MFET585 TECHNICAL MEMO (UNDERGRADUATE VERSION)

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1. Project description

For this project, a robot work cell has been designed where a palletizing task has been simulated using the ABB Robot Studio software. The problem statement assigned for this project was the Undergraduate Configuration 1, which is shown in the following figure below:

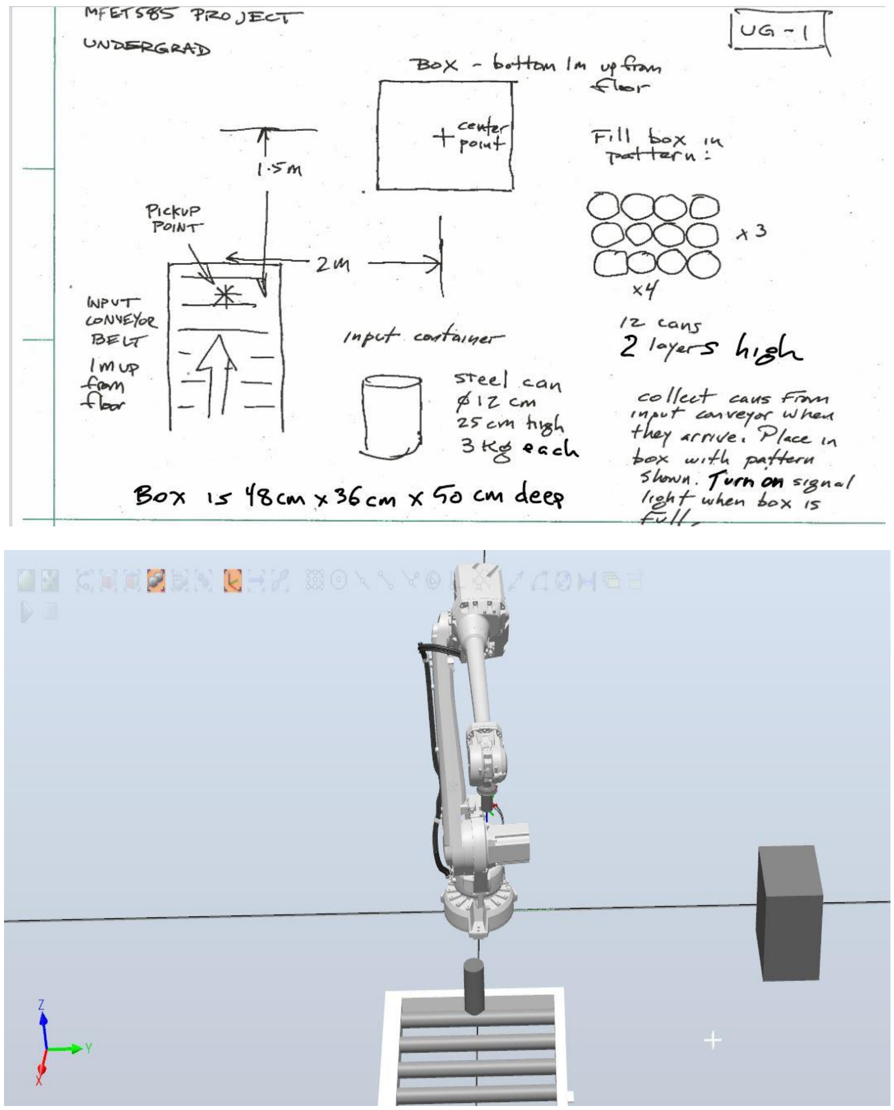


Fig 1: Project Work Cell Problem Statement

The top half of figure 1 displays the assigned configuration for this project, while the bottom half displays the setup of the assigned configuration on Robot Studio. The distance between the center feed on the conveyor belt to the box is exactly 2 meters or 2000 millimeters in the positive X direction, and 1.5 meters or 1500 millimeters in the positive Y direction. The product being palletized is a steel can with a diameter of 12 centimeters or 120 millimeters, a height of 25 centimeters or 250 millimeters, and weighing at 3 kg. These cans need to be palletized 4X3X2 configuration, i.e., 4 cans in a row, and 3 cans in a column with the box being 2 layers high.

2. Layout of Work Cell and description of operating principles

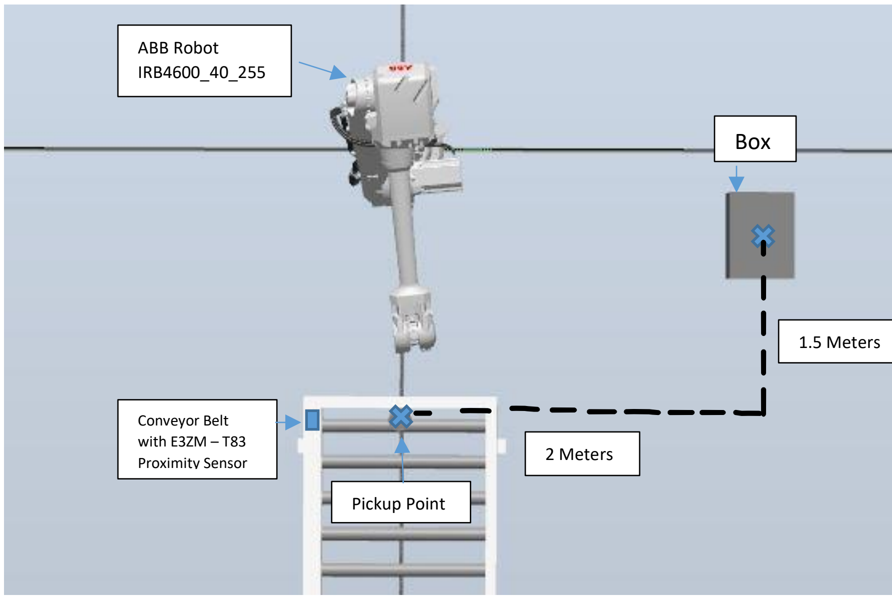
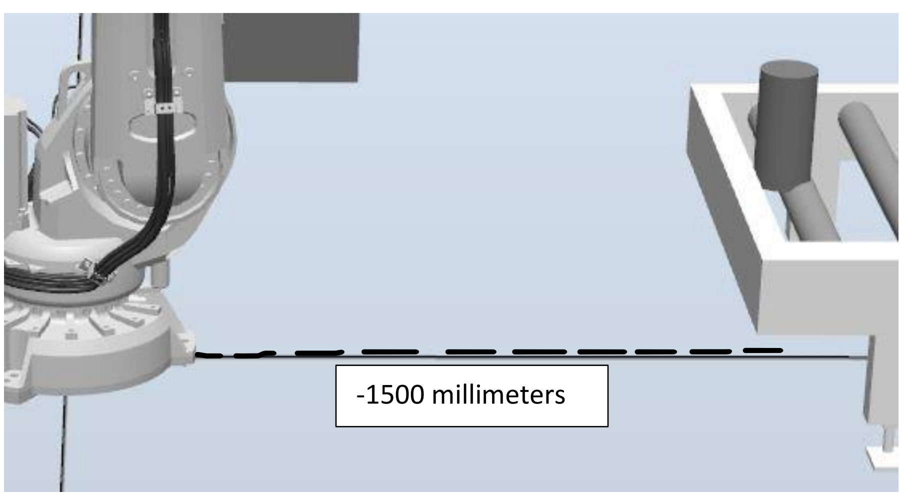


Figure 2: Work cell layout

Figure 2 displays the layout of the work cell for the assigned problem. The distance between the center of the in-feed conveyor belt and the box is 2 meters or 2000 millimeters in the positive x direction and 1.5 meters or 1500 millimeters in the positive y direction. The product being palletized is a 3 kg steel can which has a diameter of 12 centimeters or 120 millimeters and a height of 25 centimeters or 250 millimeters. The cans need to be palletized in a 4X3X2 configuration, i.e., 4 cans in each row, 3 cans in each column, 2 layers high, which is done by using an MG10 end effector. The box where the cans will be placed is exactly 480 millimeters by 360 millimeters by 500 millimeters. The conveyor belt given by Robot Studio is 4000 millimeters, by 950 millimeters, by 500 millimeters.



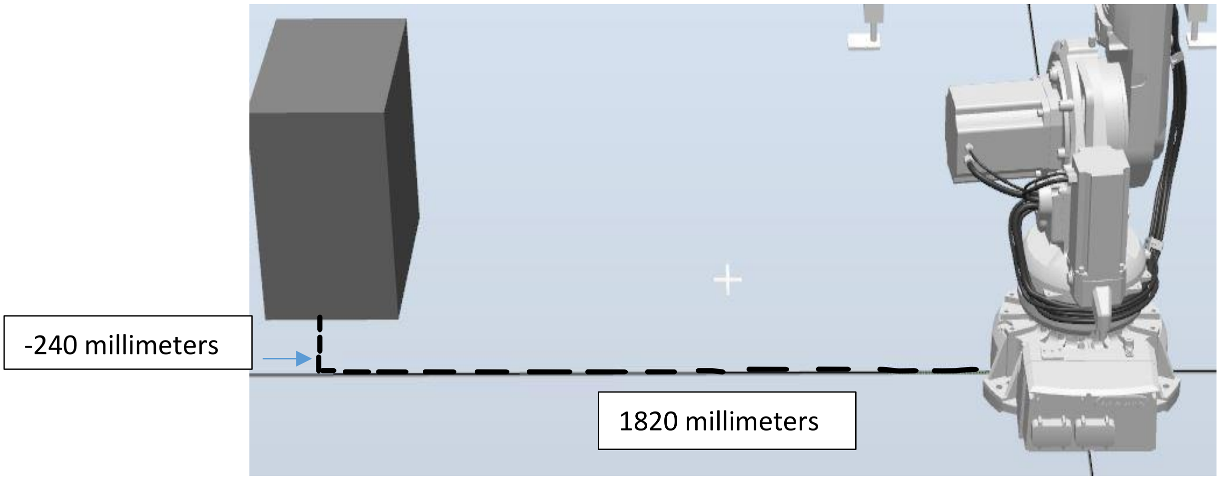


Figure 3: Distance from Robot to Work Objects

In the assigned configuration, it is shown that the center of the box and the conveyer belt must be 2meter or 2000 millimeters in the positive X direction and 1.5 meters or 1500 millimeters in the positive Y direction. The placement of the robot must be somewhere where it wouldn't be too far away from the conveyer belt or the box, but also not too close so that, even though the can may be in the work envelope, it would be out of the robots reach. As a result, the best placement for the conveyor belt end is 1.5 meters or 1500 millimeters in the negative Y direction. This is far enough for the robot to reach the can without an error. Since the box has to be exactly 2 meters or 2000 millimeters in the positive X directions as well as 1.5 meters or 1500 millimeters in the positive Y direction, it should be exactly at 0 Y and 2000 X. However, since the assigned configuration shows that its to the box's center, the box's width of 360 millimeters must be cut in half giving 180 millimeters. The 180 millimeters must then be subtracted from 2000 millimeters or 2 meters to give an exact placement of 1820 millimeters in the X direction. For the Y direction, the length of the box, which is 480 millimeters, must be cut in half and subtracted by the distance given in the assigned configuration, which is 1.5 meters or 1500 millimeters. This results in 1500 millimeters – 240 millimeters which equals 1260 In the positive Y direction. Since the center of the conveyer belt is placed at – 1500 millimeters in the Y direction, to get the exact location of the center of the box in the Y direction, 1260 millimeters must be added to -1500 millimeters equaling -240 millimeters. The exact location from the robot to the center of the box is 1820 millimeters or 1.82 meters in the X direction and -240 millimeters or -0.240 meters in the negative Y direction.

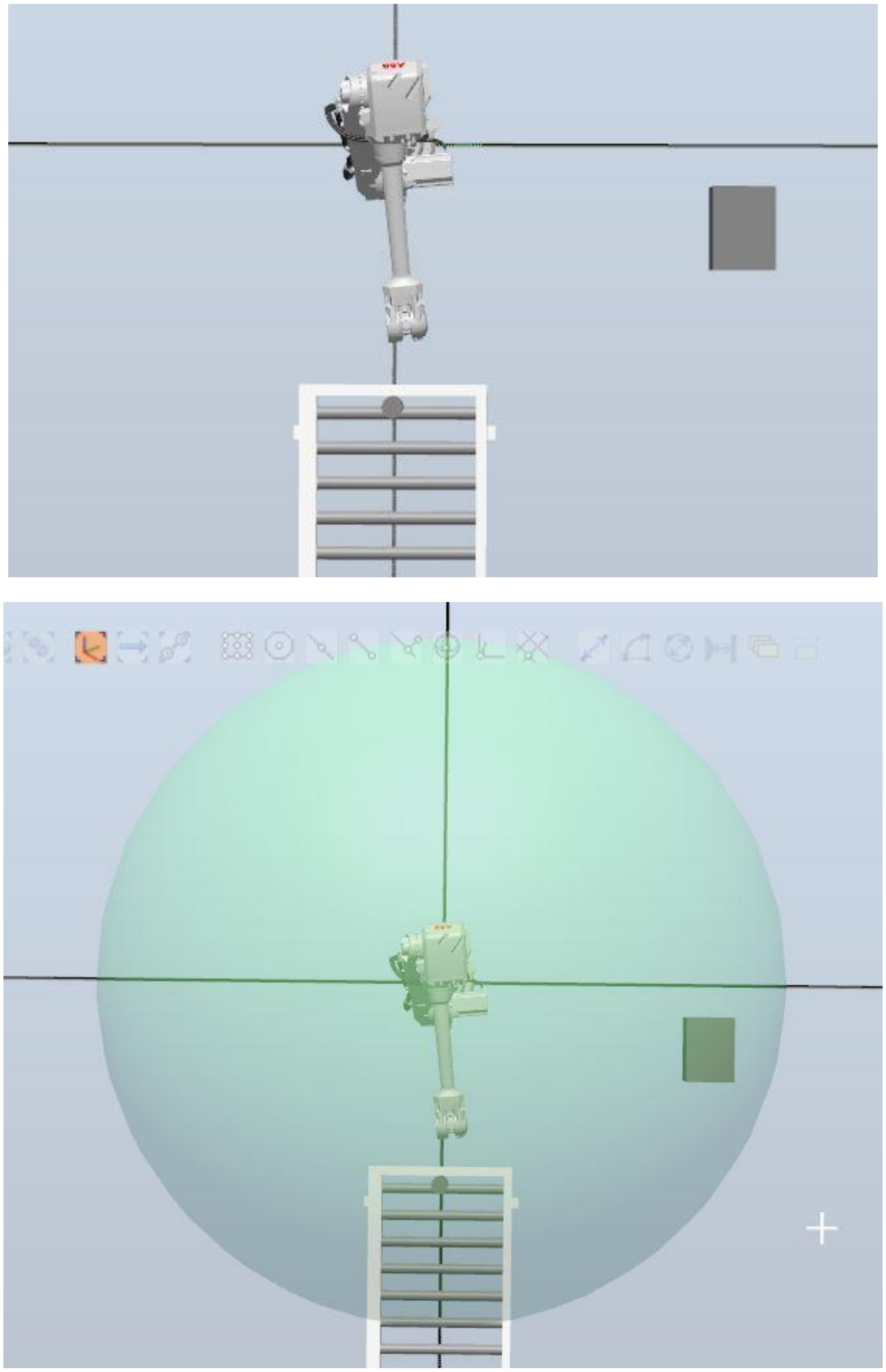


Figure 4: Work cell envelope

For this project, I needed a robot that had a reach of over 2 meters and would have a large enough payload to allow the robot to move the can from the feeding point on the conveyor belt to the box, as well as be able to hold the end effectors. The robot chosen to do the assigned configuration was the ABB IRB4600_40_255, as it has a max payload of 40 kg and a max reach of 2.55 meters. As seen in Figure 4, the reach is certainly long enough to transport the can from the conveyor feed to the box as it is inside the work envelope.

The whole process of palletizing the can will be automated by the robot which will pick up the can from the in-feed conveyer and transport it to the box to be arranged in the desired configuration. The robot will be placed near the front of the in-feed conveyer belt and to the side of the box. An E3ZM-T83 proximity sensor will be used to detect the presence of the part to be palletized on the input conveyor belt. When the sensor detects the can, the conveyer will stop and wait for the robot to pick the can up. Once the can has been transported, the conveyor will move the next can until it reaches the sensor. This process is repeated 24 times. There will also be a limit switch at the back right corner of the box, where the last can will be placed. When the limit switch is hit, a green signal light will turn on, which means that the box will be filled.

For the pick and place operation, an electric magnetic gripper, the MG10, will be used as the end effector. For this project, it is assumed that the steel cans are filled and covered, each weighing 3 kg. Since the can is made of steel, the lid would be made out of steel as well. This will allow the robot to place the magnet right on top of lid, picking it up, and transporting it to the box to be palletized.

3. End Effector design with figures and dynamics analysis

End Effector Design:

Since the can has a diameter of 120 mm, and each can must be placed side by side on a box having exactly a 360mmX480mm, a grabber is not a possible choice for an end effecter as it will collide with the other cans. The only end effectors that would work for the assigned problem would be either a vacuum gripper or a magnet gripper. The end effector being used for this project is an Electric Magnetic Gripper, the MG10, built by OnRobot. It is a cylindrical shape end effector, weighing at .8 kg, with a brushless DC motor controlling the magnet and a built-in proximity sensor which will allow the end effector to detect when it is near an object. All the user has to do to install the gripper is to place it on the quick changer attached to the robot at joint 6 and program it for the desirable outcome. The following figure displays the schematic drawing on the MG10:

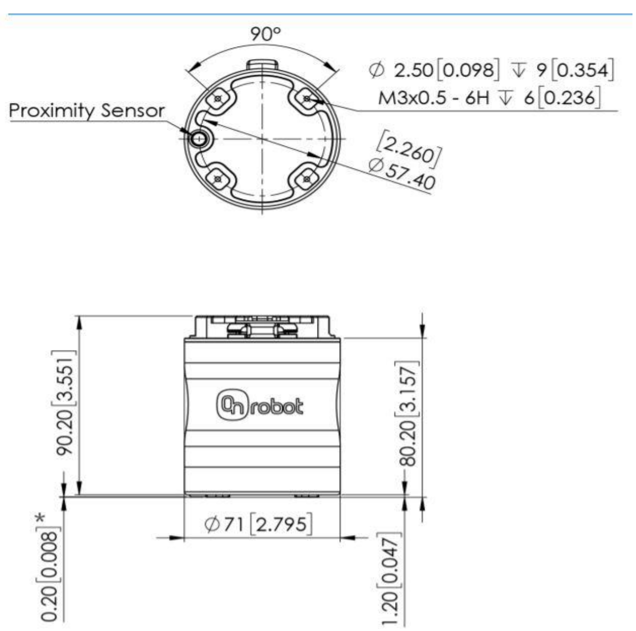


Figure 5: Drawing of OnRobot MG10

The MG10 has a diameter of 71mm which is small enough to fit inside the top of the can, which means when placing it on the box, it will not collide with the other objects being palletized. The MG10 has a max payload of 10 kg when parallel to the ground, and when it is perpendicular to the ground, the payload decreases to 3.4 kg, just above the cans weight. However, as a result of this, it is best to keep the end effector parallel to the ground for no errors to occur. Overall, this end effecter will be able to carry the weight of the can.

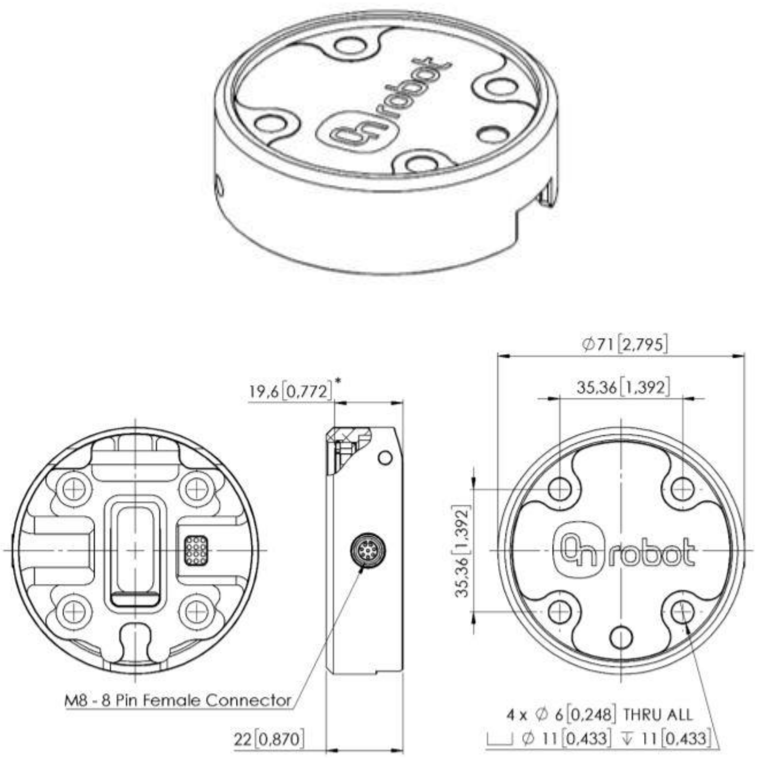
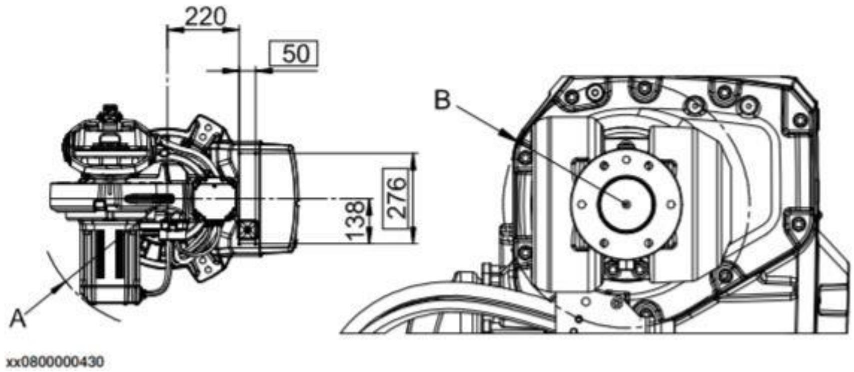


Figure 6: Quick Change Schematic Diagram

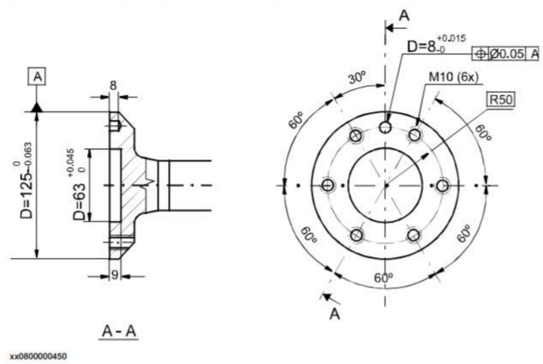
Figure 6 displays the Quick Changer which attached to the robot at joint 6 and the MG10. The quick changer is also built by OnRobot and what this does is it allows for any end effector to connect to it, without the hassle of finding different plates that would work to connect to the robot. The Quick Changer also has a diameter of 71 millimeters which allows the MG10 to fit perfectly on it. The payload for the Quick Changer is 20 kg, with the weight of the Quick Changer itself being 200 g or .2 kg, allowing it to be able to hold the MG10 and the can together without any issue.



1 Description

1.6.1 Information about mounting equipment
Continued

IRB 4600-60/2.05, IRB4600-45/2.05 and IRB 4600-40/2.55



Specification

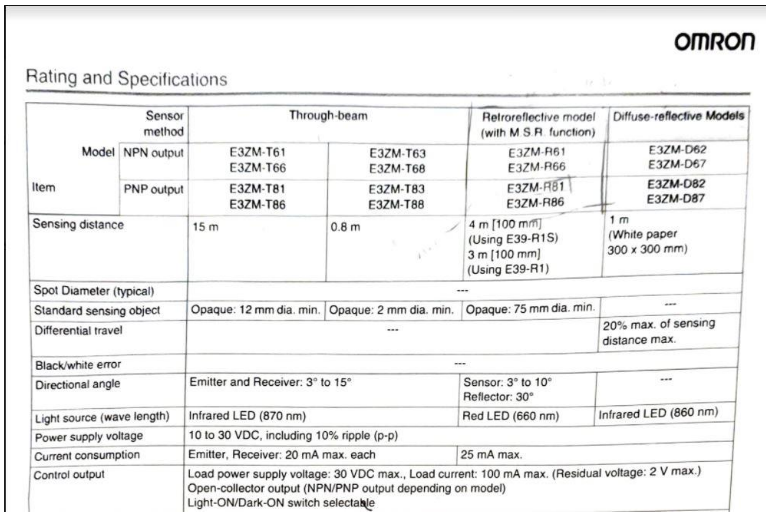
Robot version	Reach (m)	Payload (kg)	Armload (kg)
IRB 4600-60/2.05	2.05	60	20
IRB 4600-45/2.05	2.05	45	20
IRB 4600-40/2.55	2.55	40	20
IRB 4600-20/2.50	2.51	20	11
Number of axes	6+3 external (up to 36 with MultiMove)		
Protection	Standard IP67, as option Foundry Plus 2		
Mounting	Floor, shelf, inverted or tilted		
Controller	IRC5 Single cabinet		

Figure 7: Faceplate Diagram of ABB Robot IRB4600_40_255

Figure 7 displays the Faceplate Diagram of the ABB Robot IRB4600_40_255 as well as the specifications. This attaches the Quick Changer which in return attaches to the MG10. The Payload for the robot is 40 kg and with a total weight of 3 kg for the can, plus the .2 kg, plus + .8 kg for the MG10 equaling 4 kg, the robot will be able to use the end effecter without a problem.

4. Sensor/actuator list, placement, and wiring diagram

For detecting the presence of the steel can, a E3ZM-T83 proximity sensor will be used. The E3ZM – T83 is a through beam NPN proximity sensor, by Omron which will detect when the can arrives at the pickup point. When the sensor detects the can, the conveyer will stop and wait for the robot to pick the can up. The E3ZM-T83 has a sensing distance of .8 meters which is more than enough to detect the steel can, as the steel can is only 120 millimeters in diameters or .120 meters and 250 millimeters or .250 meters in height.


OMRON

Rating and Specifications

Item	Sensor method	Through-beam		Retroreflective model (with M.S.R. function)	Diffuse-reflective Models
Model	NPN output	E3ZM-T61 E3ZM-T66	E3ZM-T63 E3ZM-T68	E3ZM-R61 E3ZM-R66	E3ZM-D62 E3ZM-D67
	PNP output	E3ZM-T81 E3ZM-T86	E3ZM-T83 E3ZM-T88	E3ZM-R81 E3ZM-R86	E3ZM-D82 E3ZM-D87
Sensing distance		15 m	0.8 m	4 m [100 mm] (Using E39-R1S) 3 m [100 mm] (Using E39-R1)	1 m (White paper 300 x 300 mm)
Spot Diameter (typical)		---			
Standard sensing object		Opaque: 12 mm dia. min.	Opaque: 2 mm dia. min.	Opaque: 75 mm dia. min.	---
Differential travel		---			20% max. of sensing distance max.
Black/white error		---			
Directional angle		Emitter and Receiver: 3° to 15°		Sensor: 3° to 10° Reflector: 30°	---
Light source (wave length)		Infrared LED (870 nm)		Red LED (660 nm)	Infrared LED (860 nm)
Power supply voltage		10 to 30 VDC, including 10% ripple (p-p)			
Current consumption		Emitter, Receiver: 20 mA max. each		25 mA max.	
Control output		Load power supply voltage: 30 VDC max., Load current: 100 mA max. (Residual voltage: 2 V max.) Open-collector output (NPN/PNP output depending on model) Light-ON/Dark-ON switch selectable			

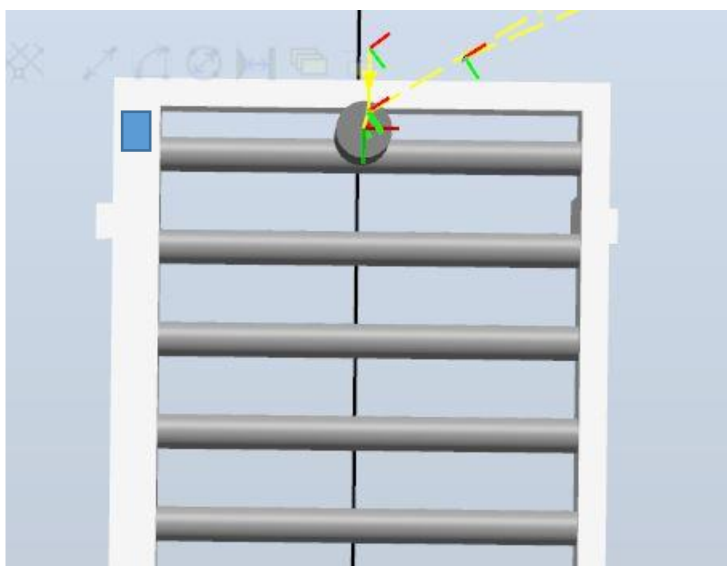


Figure 8: E3ZM-T83 proximity sensor and Data Sheet

Figure 8 shows the placement of the E3ZM-T83 proximity sensor. The sensor is placed exactly at -475 millimeters in the negative X direction from the center of the conveyer belt and -1500 millimeter in the Y direction. The sensor is also placed right on top of the edge of the conveyor belt at 500 milliliters in the Positive Z direction. This setup allows us to detect the steel can on the conveyer belt even if the can is not exactly at the center of the conveyer belt. The sensor position chosen for this project allows the steel can always be in the detection range of the sensor.

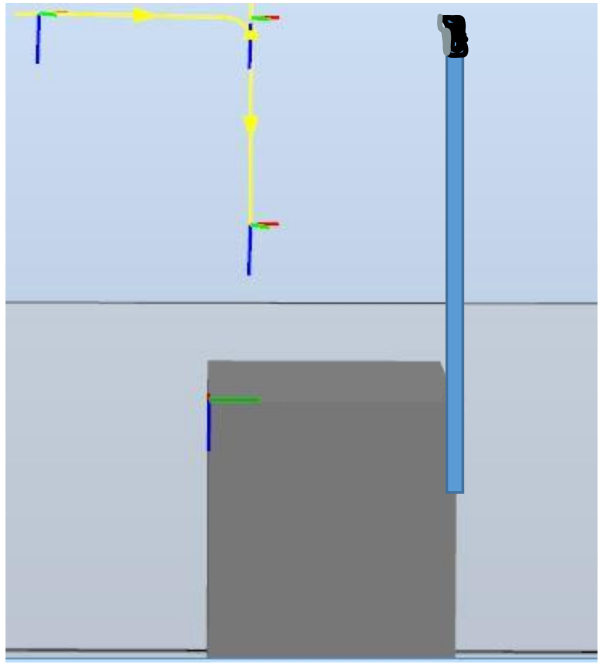


Figure 9: ME-8108 Adjustable Roller Lever Arm Arduino Limit Switch

Figure 9 displays an ME-8108 Adjustable Roller Lever Arm Arduino Limit Switch. It is placed 1050 millimeters in the positive Z direction, 360 millimeters in the positive X direction and 480 millimeters in the Y positive direction. When the final can has been placed, it will hit the limit switch, which will close the circuit, allowing current to flow to the green signal light. The dimensions of the limit switch are 129X28X50 millimeters and will be attached to a pole 1100 millimeters high so it will be able to make contact with the final can. The limit switch operates on a 115 VDC and a 5 Amp Power supply.

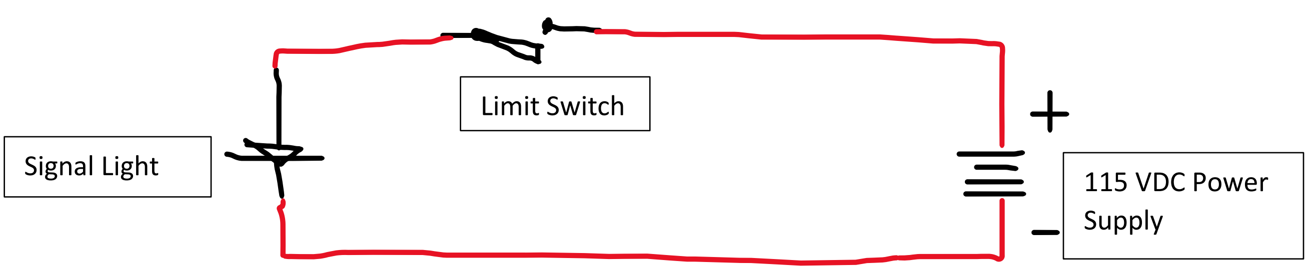


Figure 10: Circuit of Limit Switch and Diode

About this item

- Product name : mini limit switch; model no. : me8108; actuator action : Momentary
- Actuator Type : rotary adjustable lever arm with roller; contact configuration : NC + NO (dpdt); rated Voltage : AC 250V 5A, dc 115V 0.4A
- Roller dimension : 18 x 7Mm/0.71" x 0.2"(D*t); lever arm length : 9.2Cm/3.6"; fixing thread diameter : 4.5Mm/0.18
- Total size : 129 x 28x 50Mm/5.1"X 1.1 inch x 2 inch (l*w*h); mounting size : 56 x 21Mm/2.2" x 0.8 inch (l*w); material : rubber, plastic & metal
- Excellent quality, preferential price, bring you the best shopping experience. Package Content : 2 x Limit Switch

Product Specifications

Color	ME-8108
Contact Type	Normally Open , Normally Closed
Current Rating	5.0 amps
Ean	0661748052630
Material	iron
Measurement System	Imperial , Metric
Size	2Pcs ME-8108
Specification Met	
Switch Type	DPDT , Limit Switch
Terminal Type	DPDT
UNSPSC Code	39122200
UPC	661748052630

^ See less

Specification for this product family

Brand Name	TWTADE
Contact Type	Spdt
UNSPSC Code	40000000

Figure 11: Data sheet for Limit Switch

5. Cycle time analysis and robot load analysis

The robot needs to place 24 cans on a box, with 4 cans per row, 3 cans for column, and 2 layers high to cycle through one complete pallet. Therefore the average total time required to cycle through one complete pallet is about 3:40:704 minutes as shown below in Figure 12. This means that every minute 6 can has been moved to the box with a 7th can about to be palletized, and that a can is transported and palletized to the box every 11.256 seconds.

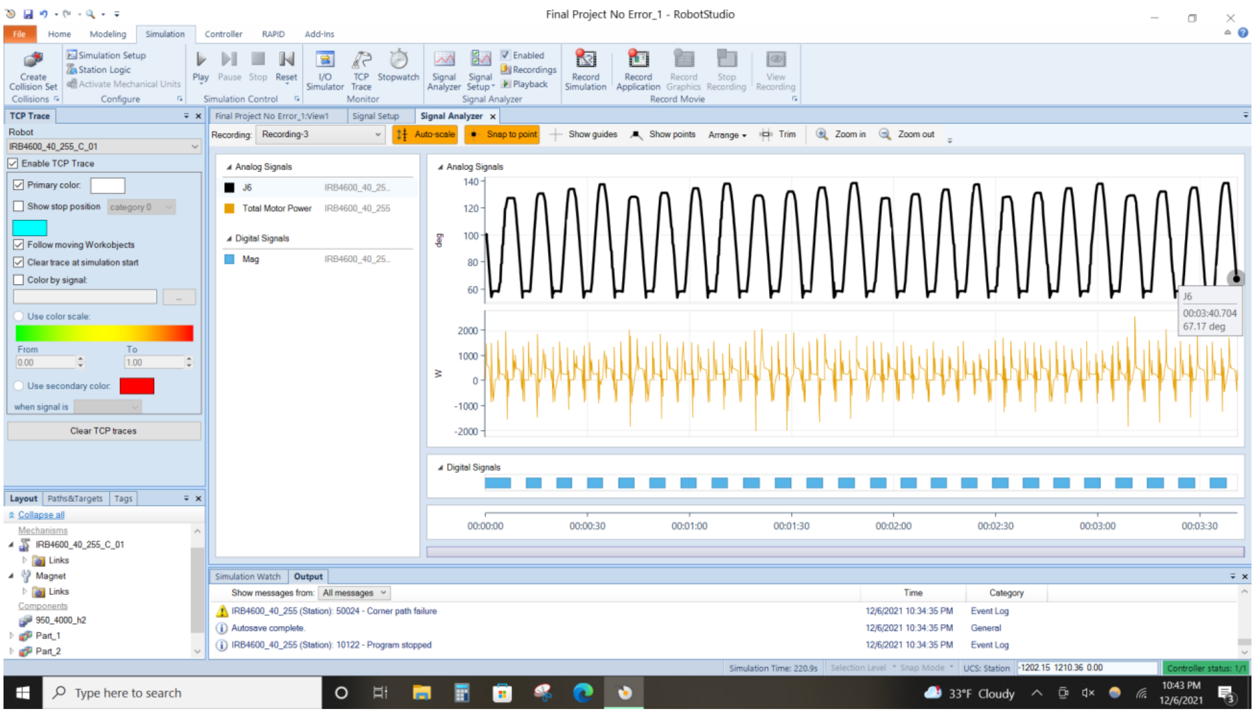


Figure 12: Cycle time

```
26
27  PROC main()
28      FOR i FROM 1 TO 2 DO
29       SpaceUp := 250;
30       FOR i FROM 1 TO 12 DO
31      space := 120;
32      MoveJ Begin, v1000, z50, Magnet;
33      MoveL AboveCan, v1000, z50, Magnet\WObj:=can;
34      MoveL PickupCan, v1000, fine, Magnet\WObj:=can;
35      Pickup;
36      MoveL CanIsLiftedFromBelt, v1000, fine, Magnet\WObj:=can;
37      MoveJ JointMotionToBox, v1000, z50, Magnet;
38      MoveL OverExactPointOnBox, v1000, z50, Magnet\WObj:=Box;
39      MoveL CanDropOff, v1000, fine, Magnet\WObj:=Box;
40      Dropoff;
41      MoveL MoveUpFromBox, v1000, z50, Magnet\WObj:=Box;
42      MoveJ End, v1000, z50, Magnet;
43
44      IF CanDropOff.trans.x >= 360 THEN
45           OverExactPointOnBox.trans.y := OverExactPointOnBox.trans.y + space;
46          CanDropOff.trans.y := CanDropOff.trans.y + space;
47          OverExactPointOnBox.trans.x := -60;
48          CanDropOff.trans.x := -60;
49      ENDIF
50      IF CanDropOff.trans.y >= 360 THEN
51          OverExactPointOnBox.trans.y := 60;
52          CanDropOff.trans.y := 60;
53      ENDIF
54      OverExactPointOnBox.trans.x := OverExactPointOnBox.trans.x + space;
55      CanDropOff.trans.x := CanDropOff.trans.x + space;
56
57       ENDFOR
58       OverExactPointOnBox.trans.z := OverExactPointOnBox.trans.z - spaceUp;
59      CanDropOff.trans.z := CanDropOff.trans.z - SpaceUp;
60      ENDFOR
61  ENDPROC
```

Figure 13: ABB Robot IRB4600_40_255 Code

Figure 13 displays the main code on Robot Studio to run the work cell. There is a nested FOR loop so that the code will create 2 layers and palletize the cans correctly. The first FOR loop tells the robot to run through 29 through 61 twice. The second FOR loop tells the robot to move and pickup the can, and then drop it off at the desired location on the box. The functions pickup() and dropoff () were created to pickup the can as well as put it down. Once the robot places the first can down, it will move the following can next to the original with an 120 millimeter space from each cans center points. This will continue until it hits the first IF statement on line 44, where it will tell the robot, that once the drop off point is equal to or greater than 360 millimeters in the positive X direction, to move up 120 millimeters in the Y direction and create another row. This process is repeated until the next IF statement at line 50 comes up, where it will tell the robot, once it reaches 360 millimeters in the y, to go back to the first can drop off point and then leave the for loop. However, because of the first FOR loop made on line 28, it will repeat the whole process again, except the new drop off point will be higher because we have changed the Z direction in lines 58 and 59.

The functions pickup and dropoff were made by creating a digital output for the end effector. To pickup the can, digital output Mag was created. Before the D/O Mag was called, a wait function was set before and after to be able to pick the can up without error. The same thing was done for the dropoff function, the only difference is that the magnet would be turning off. As a result, instead of using ‘set Mag’, Reset Mag was used instead, with a wait timer before and after the command as seen in Figure 14.

```
    PROC Pickup()
        WaitTime 0.5;
        Set Mag;
        WaitTime 0.5;
    ENDPROC
    PROC Dropoff ()
        WaitTime 0.5;
        Reset Mag;
        WaitTime 0.5;

    ENDPROC
ENDMODULE
```

Figure 14: ABB Robot IRB4600_40_255 Code Functions