reset_Flag_1
M_60
B3:6
11
Memory to activate Output 3 & 4. Output 6 is unlatched
M_1
B3:3
0
Memory to activate Out_6, deactivate Reset_Flag & activate Reset_Flag_1
M_60
B3:6
11
Memory to activate Reset_Flag to save First_Pass
M_46
B3:5
13
0014
To save First_Pass when the PLC is started after stopping
RESET_FLAG
B3:6
L
12

RESET CYCLE

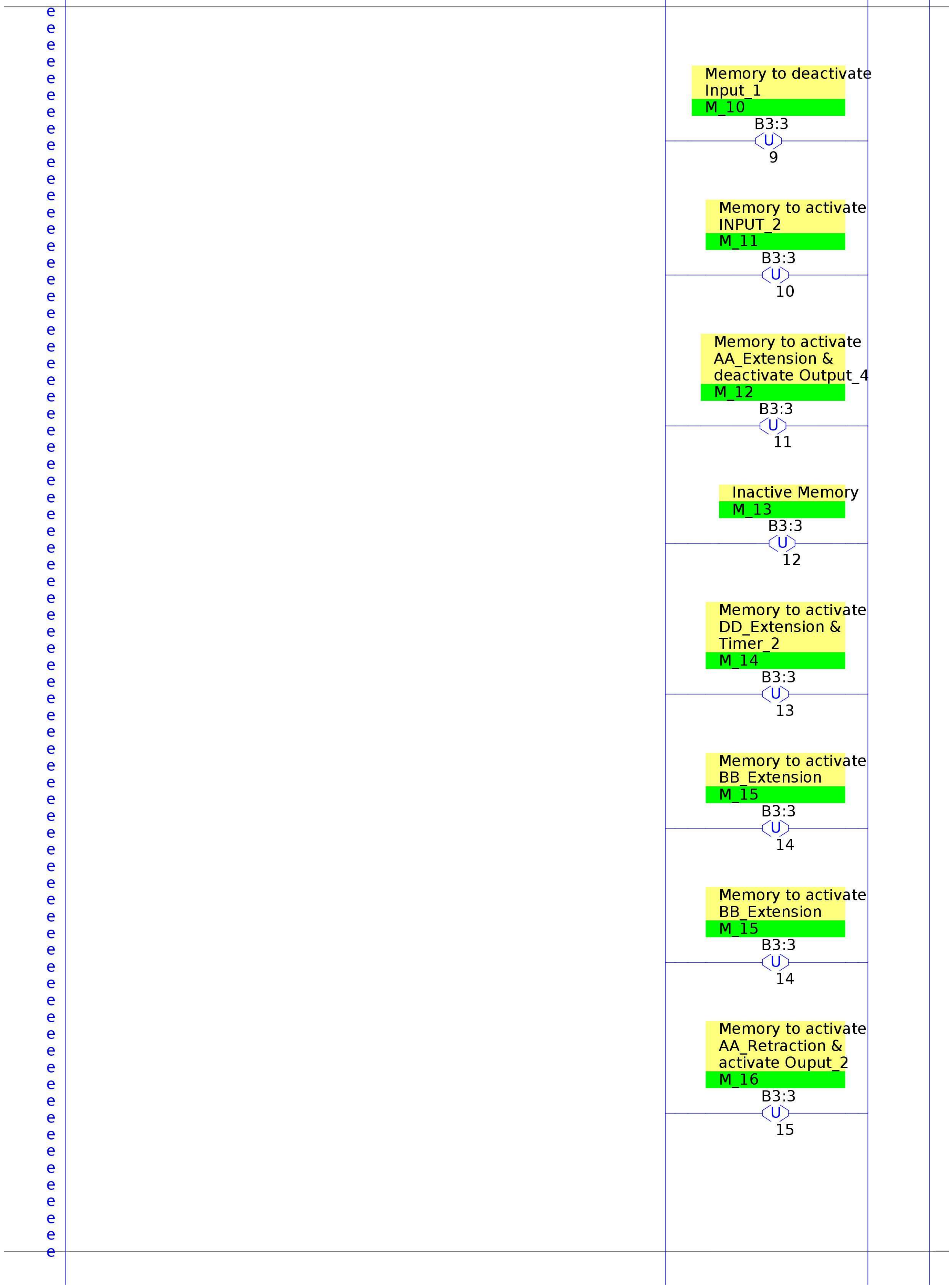
LAD 2 - --- Total Rungs in File = 30




0016
Memory to deactivate M1 till M47 & M49 till M60
M_48
B3:5
15
Memory to activate Output 3 & 4. Output 6 is unlatched
M_1
B3:3
U
0
Inactive Memory
M_2
B3:3
U
1
Memory to activate INPUT_1
M_3
B3:3
U
2
Memory to activate NN_Extension & deactivate Output 3
M_4
B3:3
U
3
Inactive Memory
M_5
B3:3
U
4
Memory to activate OO_Extension & start Timer_1
M_6
B3:3
U
5
Memory to activate RR_Extension
M_7
B3:3
U
6
Memory to activate NN_Retraction & activate Output_1
M_8
B3:3
U
7
Inactive Memory
M_9
B3:3
U
8

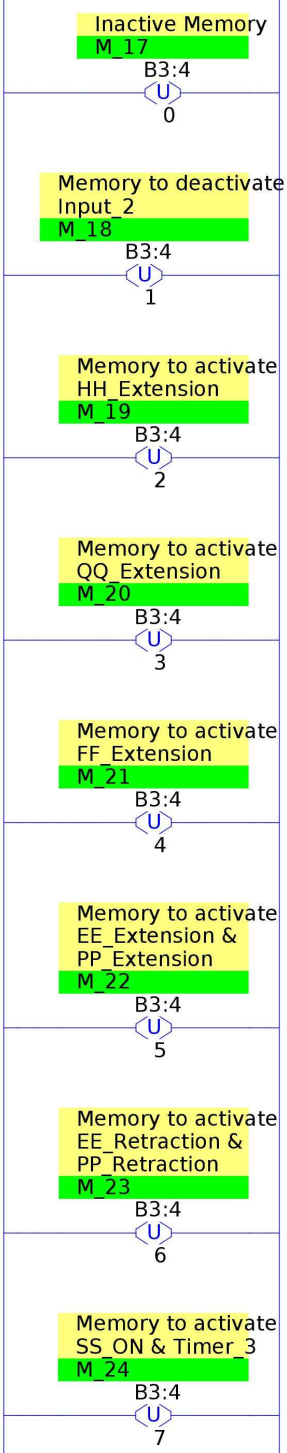
RESET CYCLE

LAD 2 - --- Total Rungs in File = 30



RESET CYCLE

LAD 2 - --- Total Rungs in File = 30



RESET CYCLE

LAD 2 - --- Total Rungs in File = 30

Memory to activate FF_Retraction & SS_Off
M_25
B3:4
U
8

Memory to activate QQ_Retraction & deactivate Output_1 & Output_2
M_26
B3:4
U
9

Inactive Memory
M_27
B3:4
U
10

Memory to activate CC_Extension, LL_Extension, II_Extension & Timer_4
M_28
B3:4
U
11

Memory to activate HH_Retraction
M_29
B3:4
U
12

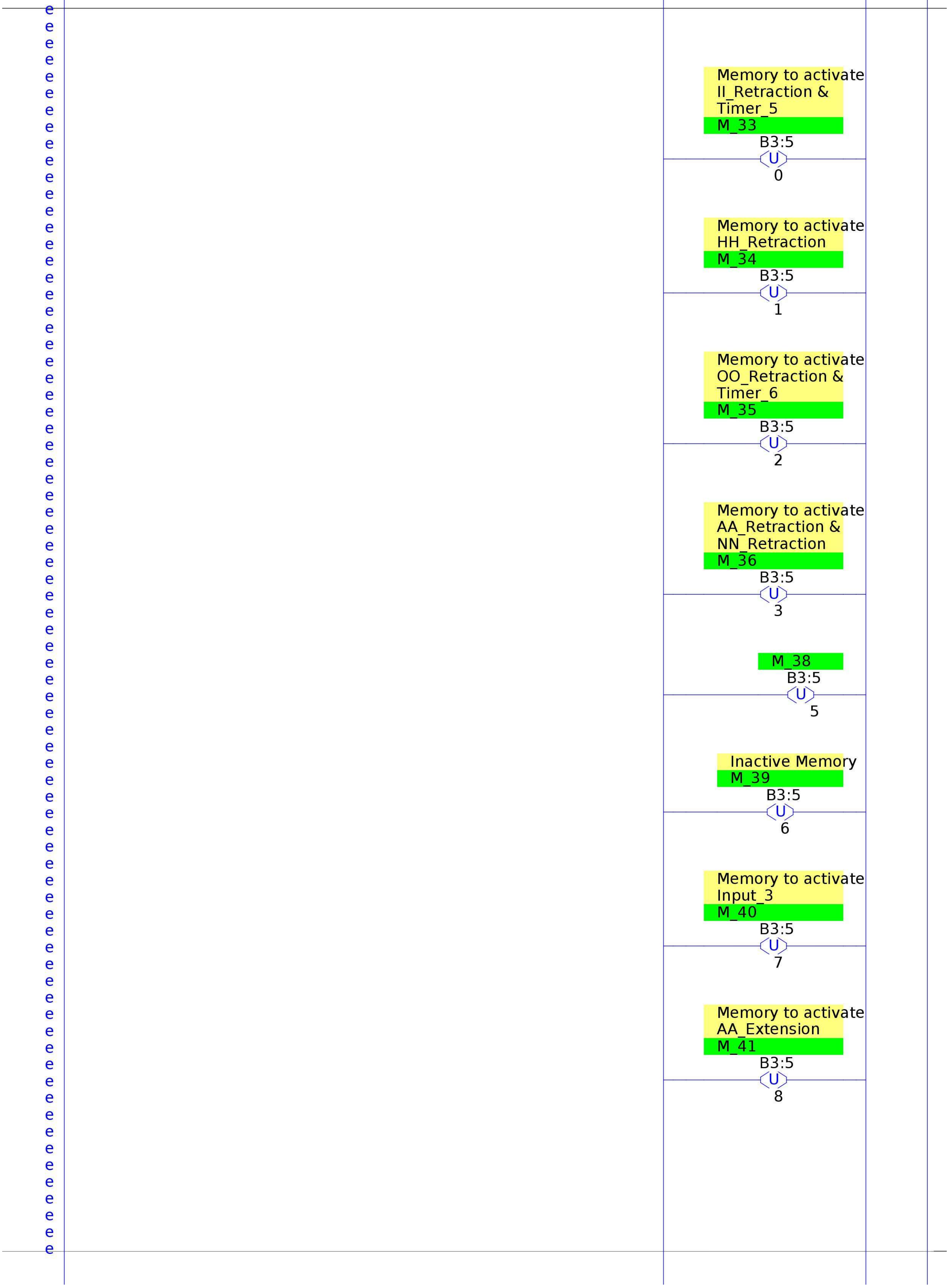
Memory to activate GG_Extension
M_30
B3:4
U
13

Memory to activate AA_Extension & NN_Extension
M_31
B3:4
U
14

Memory to activate HH_Extension
M_32
B3:4
U
15

RESET CYCLE

LAD 2 - --- Total Rungs in File = 30



RESET CYCLE

LAD 2 - --- Total Rungs in File = 30

Memory to activate BB_Retraction
M_42
B3:5
U
9

Memory to activate DD_Retraction & Timer_7
M_43
B3:5
U
10

Memory to activate AA_Retraction & deactivate Output_5 & Input_3
M_44
B3:5
U
11

Memory to activate Output_6
M_45
B3:5
U
12

Memory to activate Reset_Flag to save First_Pass
M_46
B3:5
U
13

Memory to deactivate Output_1 till Output_8
M_47
B3:5
U
14

Memory to deactivate Input_1, Input_2 & Input_3
M_49
B3:6
U
0

Memory to deactivate Timer_1 till Timer_8
M_50
B3:6
U
1

RESET CYCLE

LAD 2 - --- Total Rungs in File = 30

Memory to activate SS_Off
M_51
B3:6
U
2

Memory to activate FF_Retraction
M_52
B3:6
U
3

Memory to activate QQ_Retraction
M_53
B3:6
U
4

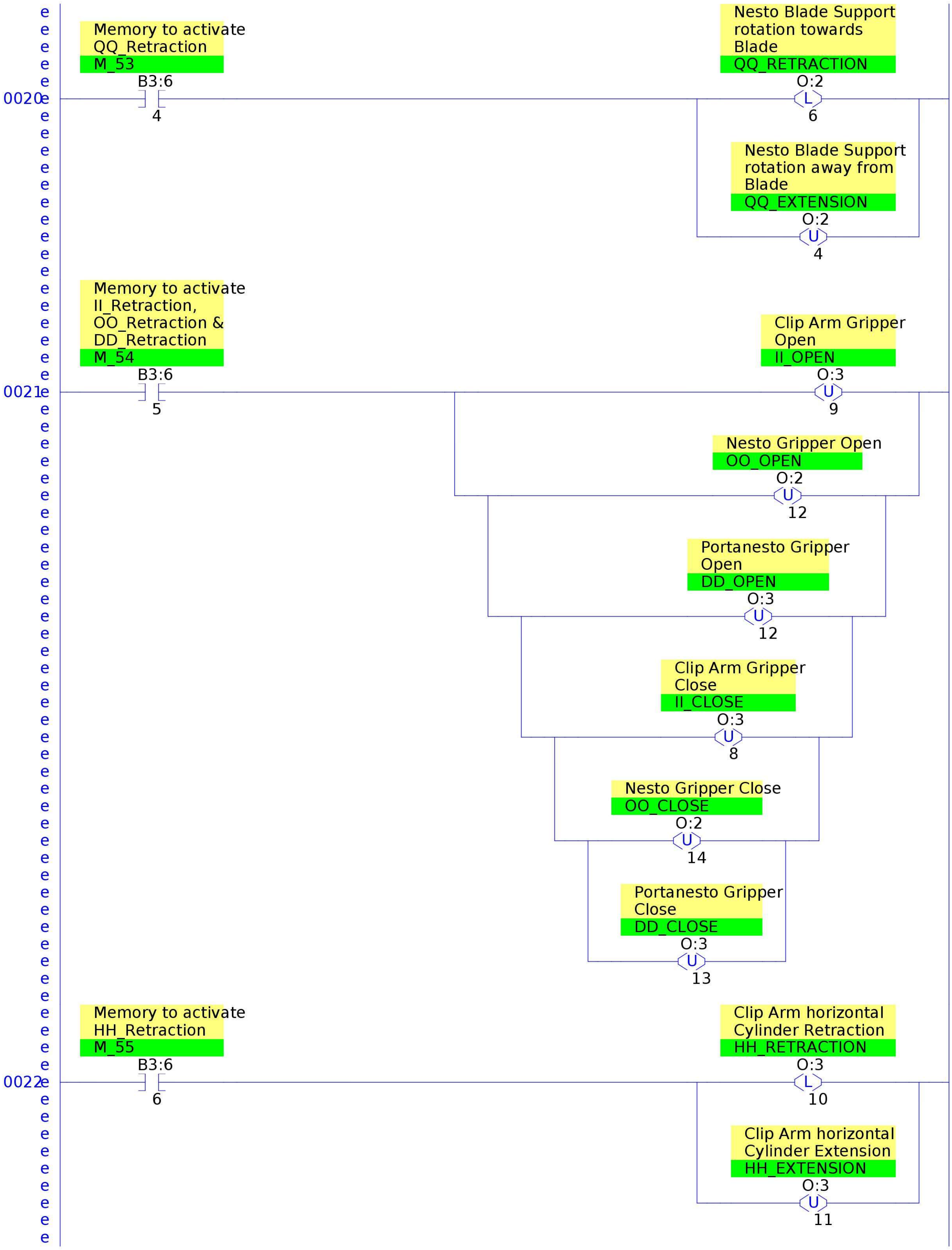
Memory to activate II_Retraction, OO_Retraction & DD_Retraction
M_54
B3:6
U
5

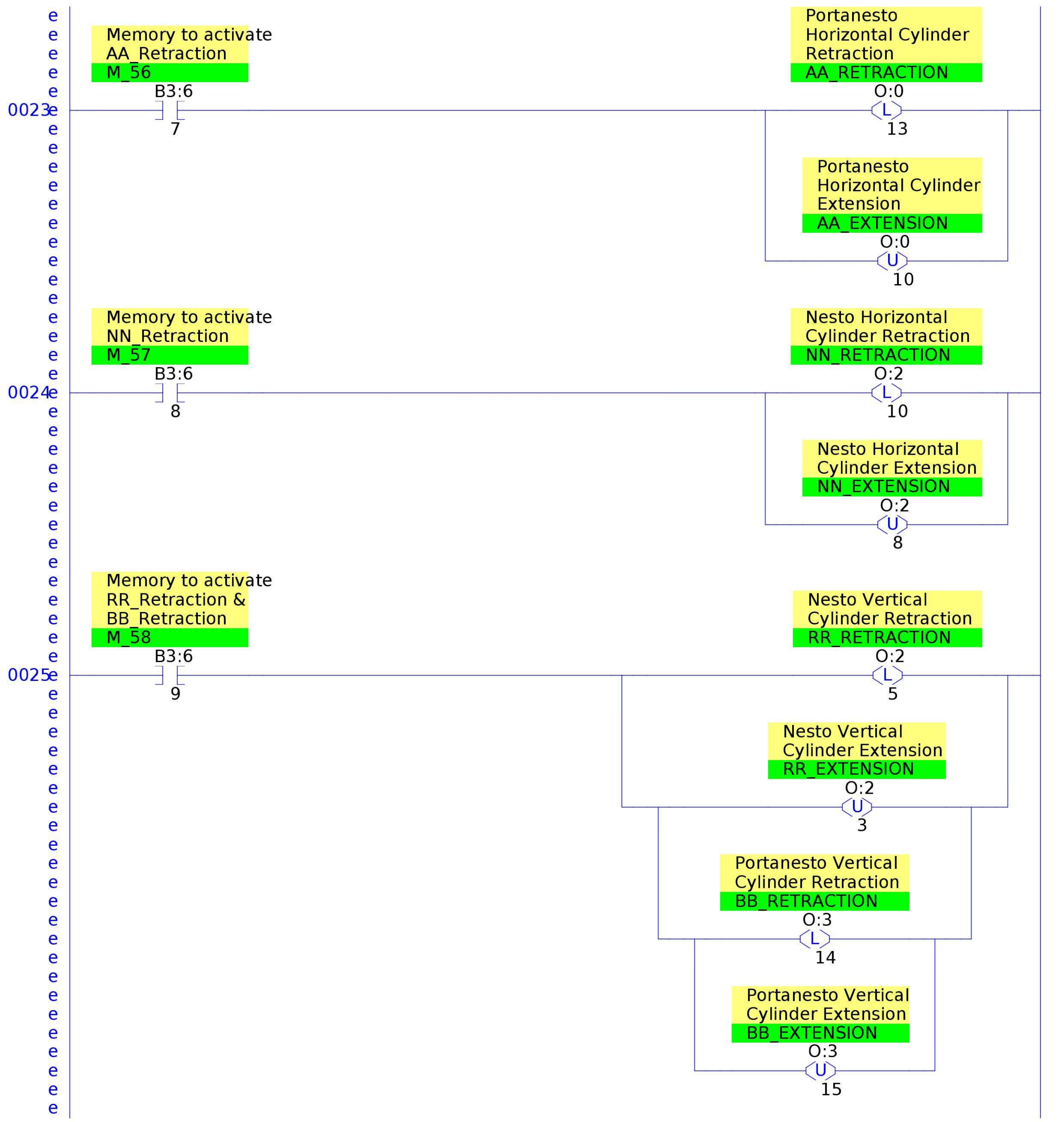
Memory to activate HH_Retraction
M_55
B3:6
U
6

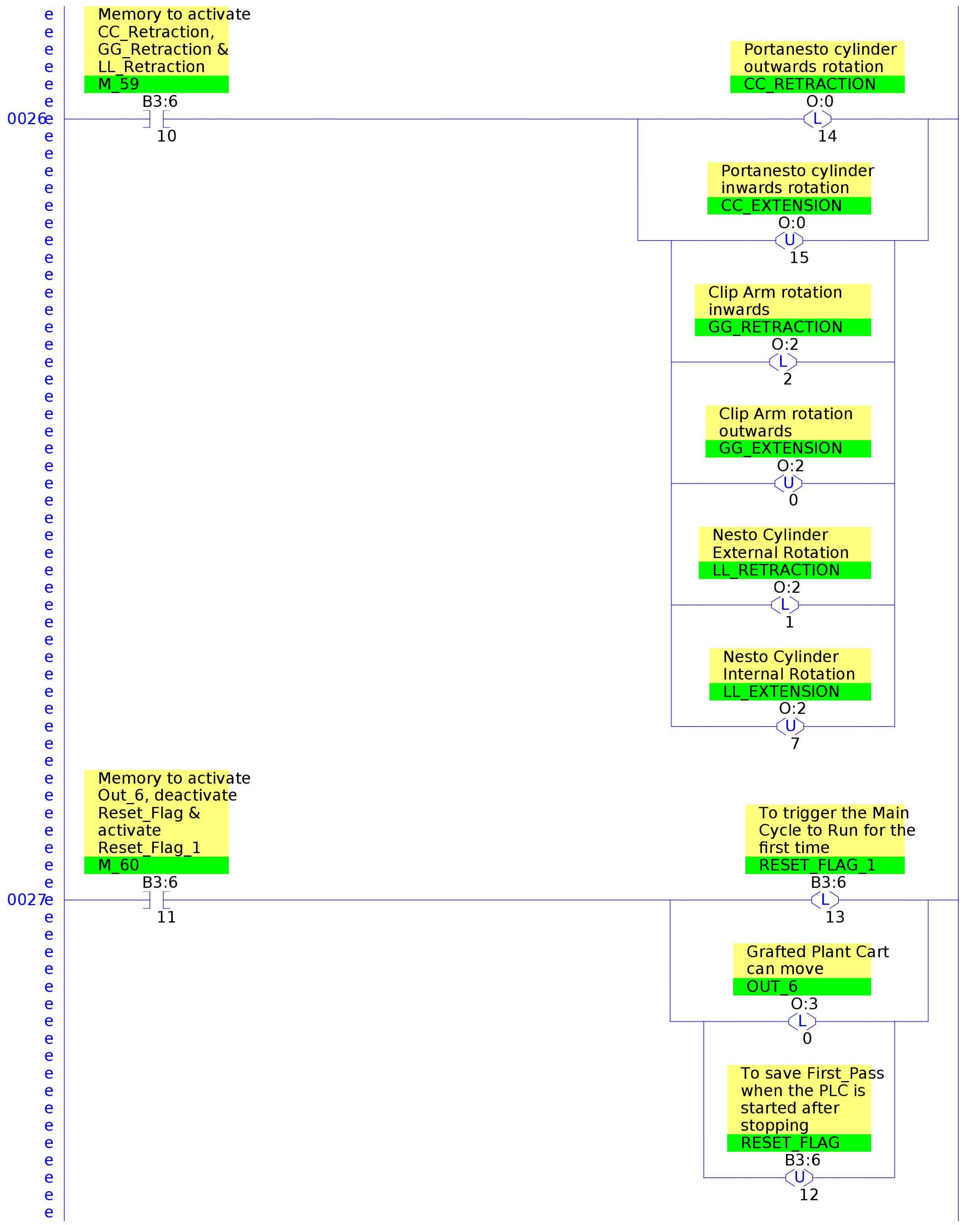
Memory to activate AA_Retraction
M_56
B3:6
U
7

Memory to activate NN_Retraction
M_57
B3:6
U
8

Memory to activate RR_Retraction & BB_Retraction
M_58
B3:6
U
9


0020
Memory to activate QQ_Retraction
M_53
B3:6
4
Nesto Blade Support rotation towards Blade
QQ_RETRACTION
O:2
L
6
Nesto Blade Support rotation away from Blade
QQ_EXTENSION
O:2
U
4
0021
Memory to activate II_Retraction, OO_Retraction & DD_Retraction
M_54
B3:6
5
Clip Arm Gripper Open
II_OPEN
O:3
U
9
Nesto Gripper Open
OO_OPEN
O:2
U
12
Portanesto Gripper Open
DD_OPEN
O:3
U
12
Clip Arm Gripper Close
II_CLOSE
O:3
U
8
Nesto Gripper Close
OO_CLOSE
O:2
U
14
Portanesto Gripper Close
DD_CLOSE
O:3
U
13
0022
Memory to activate HH_Retraction
M_55
B3:6
6
Clip Arm horizontal Cylinder Retraction
HH_RETRACTION
O:3
L
10
Clip Arm horizontal Cylinder Extension
HH_EXTENSION
O:3
U
11


0023
Memory to activate
AA_Retraction
M_56
B3:6
7
Portanesto
Horizontal Cylinder
Retraction
AA_RETRACTION
O:0
L
13
Portanesto
Horizontal Cylinder
Extension
AA_EXTENSION
O:0
U
10
0024
Memory to activate
NN_Retraction
M_57
B3:6
8
Nesto Horizontal
Cylinder Retraction
NN_RETRACTION
O:2
L
10
Nesto Horizontal
Cylinder Extension
NN_EXTENSION
O:2
U
8
0025
Memory to activate
RR_Retraction &
BB_Retraction
M_58
B3:6
9
Nesto Vertical
Cylinder Retraction
RR_RETRACTION
O:2
L
5
Nesto Vertical
Cylinder Extension
RR_EXTENSION
O:2
U
3
Portanesto Vertical
Cylinder Retraction
BB_RETRACTION
O:3
L
14
Portanesto Vertical
Cylinder Extension
BB_EXTENSION
O:3
U
15


0026
Memory to activate CC_Retraction, GG_Retraction & LL_Retraction
M_59
B3:6
10
Portanesto cylinder outwards rotation
CC_RETRACTION
O:0
L
14
Portanesto cylinder inwards rotation
CC_EXTENSION
O:0
U
15
Clip Arm rotation inwards
GG_RETRACTION
O:2
L
2
Clip Arm rotation outwards
GG_EXTENSION
O:2
U
0
Nesto Cylinder External Rotation
LL_RETRACTION
O:2
L
1
Nesto Cylinder Internal Rotation
LL_EXTENSION
O:2
U
7
0027
Memory to activate Out_6, deactivate Reset_Flag & activate Reset_Flag_1
M_60
B3:6
11
To trigger the Main Cycle to Run for the first time
RESET_FLAG_1
B3:6
L
13
Grafted Plant Cart can move
OUT_6
O:3
L
0
To save First_Pass when the PLC is started after stopping
RESET_FLAG
B3:6
U
12

To save First_Pass when the PLC is started after stopping

0028

RESET_FLAG
B3:6
12

First Pass
S:1
15

JSR
Jump To Subroutine
SBR File Number ?

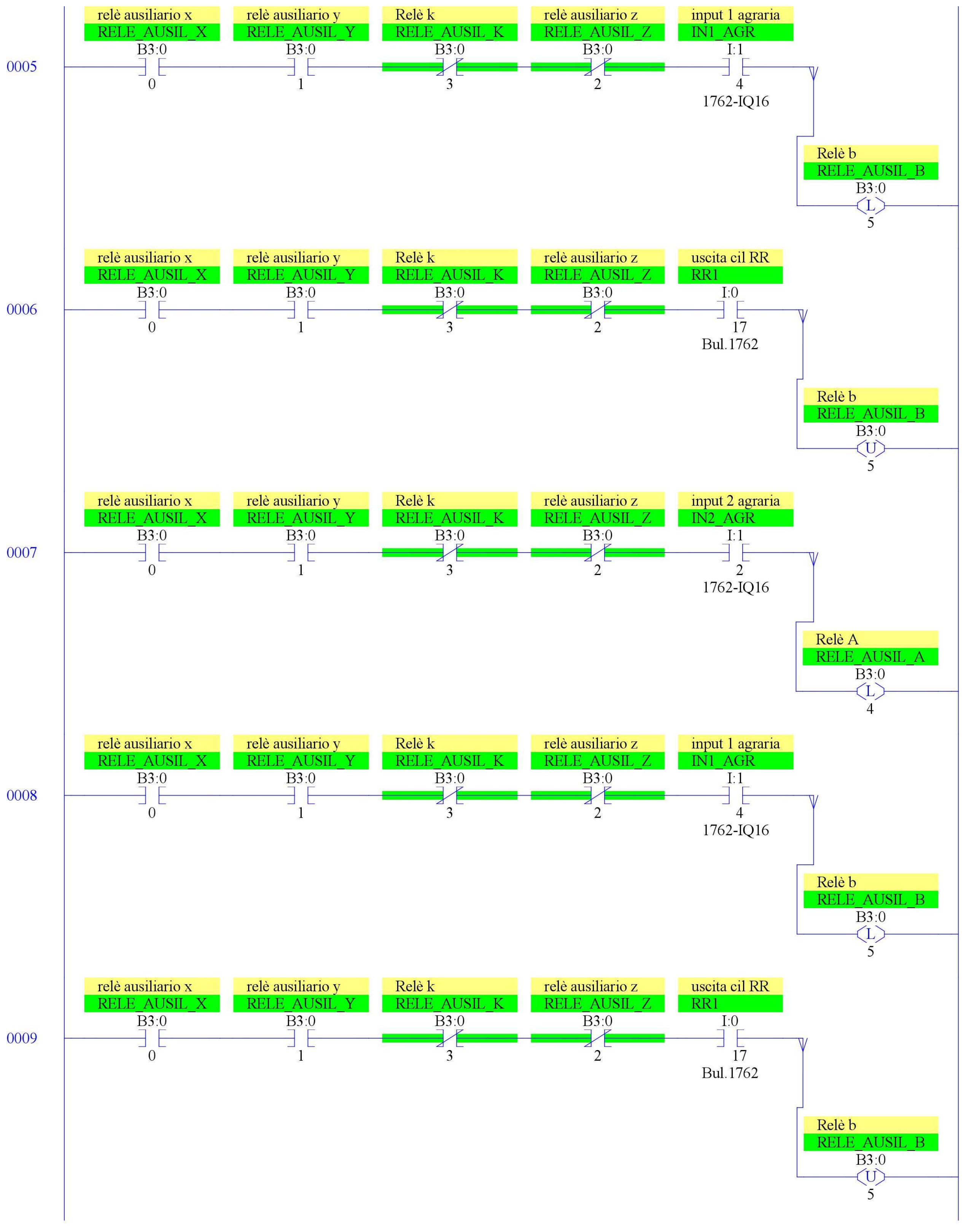
0029

END

Appendix 3 – Belluco Main Cycle with Blower

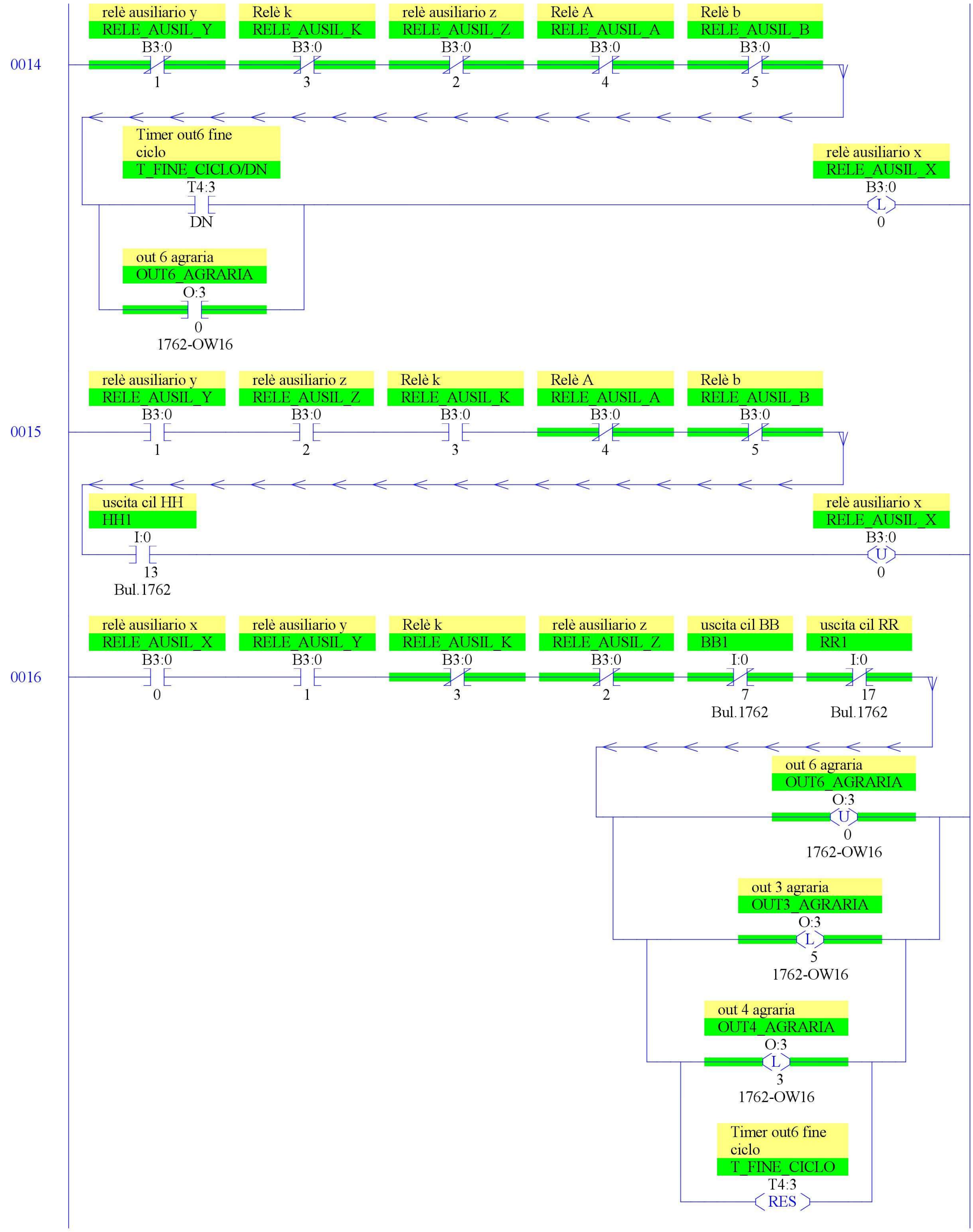
COMPLETE CYCLE WITH BLOWER

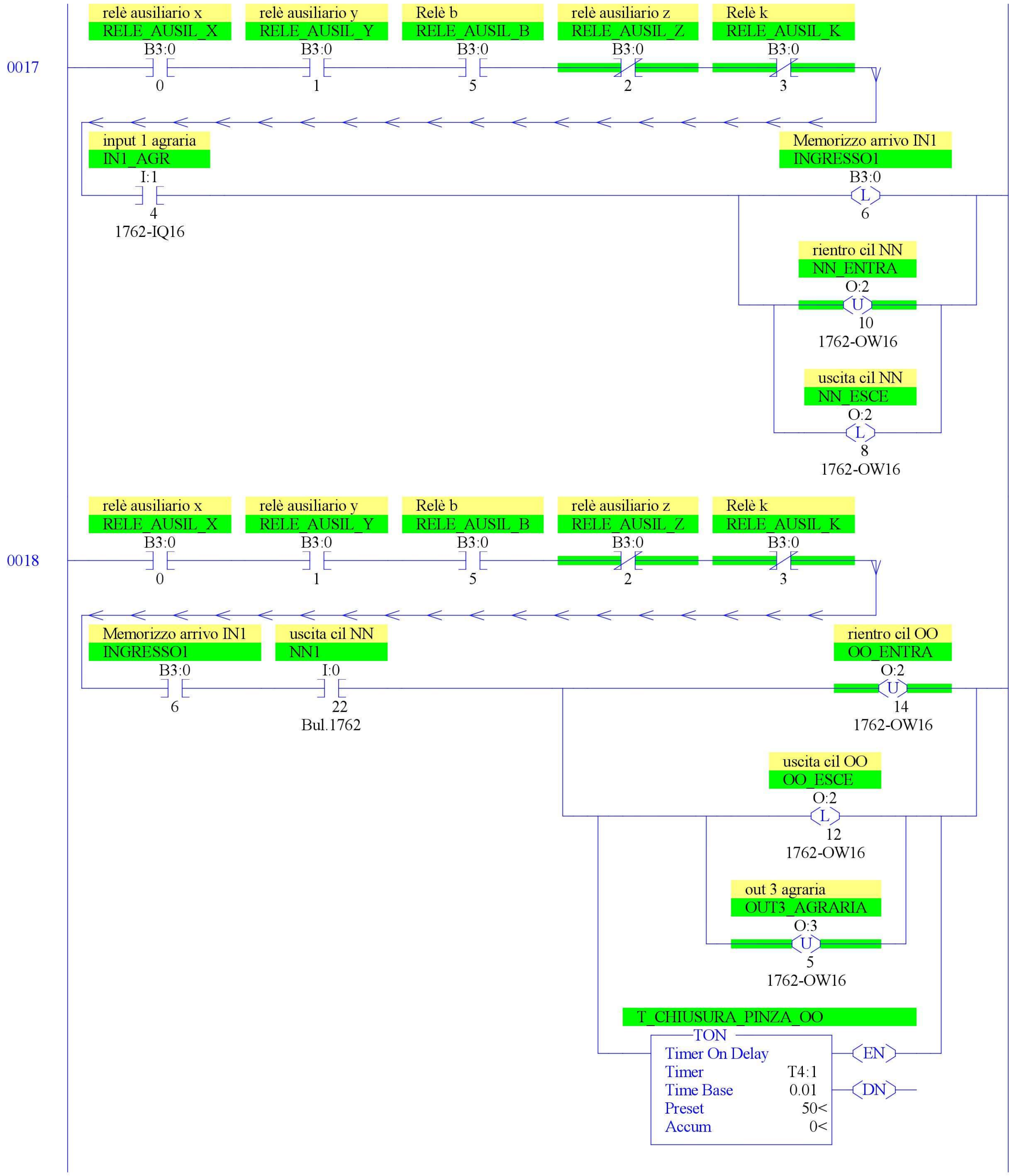
LAD 3 - CICLOCOMPL --- Total Rungs in File = 54

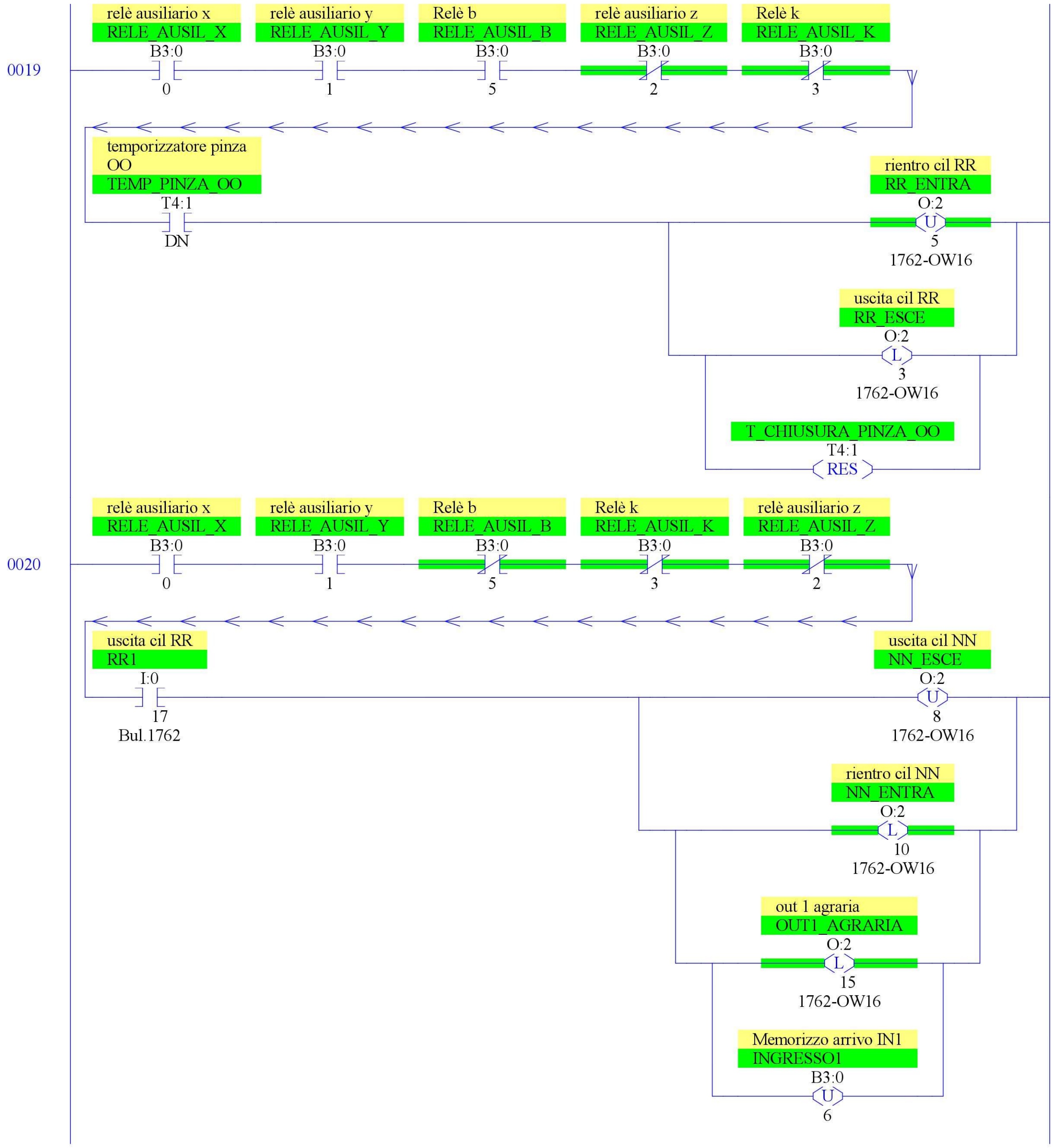

0005
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
Relè k
RELE_AUSIL_K
B3:0
3
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
input 1 agraria
IN1_AGR
I:1
4
1762-IQ16
Relè b
RELE_AUSIL_B
B3:0
L
5
0006
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
Relè k
RELE_AUSIL_K
B3:0
3
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
uscita cil RR
RR1
I:0
17
Bul.1762
Relè b
RELE_AUSIL_B
B3:0
U
5
0007
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
Relè k
RELE_AUSIL_K
B3:0
3
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
input 2 agraria
IN2_AGR
I:1
2
1762-IQ16
Relè A
RELE_AUSIL_A
B3:0
L
4
0008
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
Relè k
RELE_AUSIL_K
B3:0
3
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
input 1 agraria
IN1_AGR
I:1
4
1762-IQ16
Relè b
RELE_AUSIL_B
B3:0
L
5
0009
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
Relè k
RELE_AUSIL_K
B3:0
3
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
uscita cil RR
RR1
I:0
17
Bul.1762
Relè b
RELE_AUSIL_B
B3:0
U
5

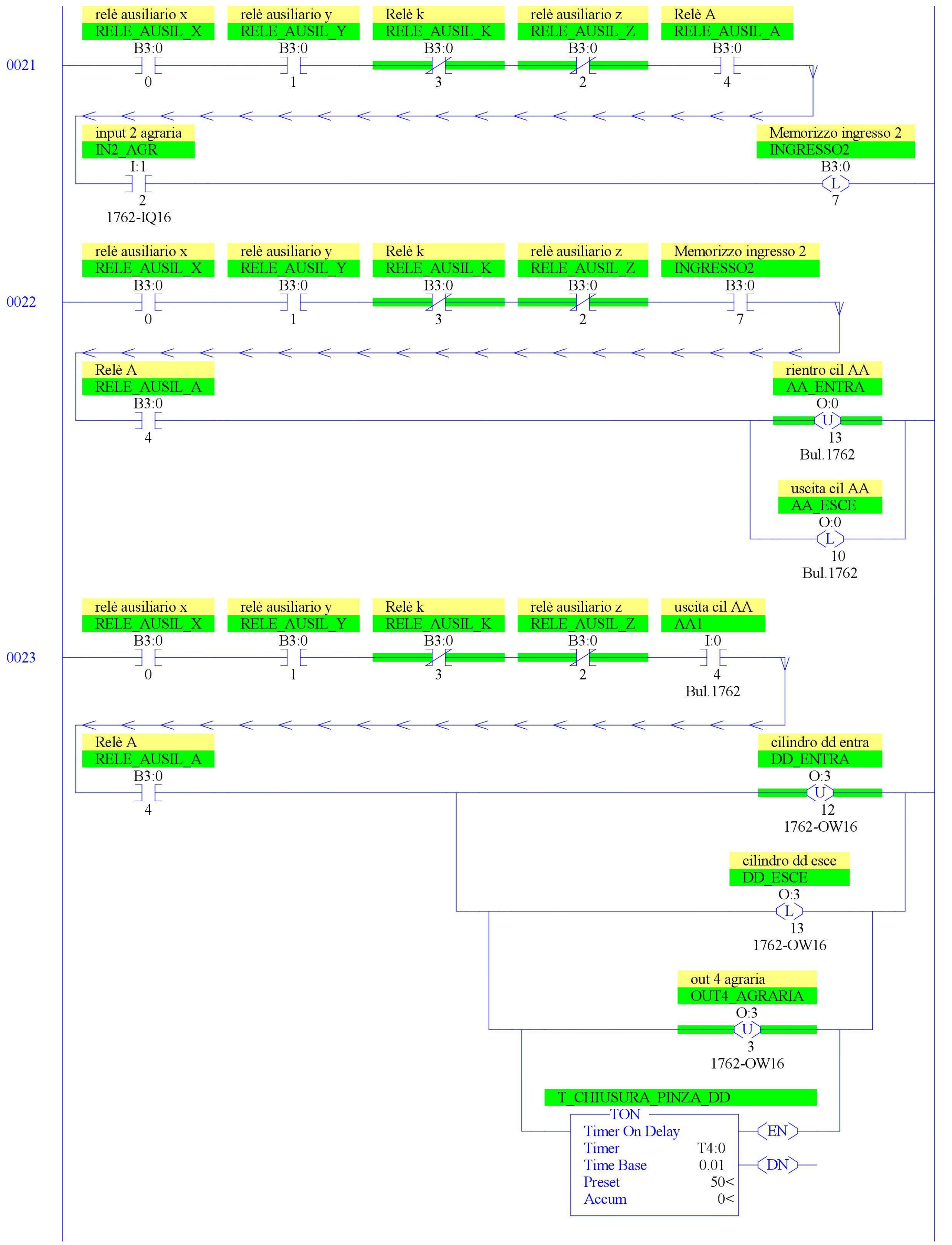
COMPLETE CYCLE WITH BLOWER

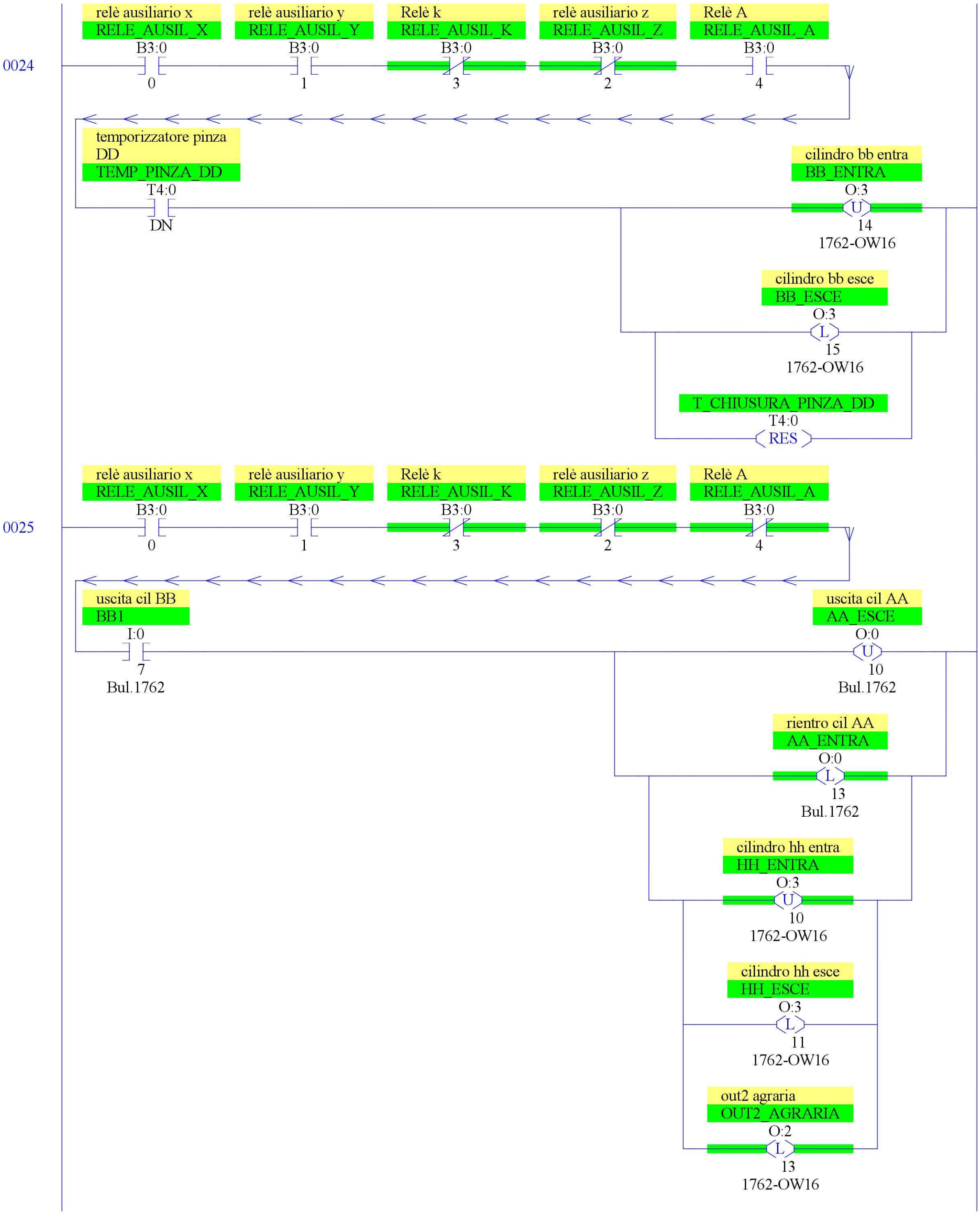
LAD 3 - CICLOCOMPL --- Total Rungs in File = 54

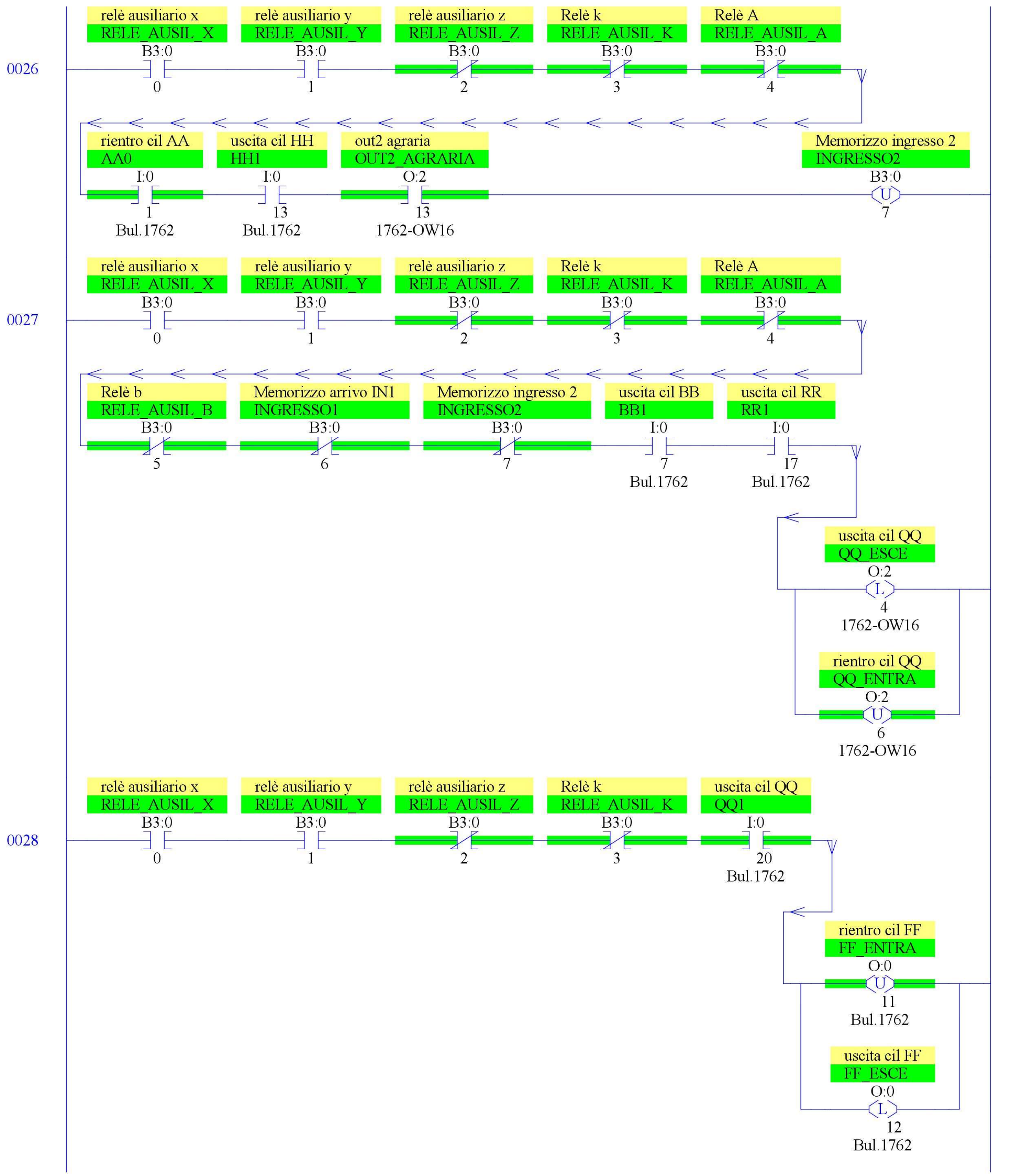

0014
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
Relè k
RELE_AUSIL_K
B3:0
3
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Relè A
RELE_AUSIL_A
B3:0
4
Relè b
RELE_AUSIL_B
B3:0
5
Timer out6 fine ciclo
T_FINE_CICLO/DN
T4:3
DN
relè ausiliario x
RELE_AUSIL_X
B3:0
L
0
out 6 agraria
OUT6_AGRARIA
O:3
0
1762-OW16
0015
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Relè k
RELE_AUSIL_K
B3:0
3
Relè A
RELE_AUSIL_A
B3:0
4
Relè b
RELE_AUSIL_B
B3:0
5
uscita cil HH
HH1
I:0
13
Bul.1762
relè ausiliario x
RELE_AUSIL_X
B3:0
U
0
0016
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
Relè k
RELE_AUSIL_K
B3:0
3
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
uscita cil BB
BB1
I:0
7
Bul.1762
uscita cil RR
RR1
I:0
17
Bul.1762
out 6 agraria
OUT6_AGRARIA
O:3
U
0
1762-OW16
out 3 agraria
OUT3_AGRARIA
O:3
L
5
1762-OW16
out 4 agraria
OUT4_AGRARIA
O:3
L
3
1762-OW16
Timer out6 fine ciclo
T_FINE_CICLO
T4:3
RES

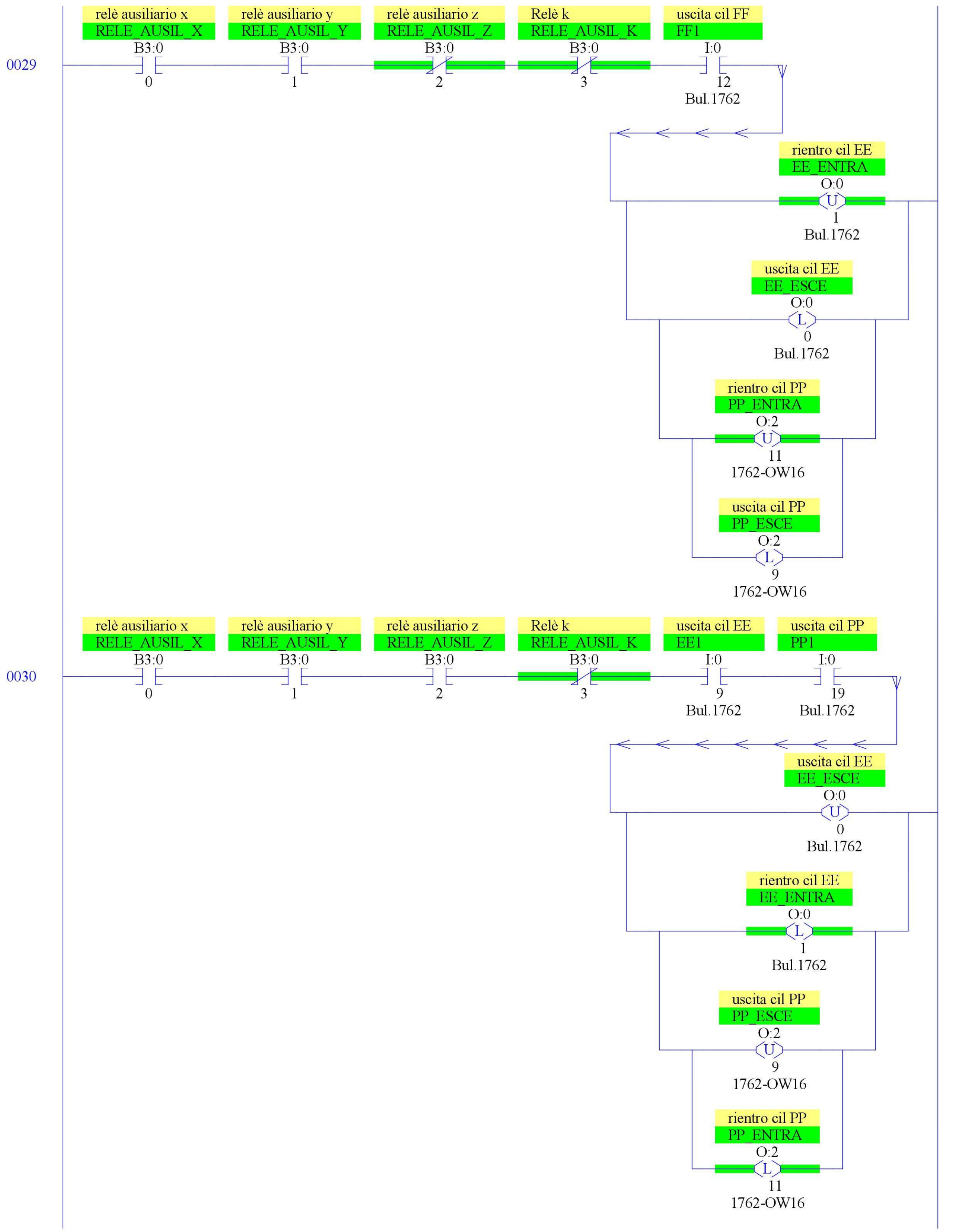

0017
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
Relè b
RELE_AUSIL_B
B3:0
5
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Relè k
RELE_AUSIL_K
B3:0
3
input 1 agraria
IN1_AGR
I:1
4
1762-IQ16
Memorizzo arrivo IN1
INGRESSO1
B3:0
L
6
rientro cil NN
NN_ENTRA
O:2
U
10
1762-OW16
uscita cil NN
NN_ESCE
O:2
L
8
1762-OW16
0018
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
Relè b
RELE_AUSIL_B
B3:0
5
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Relè k
RELE_AUSIL_K
B3:0
3
Memorizzo arrivo IN1
INGRESSO1
B3:0
6
uscita cil NN
NN1
I:0
22
Bul.1762
rientro cil OO
OO_ENTRA
O:2
U
14
1762-OW16
uscita cil OO
OO_ESCE
O:2
L
12
1762-OW16
out 3 agraria
OUT3_AGRARIA
O:3
U
5
1762-OW16
T_CHIUSURA_PINZA_OO
TON
Timer On Delay
Timer T4:1
Time Base 0.01
Preset 50<
Accum 0<
EN
DN

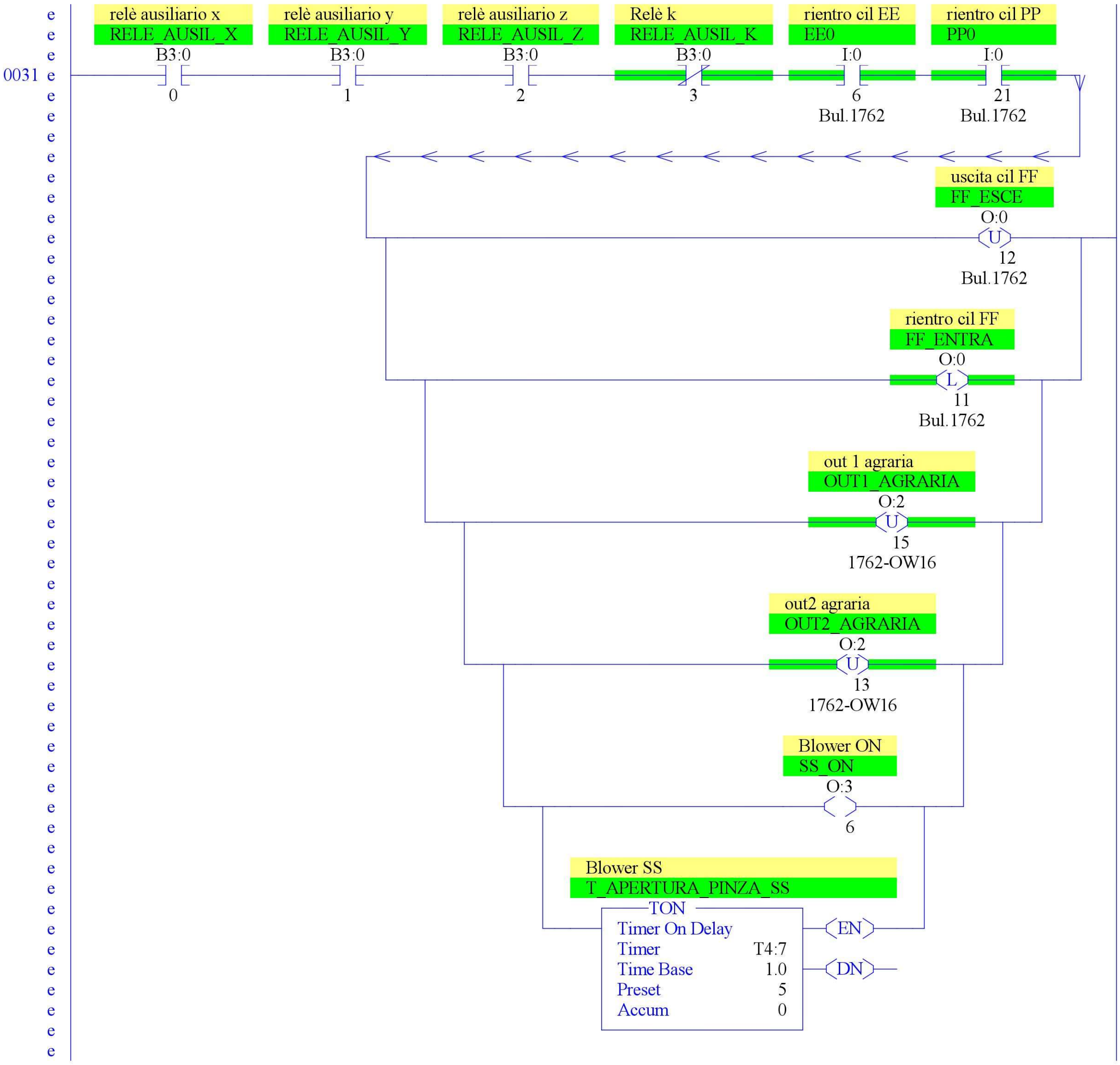

0019
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
Relè b
RELE_AUSIL_B
B3:0
5
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Relè k
RELE_AUSIL_K
B3:0
3
temporizzatore pinza OO
TEMP_PINZA_OO
T4:1
DN
rientro cil RR
RR_ENTRA
O:2
U
5
1762-OW16
uscita cil RR
RR_ESCE
O:2
L
3
1762-OW16
T_CHIUSURA_PINZA_OO
T4:1
RES
0020
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
Relè b
RELE_AUSIL_B
B3:0
5
Relè k
RELE_AUSIL_K
B3:0
3
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
uscita cil RR
RR1
I:0
17
Bul.1762
uscita cil NN
NN_ESCE
O:2
U
8
1762-OW16
rientro cil NN
NN_ENTRA
O:2
L
10
1762-OW16
out 1 agraria
OUT1_AGRARIA
O:2
L
15
1762-OW16
Memorizzo arrivo IN1
INGRESSO1
B3:0
U
6

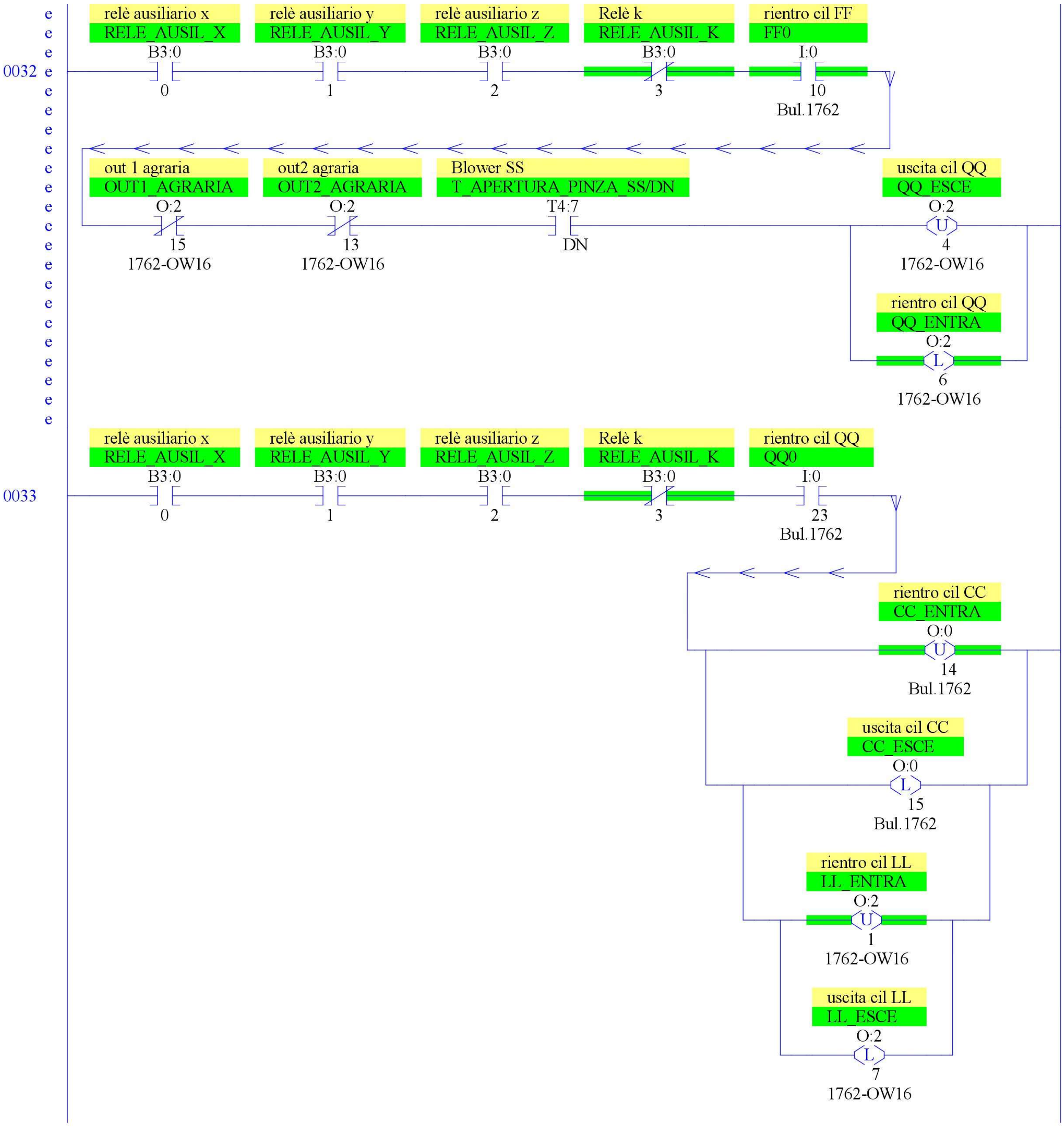

0021
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
Relè k
RELE_AUSIL_K
B3:0
3
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Relè A
RELE_AUSIL_A
B3:0
4
input 2 agraria
IN2_AGR
I:1
2
1762-IQ16
Memorizzo ingresso 2
INGRESSO2
B3:0
L
7
0022
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
Relè k
RELE_AUSIL_K
B3:0
3
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Memorizzo ingresso 2
INGRESSO2
B3:0
7
Relè A
RELE_AUSIL_A
B3:0
4
rientro cil AA
AA_ENTRA
O:0
U
13
Bul.1762
uscita cil AA
AA_ESCE
O:0
L
10
Bul.1762
0023
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
Relè k
RELE_AUSIL_K
B3:0
3
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
uscita cil AA
AA1
I:0
4
Bul.1762
Relè A
RELE_AUSIL_A
B3:0
4
cilindro dd entra
DD_ENTRA
O:3
U
12
1762-OW16
cilindro dd esce
DD_ESCE
O:3
L
13
1762-OW16
out 4 agraria
OUT4_AGRARIA
O:3
U
3
1762-OW16
T_CHIUSURA_PINZA_DD
TON
Timer On Delay
Timer T4:0
Time Base 0.01
Preset 50<
Accum 0<
EN
DN

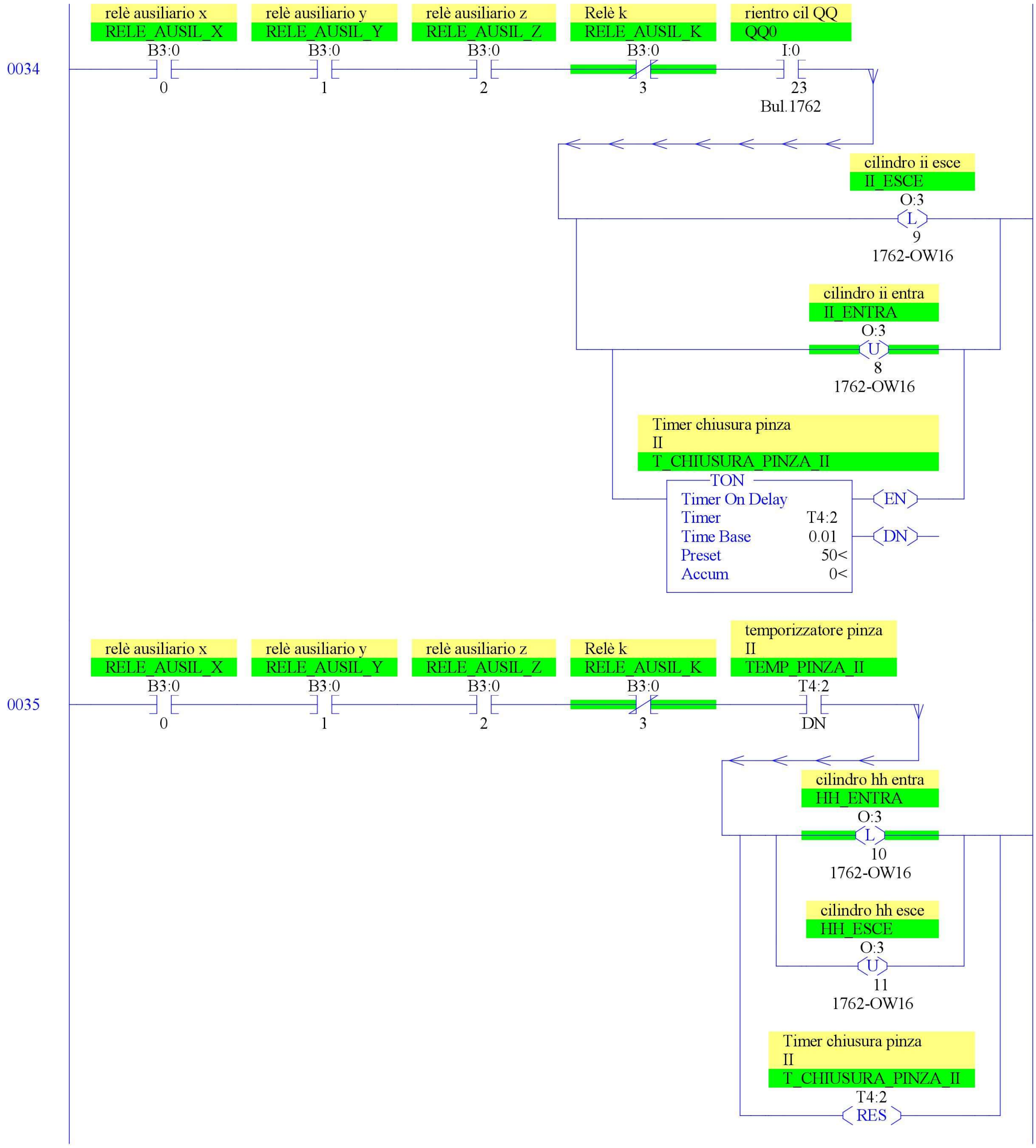

0024
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
Relè k
RELE_AUSIL_K
B3:0
3
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Relè A
RELE_AUSIL_A
B3:0
4
temporizzatore pinza DD
TEMP_PINZA_DD
T4:0
DN
cilindro bb entra
BB_ENTRA
O:3
U
14
1762-OW16
cilindro bb esce
BB_ESCE
O:3
L
15
1762-OW16
T_CHIUSURA_PINZA_DD
T4:0
RES
0025
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
Relè k
RELE_AUSIL_K
B3:0
3
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Relè A
RELE_AUSIL_A
B3:0
4
uscita cil BB
BB1
I:0
7
Bul.1762
uscita cil AA
AA_ESCE
O:0
U
10
Bul.1762
rientro cil AA
AA_ENTRA
O:0
L
13
Bul.1762
cilindro hh entra
HH_ENTRA
O:3
U
10
1762-OW16
cilindro hh esce
HH_ESCE
O:3
L
11
1762-OW16
out2 agraria
OUT2_AGRARIA
O:2
L
13
1762-OW16

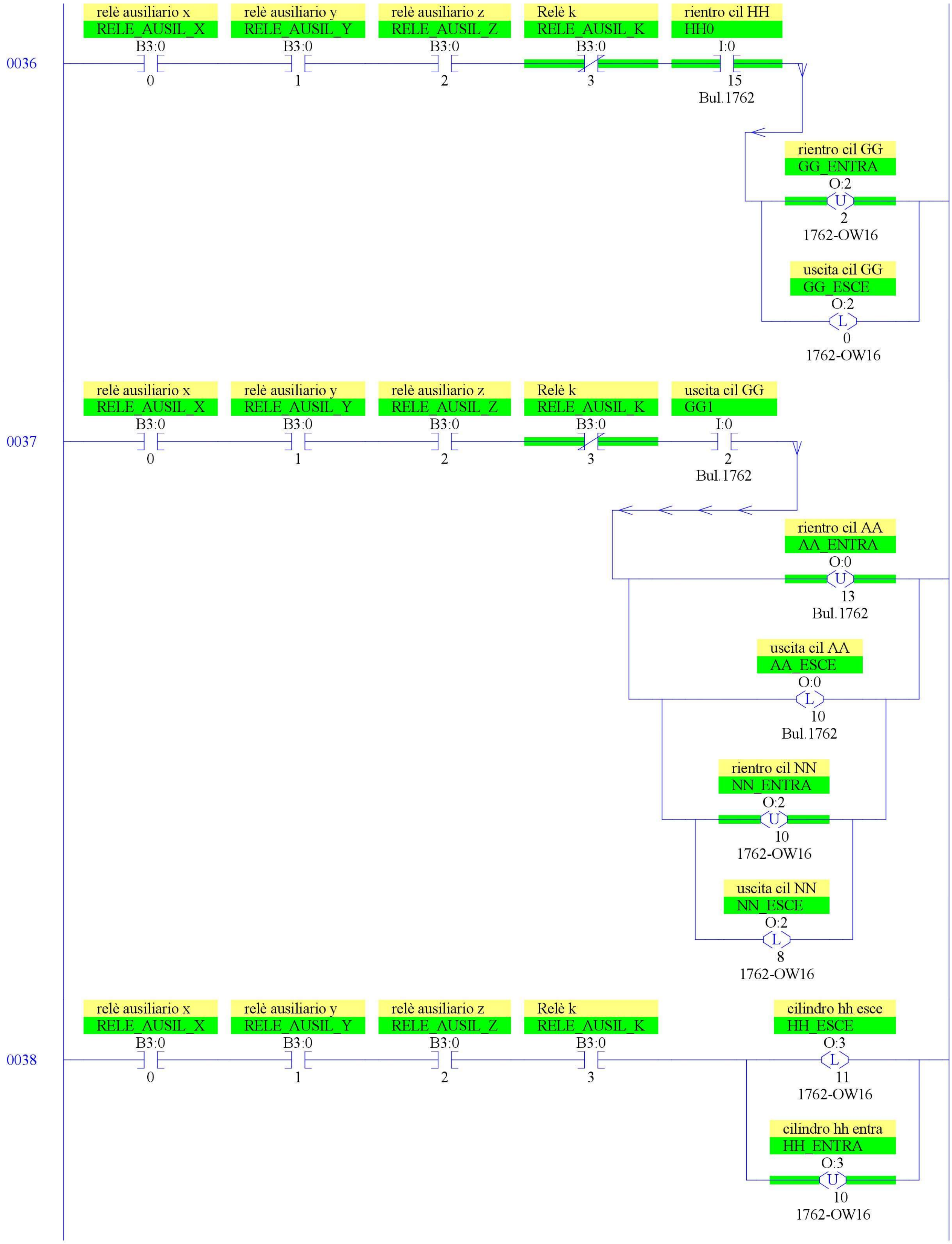

0026
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Relè k
RELE_AUSIL_K
B3:0
3
Relè A
RELE_AUSIL_A
B3:0
4
rientro cil AA
AA0
I:0
1
Bul.1762
uscita cil HH
HH1
I:0
13
Bul.1762
out2 agraria
OUT2_AGRARIA
O:2
13
1762-OW16
Memorizzo ingresso 2
INGRESSO2
B3:0
U
7
0027
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Relè k
RELE_AUSIL_K
B3:0
3
Relè A
RELE_AUSIL_A
B3:0
4
Relè b
RELE_AUSIL_B
B3:0
5
Memorizzo arrivo IN1
INGRESSO1
B3:0
6
Memorizzo ingresso 2
INGRESSO2
B3:0
7
uscita cil BB
BB1
I:0
7
Bul.1762
uscita cil RR
RR1
I:0
17
Bul.1762
uscita cil QQ
QQ_ESCE
O:2
L
4
1762-OW16
rientro cil QQ
QQ_ENTRA
O:2
U
6
1762-OW16
0028
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Relè k
RELE_AUSIL_K
B3:0
3
uscita cil QQ
QQ1
I:0
20
Bul.1762
rientro cil FF
FF_ENTRA
O:0
U
11
Bul.1762
uscita cil FF
FF_ESCE
O:0
L
12
Bul.1762

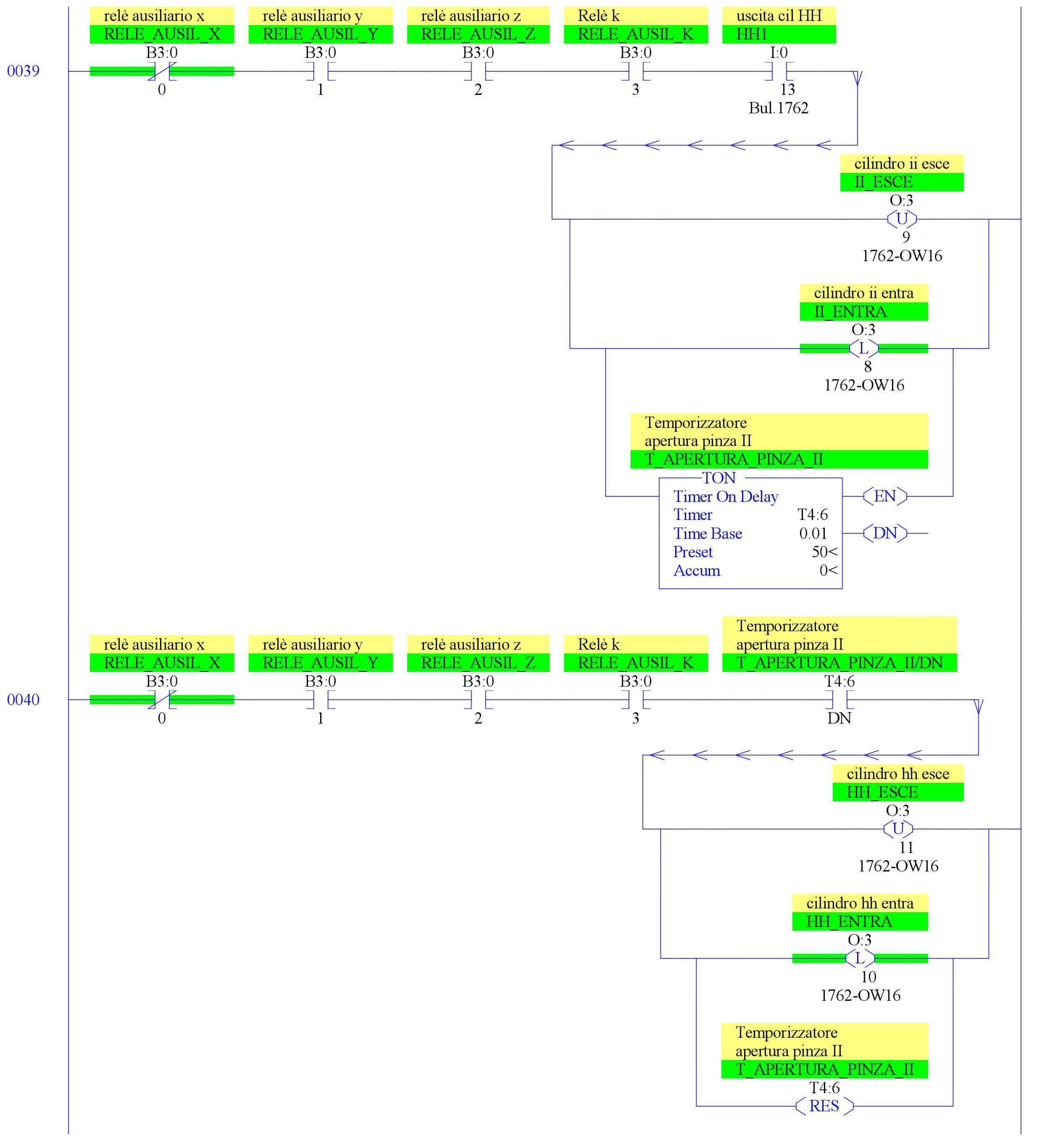

0029
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Relè k
RELE_AUSIL_K
B3:0
3
uscita cil FF
FF1
I:0
12
Bul.1762
rientro cil EE
EE_ENTRA
O:0
U
1
Bul.1762
uscita cil EE
EE_ESCE
O:0
L
0
Bul.1762
rientro cil PP
PP_ENTRA
O:2
U
11
1762-OW16
uscita cil PP
PP_ESCE
O:2
L
9
1762-OW16
0030
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Relè k
RELE_AUSIL_K
B3:0
3
uscita cil EE
EE1
I:0
9
Bul.1762
uscita cil PP
PP1
I:0
19
Bul.1762
uscita cil EE
EE_ESCE
O:0
U
0
Bul.1762
rientro cil EE
EE_ENTRA
O:0
L
1
Bul.1762
uscita cil PP
PP_ESCE
O:2
U
9
1762-OW16
rientro cil PP
PP_ENTRA
O:2
L
11
1762-OW16


0031
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Relè k
RELE_AUSIL_K
B3:0
3
rientro cil EE
EE0
I:0
6
Bul.1762
rientro cil PP
PP0
I:0
21
Bul.1762
uscita cil FF
FF_ESCE
O:0
U
12
Bul.1762
rientro cil FF
FF_ENTRA
O:0
L
11
Bul.1762
out 1 agraria
OUT1_AGRARIA
O:2
U
15
1762-OW16
out2 agraria
OUT2_AGRARIA
O:2
U
13
1762-OW16
Blower ON
SS_ON
O:3
6
Blower SS
T_APERTURA_PINZA_SS
TON
Timer On Delay
Timer T4:7
Time Base 1.0
Preset 5
Accum 0
EN
DN


0032
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Relè k
RELE_AUSIL_K
B3:0
3
rientro cil FF
FF0
I:0
10
Bul.1762
out 1 agraria
OUT1_AGRARIA
O:2
15
1762-OW16
out2 agraria
OUT2_AGRARIA
O:2
13
1762-OW16
Blower SS
T_APERTURA_PINZA_SS/DN
T4:7
DN
uscita cil QQ
QQ_ESCE
O:2
U
4
1762-OW16
rientro cil QQ
QQ_ENTRA
O:2
L
6
1762-OW16
0033
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Relè k
RELE_AUSIL_K
B3:0
3
rientro cil QQ
QQ0
I:0
23
Bul.1762
rientro cil CC
CC_ENTRA
O:0
U
14
Bul.1762
uscita cil CC
CC_ESCE
O:0
L
15
Bul.1762
rientro cil LL
LL_ENTRA
O:2
U
1
1762-OW16
uscita cil LL
LL_ESCE
O:2
L
7
1762-OW16

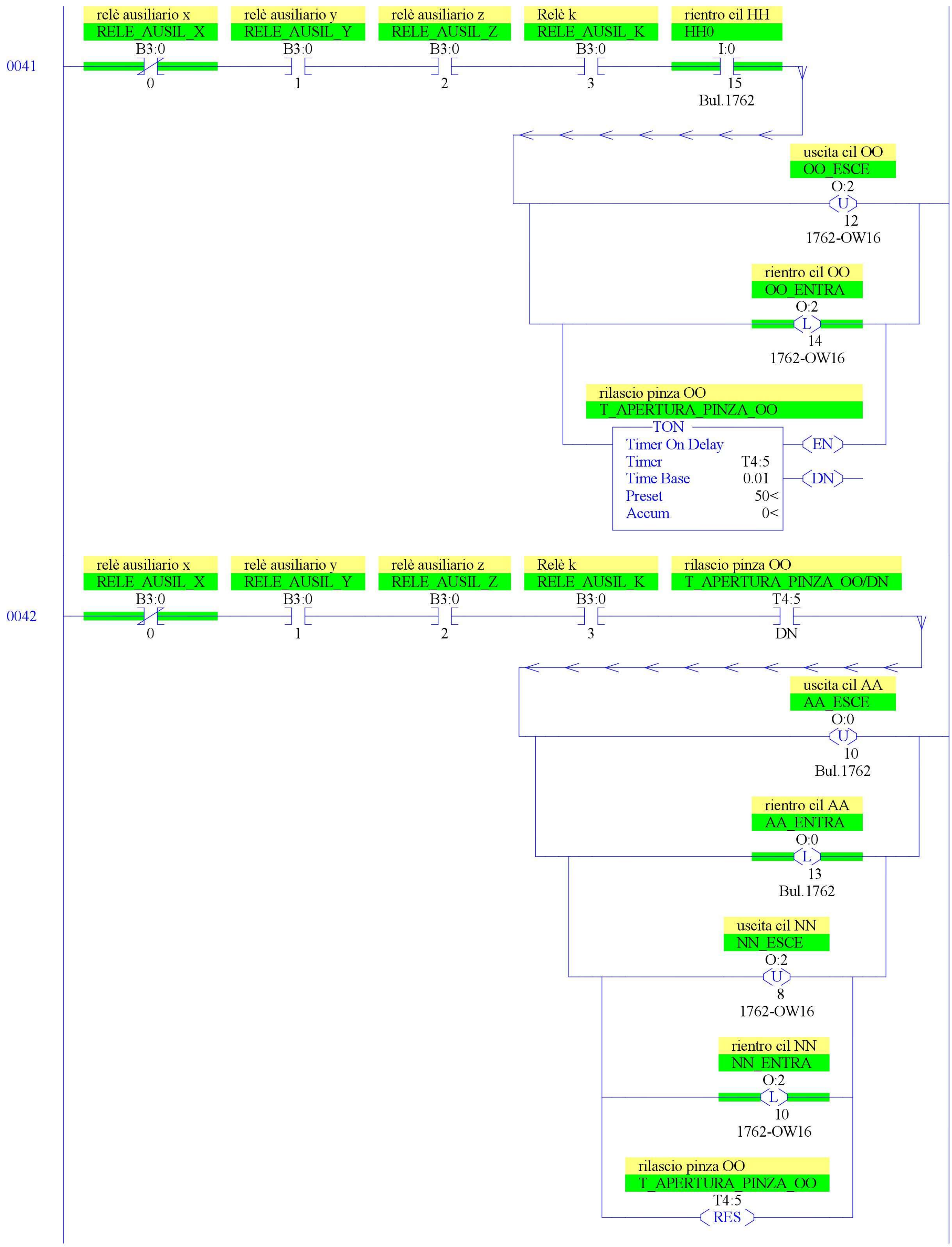

0034
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Relè k
RELE_AUSIL_K
B3:0
3
rientro cil QQ
QQ0
I:0
23
Bul.1762
cilindro ii esce
II_ESCE
O:3
L
9
1762-OW16
cilindro ii entra
II_ENTRA
O:3
U
8
1762-OW16
Timer chiusura pinza II
T_CHIUSURA_PINZA_II
TON
Timer On Delay
Timer T4:2
Time Base 0.01
Preset 50<
Accum 0<
EN
DN
0035
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Relè k
RELE_AUSIL_K
B3:0
3
temporizzatore pinza II
TEMP_PINZA_II
T4:2
DN
cilindro hh entra
HH_ENTRA
O:3
L
10
1762-OW16
cilindro hh esce
HH_ESCE
O:3
U
11
1762-OW16
Timer chiusura pinza II
T_CHIUSURA_PINZA_II
T4:2
RES

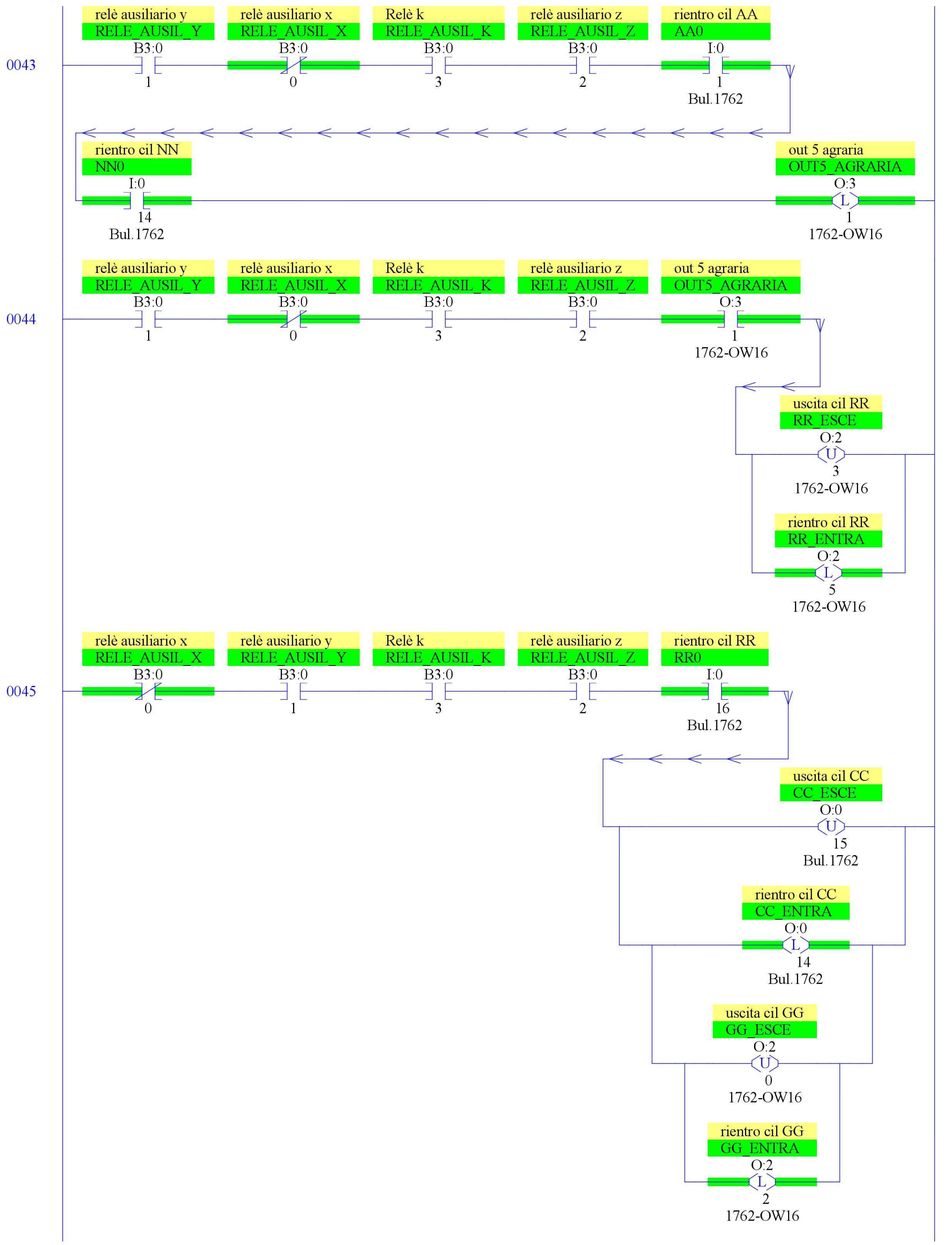

0036
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Relè k
RELE_AUSIL_K
B3:0
3
rientro cil HH
HH0
I:0
15
Bul.1762
rientro cil GG
GG_ENTRA
O:2
U
2
1762-OW16
uscita cil GG
GG_ESCE
O:2
L
0
1762-OW16
0037
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Relè k
RELE_AUSIL_K
B3:0
3
uscita cil GG
GG1
I:0
2
Bul.1762
rientro cil AA
AA_ENTRA
O:0
U
13
Bul.1762
uscita cil AA
AA_ESCE
O:0
L
10
Bul.1762
rientro cil NN
NN_ENTRA
O:2
U
10
1762-OW16
uscita cil NN
NN_ESCE
O:2
L
8
1762-OW16
0038
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Relè k
RELE_AUSIL_K
B3:0
3
cilindro hh esce
HH_ESCE
O:3
L
11
1762-OW16
cilindro hh entra
HH_ENTRA
O:3
U
10
1762-OW16

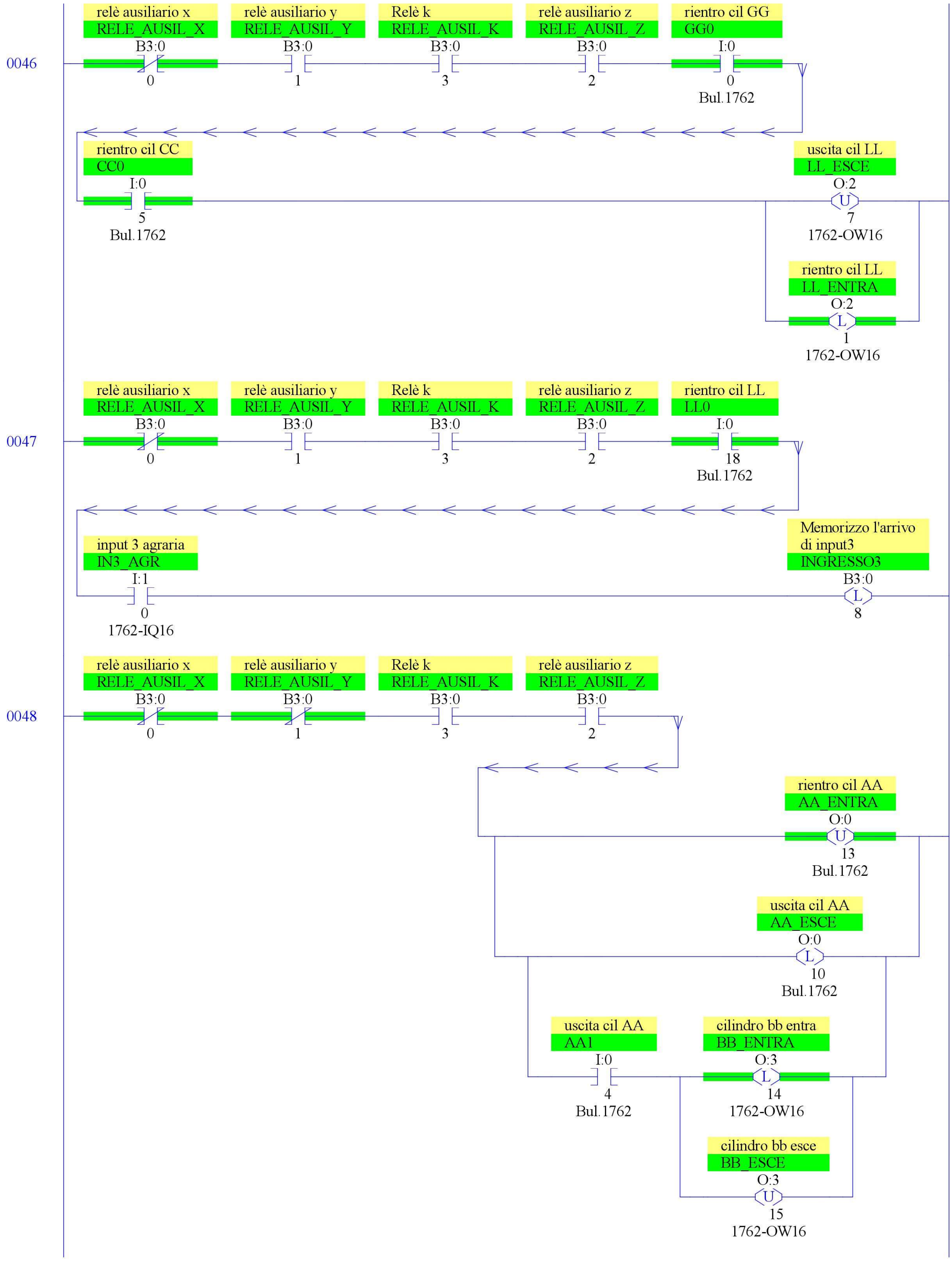

0039
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Relè k
RELE_AUSIL_K
B3:0
3
uscita cil HH
HH1
I:0
13
Bul.1762
cilindro ii esce
II_ESCE
O:3
U
9
1762-OW16
cilindro ii entra
II_ENTRA
O:3
L
8
1762-OW16
Temporizzatore
apertura pinza II
T_APERTURA_PINZA_II
TON
Timer On Delay
Timer T4:6
Time Base 0.01
Preset 50<
Accum 0<
EN
DN
0040
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Relè k
RELE_AUSIL_K
B3:0
3
Temporizzatore
apertura pinza II
T_APERTURA_PINZA_II/DN
T4:6
DN
cilindro hh esce
HH_ESCE
O:3
U
11
1762-OW16
cilindro hh entra
HH_ENTRA
O:3
L
10
1762-OW16
Temporizzatore
apertura pinza II
T_APERTURA_PINZA_II
T4:6
RES

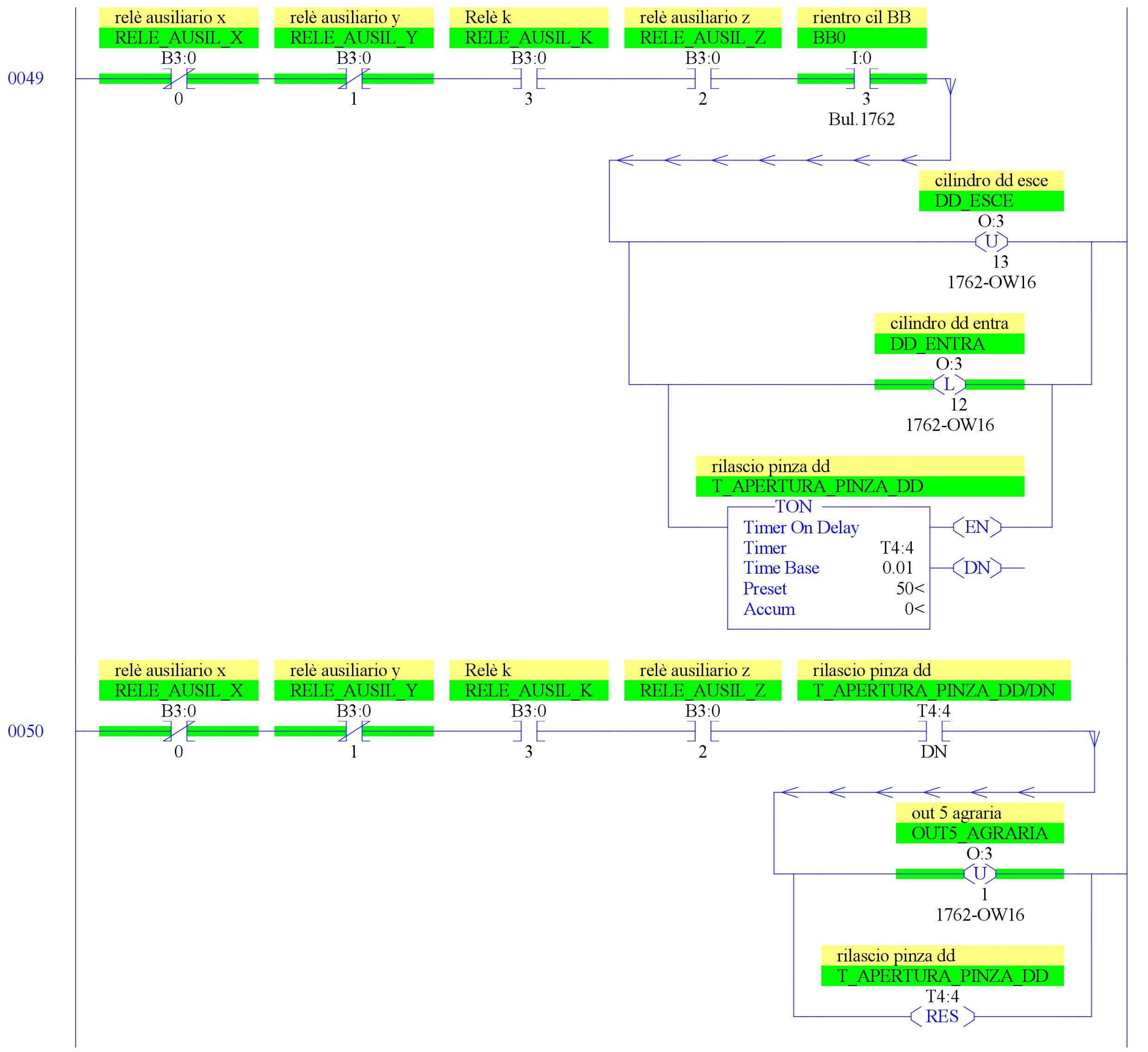
COMPLETE CYCLE WITH BLOWER

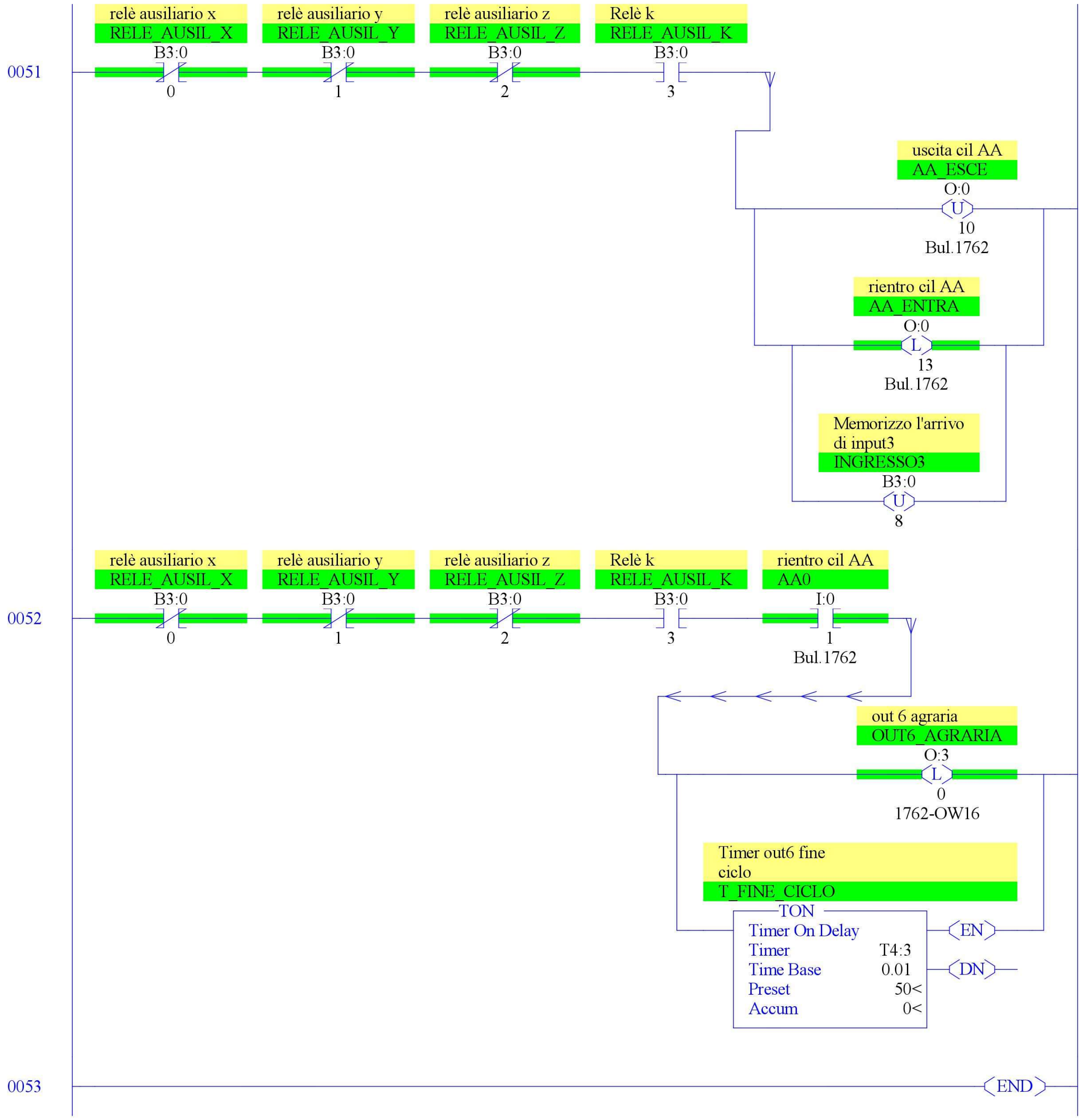
LAD 3 - CICLOCOMPL --- Total Rungs in File = 54




0043
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
relè ausiliario x
RELE_AUSIL_X
B3:0
0
Relè k
RELE_AUSIL_K
B3:0
3
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
rientro cil AA
AA0
I:0
1
Bul.1762
rientro cil NN
NN0
I:0
14
Bul.1762
out 5 agraria
OUT5_AGRARIA
O:3
L
1
1762-OW16
0044
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
relè ausiliario x
RELE_AUSIL_X
B3:0
0
Relè k
RELE_AUSIL_K
B3:0
3
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
out 5 agraria
OUT5_AGRARIA
O:3
1
1762-OW16
uscita cil RR
RR_ESCE
O:2
U
3
1762-OW16
rientro cil RR
RR_ENTRA
O:2
L
5
1762-OW16
0045
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
Relè k
RELE_AUSIL_K
B3:0
3
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
rientro cil RR
RR0
I:0
16
Bul.1762
uscita cil CC
CC_ESCE
O:0
U
15
Bul.1762
rientro cil CC
CC_ENTRA
O:0
L
14
Bul.1762
uscita cil GG
GG_ESCE
O:2
U
0
1762-OW16
rientro cil GG
GG_ENTRA
O:2
L
2
1762-OW16


0046
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
Relè k
RELE_AUSIL_K
B3:0
3
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
rientro cil GG
GG0
I:0
0
Bul.1762
rientro cil CC
CC0
I:0
5
Bul.1762
uscita cil LL
LL_ESCE
O:2
U
7
1762-OW16
rientro cil LL
LL_ENTRA
O:2
L
1
1762-OW16
0047
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
Relè k
RELE_AUSIL_K
B3:0
3
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
rientro cil LL
LL0
I:0
18
Bul.1762
input 3 agraria
IN3_AGR
I:1
0
1762-IQ16
Memorizzo l'arrivo di input3
INGRESSO3
B3:0
L
8
0048
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
Relè k
RELE_AUSIL_K
B3:0
3
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
rientro cil AA
AA_ENTRA
O:0
U
13
Bul.1762
uscita cil AA
AA_ESCE
O:0
L
10
Bul.1762
uscita cil AA
AA1
I:0
4
Bul.1762
cilindro bb entra
BB_ENTRA
O:3
L
14
1762-OW16
cilindro bb esce
BB_ESCE
O:3
U
15
1762-OW16

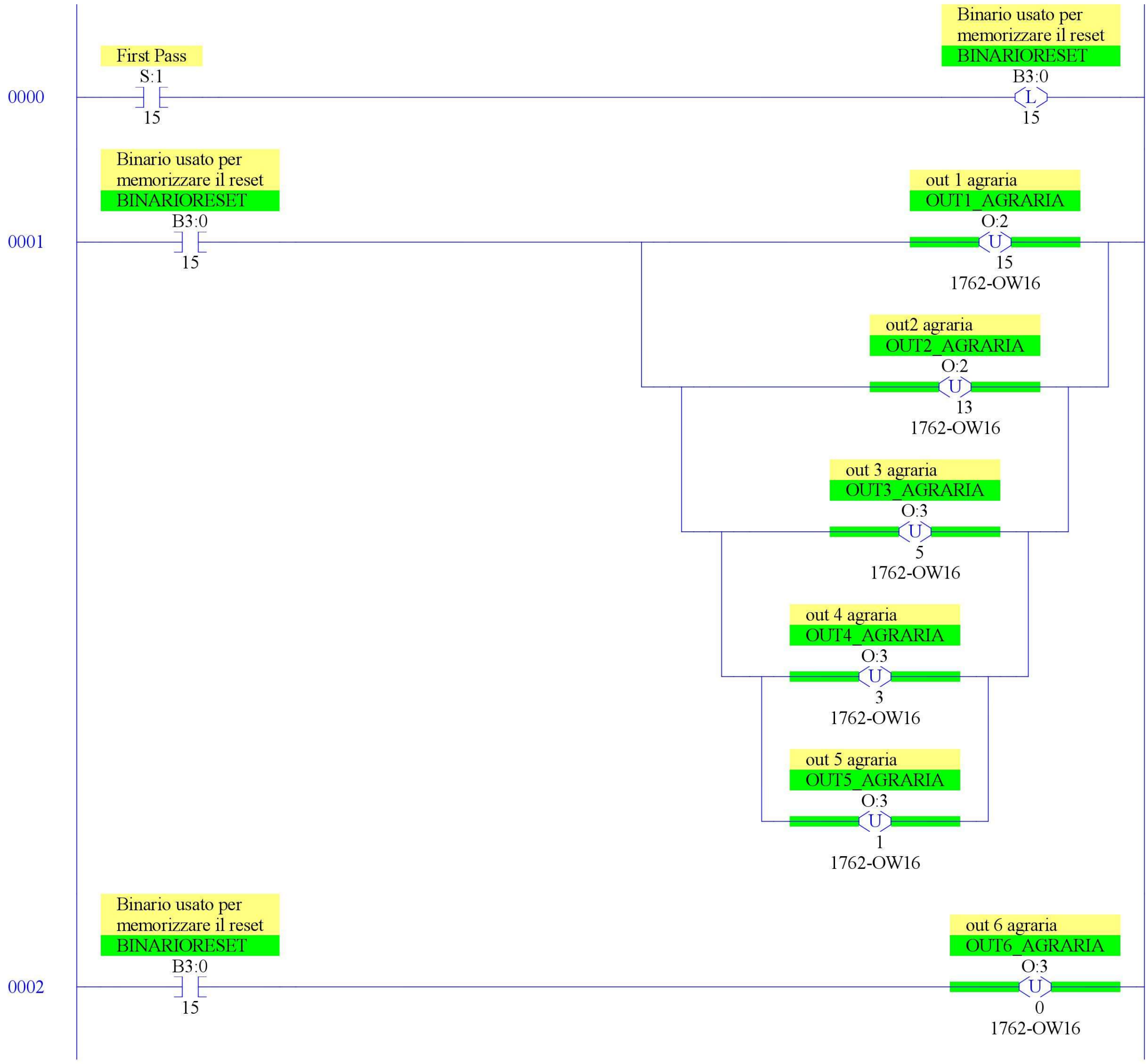

0049
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
Relè k
RELE_AUSIL_K
B3:0
3
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
rientro cil BB
BB0
I:0
3
Bul.1762
cilindro dd esce
DD_ESCE
O:3
U
13
1762-OW16
cilindro dd entra
DD_ENTRA
O:3
L
12
1762-OW16
rilascio pinza dd
T_APERTURA_PINZA_DD
TON
Timer On Delay
Timer T4:4
Time Base 0.01
Preset 50<
Accum 0<
EN
DN
0050
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
Relè k
RELE_AUSIL_K
B3:0
3
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
rilascio pinza dd
T_APERTURA_PINZA_DD/DN
T4:4
DN
out 5 agraria
OUT5_AGRARIA
O:3
U
1
1762-OW16
rilascio pinza dd
T_APERTURA_PINZA_DD
T4:4
RES

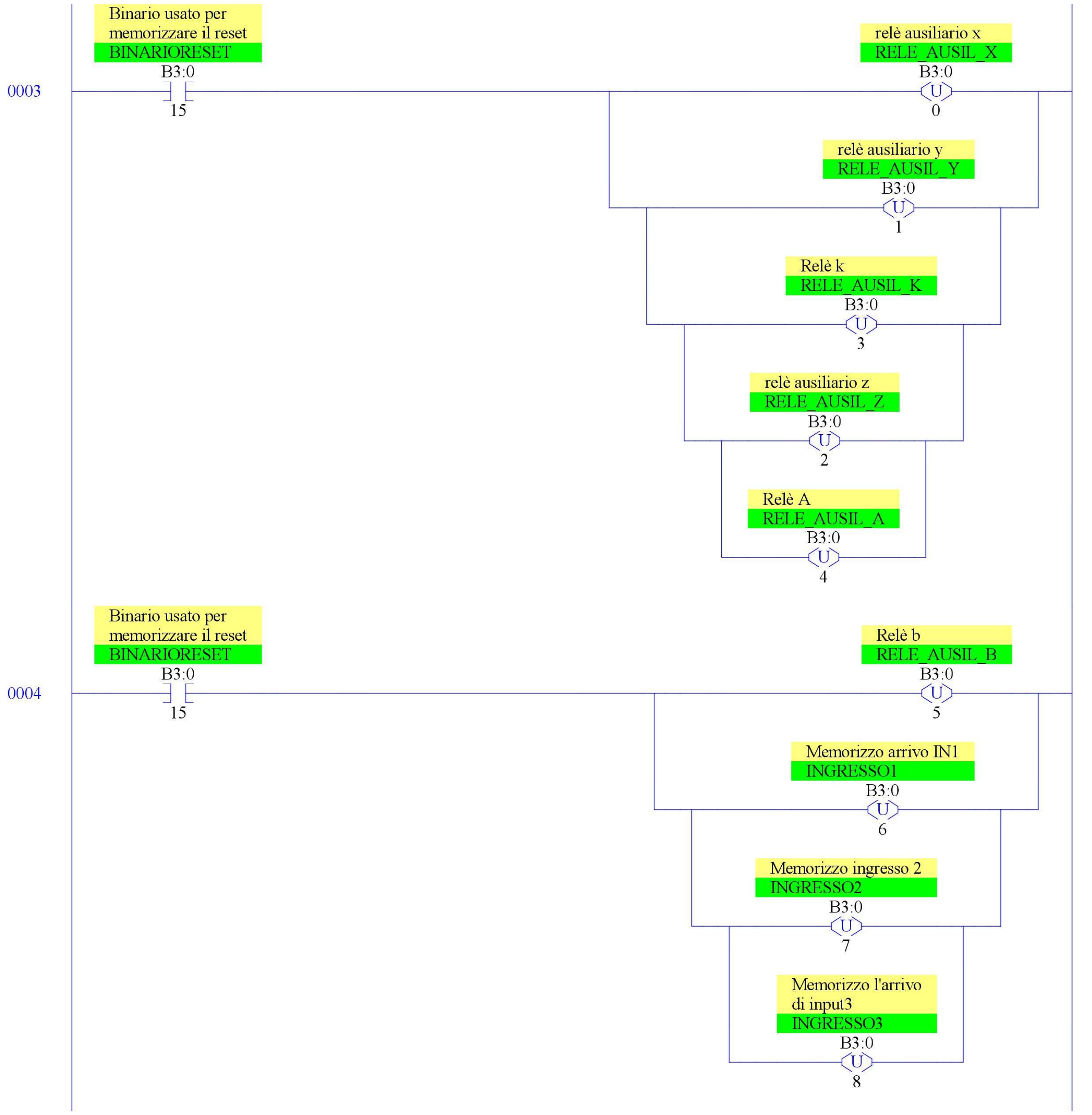

0051
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Relè k
RELE_AUSIL_K
B3:0
3
uscita cil AA
AA_ESCE
O:0
U
10
Bul.1762
rientro cil AA
AA_ENTRA
O:0
L
13
Bul.1762
Memorizzo l'arrivo di input3
INGRESSO3
B3:0
U
8
0052
relè ausiliario x
RELE_AUSIL_X
B3:0
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
1
relè ausiliario z
RELE_AUSIL_Z
B3:0
2
Relè k
RELE_AUSIL_K
B3:0
3
rientro cil AA
AA0
I:0
1
Bul.1762
out 6 agraria
OUT6_AGRARIA
O:3
L
0
1762-OW16
Timer out6 fine ciclo
T_FINE_CICLO
TON
Timer On Delay
Timer T4:3
Time Base 0.01
Preset 50<
Accum 0<
EN
DN
0053
END

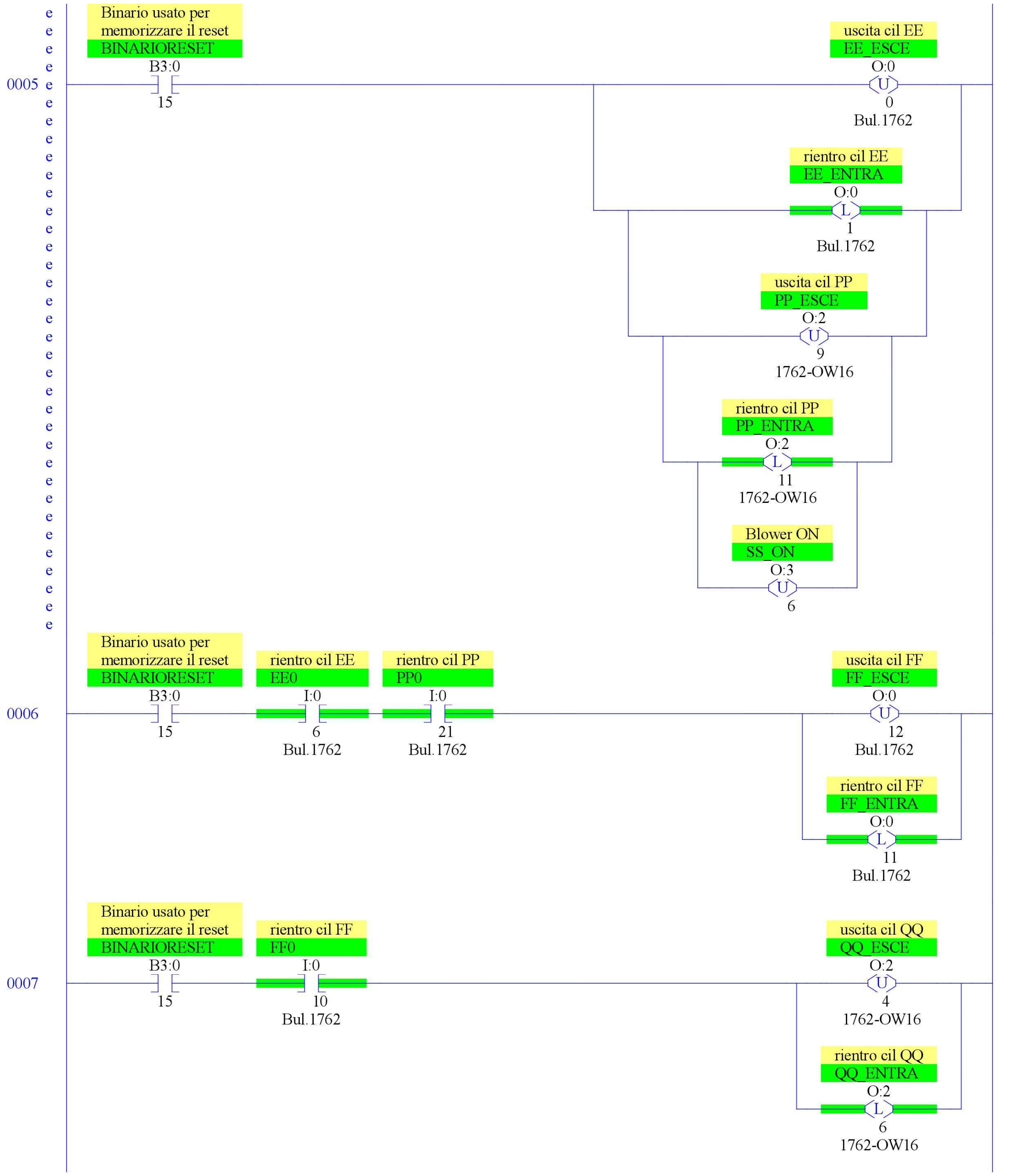
Appendix 4 - Belluco Reset Cycle with Blower

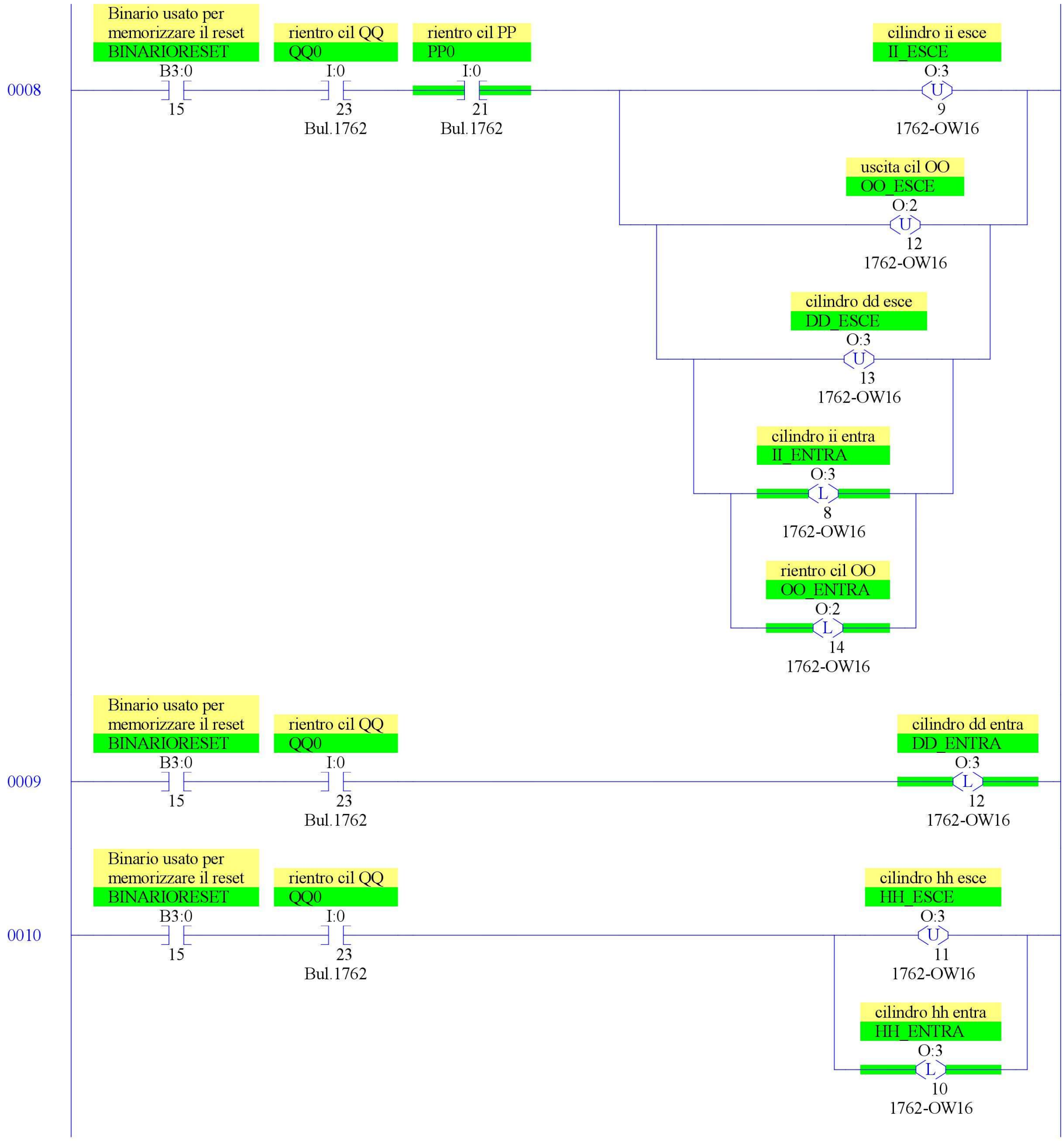
COMPLETE CYCLE WITH BLOWER

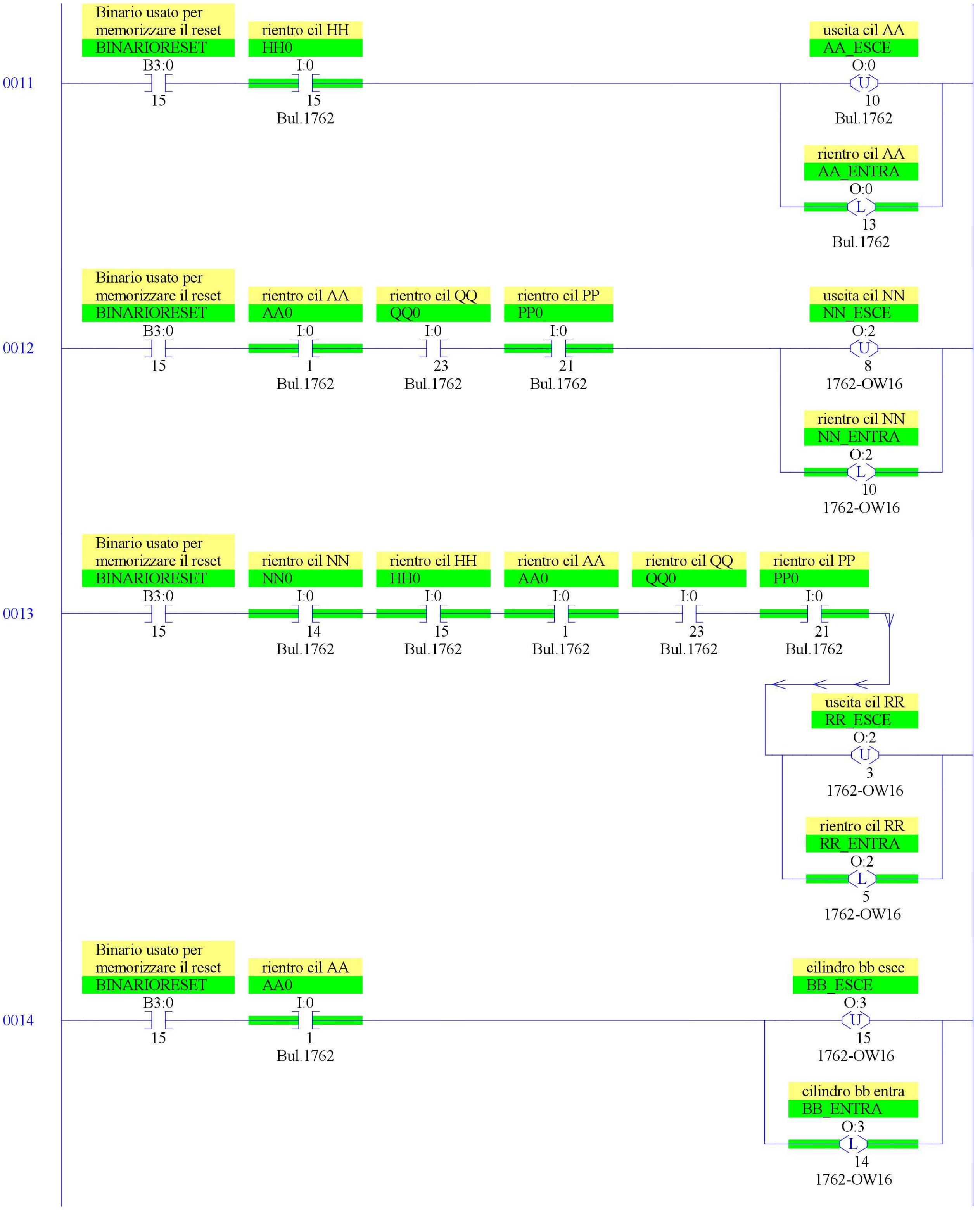
LAD 2 - CICLO RESE --- Total Rungs in File = 21

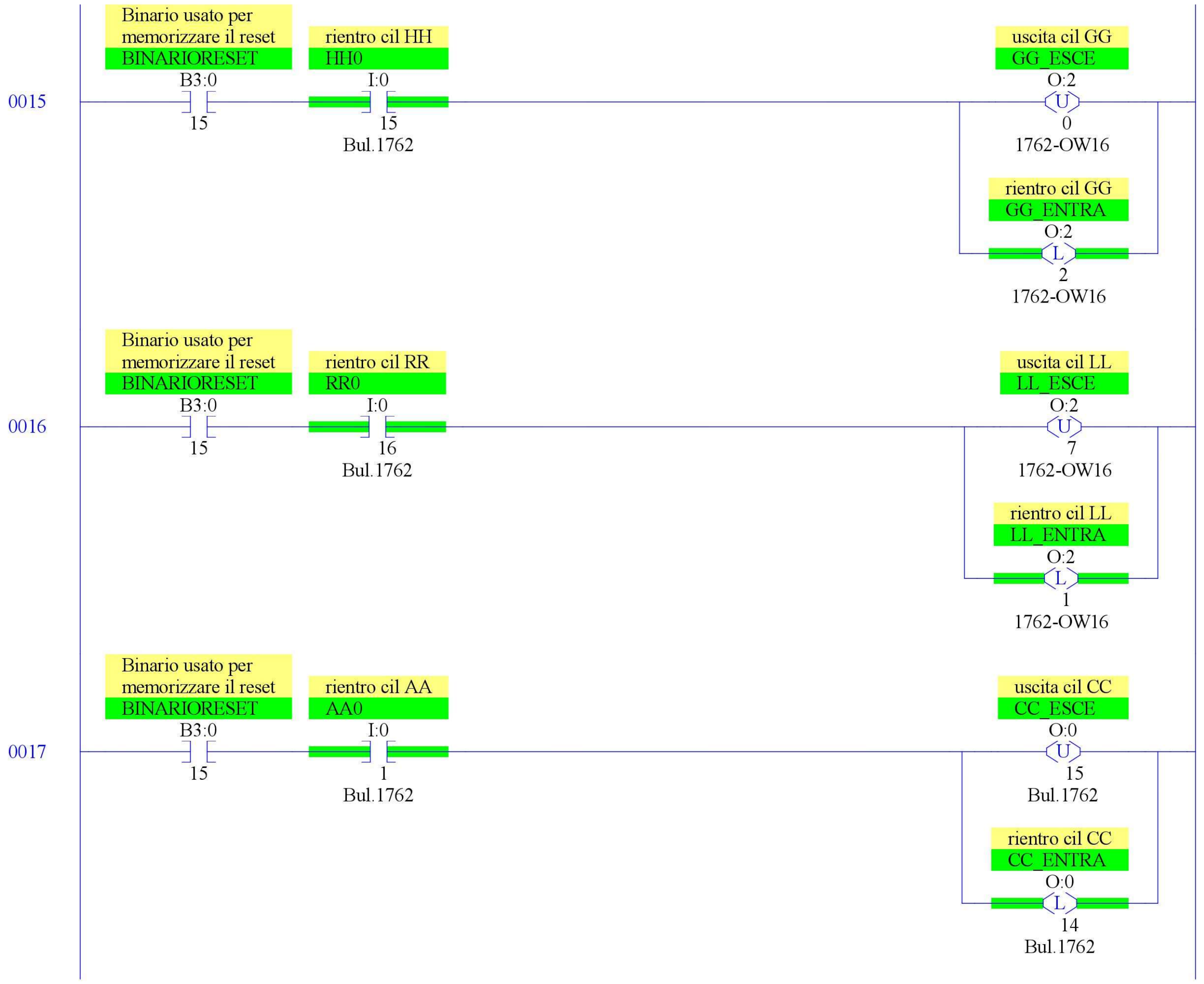


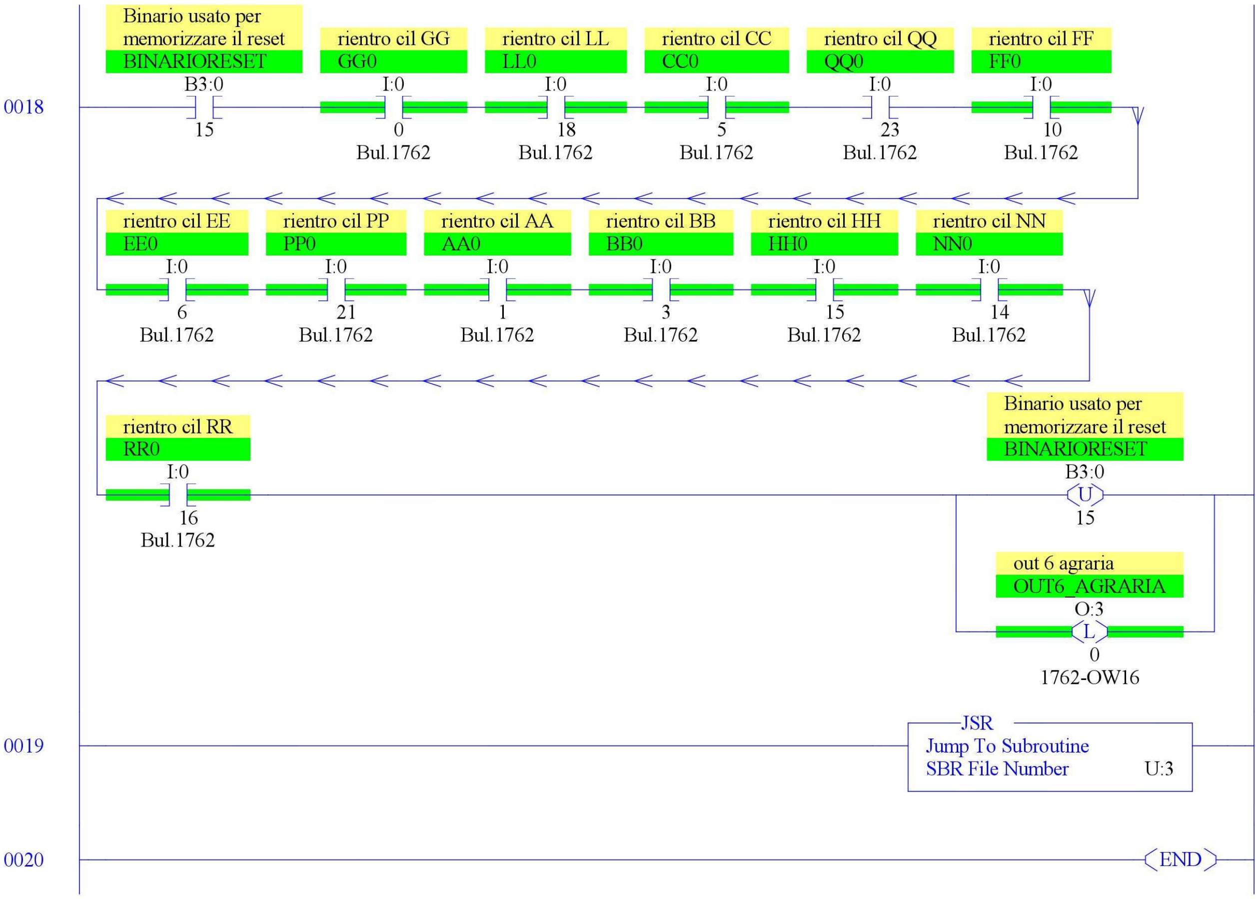

0003
Binario usato per memorizzare il reset
BINARIORESET
B3:0
15
relè ausiliario x
RELE_AUSIL_X
B3:0
U
0
relè ausiliario y
RELE_AUSIL_Y
B3:0
U
1
Relè k
RELE_AUSIL_K
B3:0
U
3
relè ausiliario z
RELE_AUSIL_Z
B3:0
U
2
Relè A
RELE_AUSIL_A
B3:0
U
4
0004
Binario usato per memorizzare il reset
BINARIORESET
B3:0
15
Relè b
RELE_AUSIL_B
B3:0
U
5
Memorizzo arrivo IN1
INGRESSO1
B3:0
U
6
Memorizzo ingresso 2
INGRESSO2
B3:0
U
7
Memorizzo l'arrivo di input3
INGRESSO3
B3:0
U
8


0005
Binario usato per memorizzare il reset
BINARIORESET
B3:0
15
uscita cil EE
EE_ESCE
O:0
U
0
Bul.1762
rientro cil EE
EE_ENTRA
O:0
L
1
Bul.1762
uscita cil PP
PP_ESCE
O:2
U
9
1762-OW16
rientro cil PP
PP_ENTRA
O:2
L
11
1762-OW16
Blower ON
SS_ON
O:3
U
6
0006
Binario usato per memorizzare il reset
BINARIORESET
B3:0
15
rientro cil EE
EE0
I:0
6
Bul.1762
rientro cil PP
PP0
I:0
21
Bul.1762
uscita cil FF
FF_ESCE
O:0
U
12
Bul.1762
rientro cil FF
FF_ENTRA
O:0
L
11
Bul.1762
0007
Binario usato per memorizzare il reset
BINARIORESET
B3:0
15
rientro cil FF
FF0
I:0
10
Bul.1762
uscita cil QQ
QQ_ESCE
O:2
U
4
1762-OW16
rientro cil QQ
QQ_ENTRA
O:2
L
6
1762-OW16


0008
Binario usato per memorizzare il reset
BINARIORESET
B3:0
15
rientro cil QQ
QQ0
I:0
23
Bul.1762
rientro cil PP
PP0
I:0
21
Bul.1762
cilindro ii esce
II_ESCE
O:3
U
9
1762-OW16
uscita cil OO
OO_ESCE
O:2
U
12
1762-OW16
cilindro dd esce
DD_ESCE
O:3
U
13
1762-OW16
cilindro ii entra
II_ENTRA
O:3
L
8
1762-OW16
rientro cil OO
OO_ENTRA
O:2
L
14
1762-OW16
0009
Binario usato per memorizzare il reset
BINARIORESET
B3:0
15
rientro cil QQ
QQ0
I:0
23
Bul.1762
cilindro dd entra
DD_ENTRA
O:3
L
12
1762-OW16
0010
Binario usato per memorizzare il reset
BINARIORESET
B3:0
15
rientro cil QQ
QQ0
I:0
23
Bul.1762
cilindro hh esce
HH_ESCE
O:3
U
11
1762-OW16
cilindro hh entra
HH_ENTRA
O:3
L
10
1762-OW16


0011
Binario usato per memorizzare il reset
BINARIORESET
B3:0
15
rientro cil HH
HH0
I:0
15
Bul.1762
uscita cil AA
AA_ESCE
O:0
U
10
Bul.1762
rientro cil AA
AA_ENTRA
O:0
L
13
Bul.1762
0012
Binario usato per memorizzare il reset
BINARIORESET
B3:0
15
rientro cil AA
AA0
I:0
1
Bul.1762
rientro cil QQ
QQ0
I:0
23
Bul.1762
rientro cil PP
PP0
I:0
21
Bul.1762
uscita cil NN
NN_ESCE
O:2
U
8
1762-OW16
rientro cil NN
NN_ENTRA
O:2
L
10
1762-OW16
0013
Binario usato per memorizzare il reset
BINARIORESET
B3:0
15
rientro cil NN
NN0
I:0
14
Bul.1762
rientro cil HH
HH0
I:0
15
Bul.1762
rientro cil AA
AA0
I:0
1
Bul.1762
rientro cil QQ
QQ0
I:0
23
Bul.1762
rientro cil PP
PP0
I:0
21
Bul.1762
uscita cil RR
RR_ESCE
O:2
U
3
1762-OW16
rientro cil RR
RR_ENTRA
O:2
L
5
1762-OW16
0014
Binario usato per memorizzare il reset
BINARIORESET
B3:0
15
rientro cil AA
AA0
I:0
1
Bul.1762
cilindro bb esce
BB_ESCE
O:3
U
15
1762-OW16
cilindro bb entra
BB_ENTRA
O:3
L
14
1762-OW16


0015
Binario usato per memorizzare il reset
BINARIORESET
B3:0
15
rientro cil HH
HH0
I:0
15
Bul.1762
uscita cil GG
GG_ESCE
O:2
U
0
1762-OW16
rientro cil GG
GG_ENTRA
O:2
L
2
1762-OW16
0016
Binario usato per memorizzare il reset
BINARIORESET
B3:0
15
rientro cil RR
RR0
I:0
16
Bul.1762
uscita cil LL
LL_ESCE
O:2
U
7
1762-OW16
rientro cil LL
LL_ENTRA
O:2
L
1
1762-OW16
0017
Binario usato per memorizzare il reset
BINARIORESET
B3:0
15
rientro cil AA
AA0
I:0
1
Bul.1762
uscita cil CC
CC_ESCE
O:0
U
15
Bul.1762
rientro cil CC
CC_ENTRA
O:0
L
14
Bul.1762


0018
Binario usato per memorizzare il reset
BINARIORESET
B3:0
15
rientro cil GG
GG0
I:0
0
Bul.1762
rientro cil LL
LL0
I:0
18
Bul.1762
rientro cil CC
CC0
I:0
5
Bul.1762
rientro cil QQ
QQ0
I:0
23
Bul.1762
rientro cil FF
FF0
I:0
10
Bul.1762
rientro cil EE
EE0
I:0
6
Bul.1762
rientro cil PP
PP0
I:0
21
Bul.1762
rientro cil AA
AA0
I:0
1
Bul.1762
rientro cil BB
BB0
I:0
3
Bul.1762
rientro cil HH
HH0
I:0
15
Bul.1762
rientro cil NN
NN0
I:0
14
Bul.1762
rientro cil RR
RR0
I:0
16
Bul.1762
Binario usato per memorizzare il reset
BINARIORESET
B3:0
U
15
out 6 agraria
OUT6_AGRARIA
O:3
L
0
1762-OW16
0019
JSR
Jump To Subroutine
SBR File Number U:3
0020
END

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