Mitsubishi Electric MEL-FACS

Part 1 – MEL-FACS and Assembly Process Overview

Release 4.10

MEAU – Engineering Group

Content

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1 Introduction

This document describes the overview of an assembly process and the FACS system (“Flexible Assembly Configuration System”) that is used in the process. The FACS system defines a standardized control concept for assembly line operations.

The main components of a FACS system include:

- an assembly system configuration system, eFACS – provided by eFlex Systems
- a standardized assembly station hardware architecture, and
- a standardized assembly station PLC control logic – MEL-FACS Library – provided by MEAU

The assembly station operations and tasks are configured by means of a configuration system instead of being programmed individually.

Each assembly station is based on standardized hardware architecture, which is capable of controlling all devices required for the predefined task types. Figure 1 illustrates a typical assembly line with FACS system with FACS configuration server and workstation connecting to the manual work station PLC’s on the line.

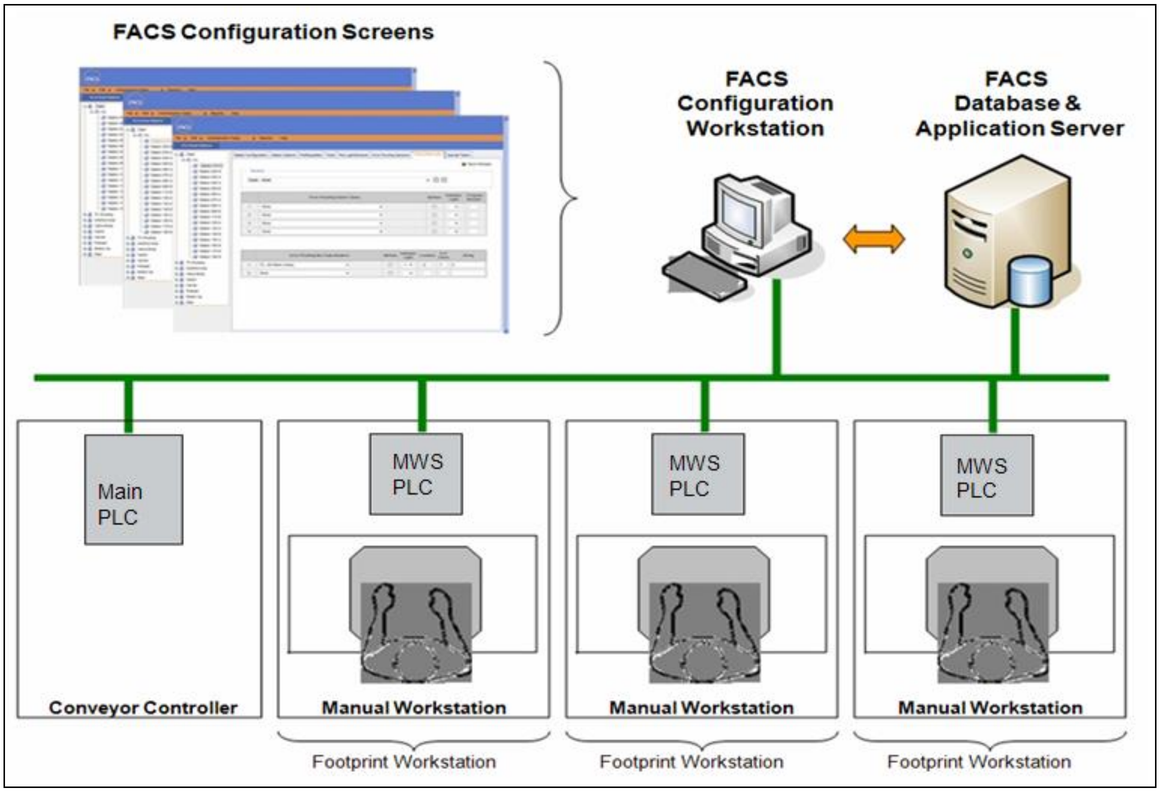


Figure 1 FACS Overall System Architecture

1.1 FACS Configuration System

A “FACS Configuration System” is used to configure the assembly station control logic. The configuration parameters include:

- Configuration of station operations
- Configuration of station tasks
- Build matrix configuration
- Prerequisite configuration
- Task sequencing configuration

The assembly station configuration parameters are downloaded to the individual stations by means of a communication network. All configuration parameters are stored in the station controller (PLC) and then executed by the standard function blocks in the PLC as shown in Figure 2.

The details of Mitsubishi MEL-FACS hardware and software architectures are described in Part 2 of the Mitsubishi Electric MEL-FACS Manuals.

Note:

The FACS configuration system is only required to configure the assembly stations. The assembly stations control logic does not require an online connection with the configuration system in order to control the process.

However, status information can be sent to the FACS configuration system as long as the configuration system maintains a connection with the station controller and the status upload capability is enabled.

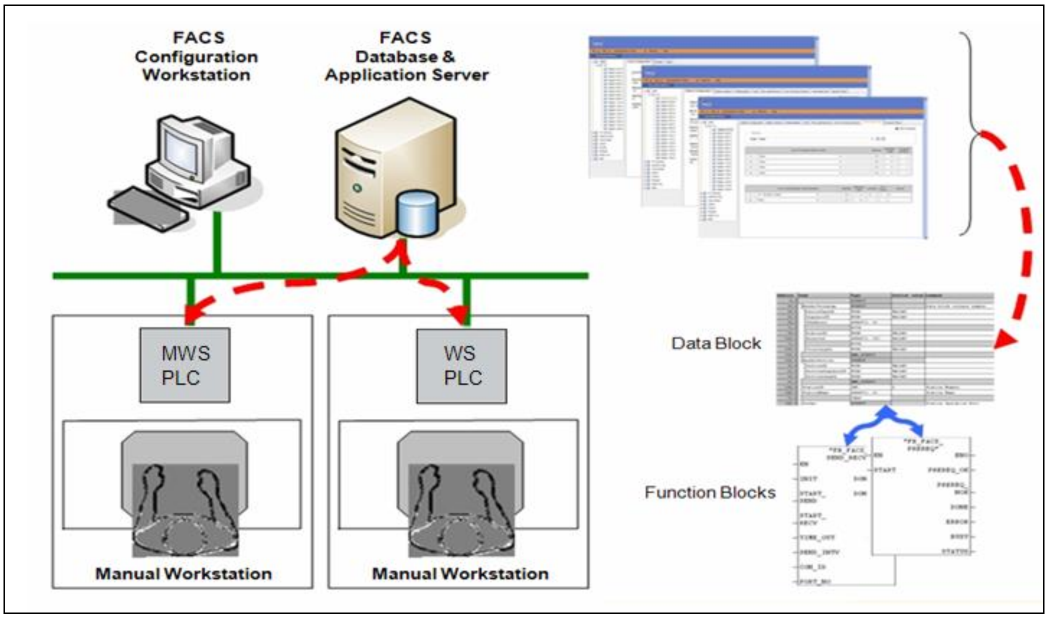


Figure 2 Flexible Assembly Configuration System Operation

The FACS Configuration system is a server-based system that is capable of configuring a large number of manual work stations on an assembly line.

Note:

eFlex Systems provides a configuration system that has been verified with the MEL-FACS system.

eFlex Systems

210 W. Tienken Rd
Rochester, MI 48306 (USA)
Phone: (248) 651-5979
http://www.eFlexSystem.com

1.2 MEL-FACS Hardware Architecture

The Mitsubishi MEL-FACS hardware architecture is based on the MELSEC iQ series PLC/Modules.

The MEL-FACS Hardware architecture is shown as below.

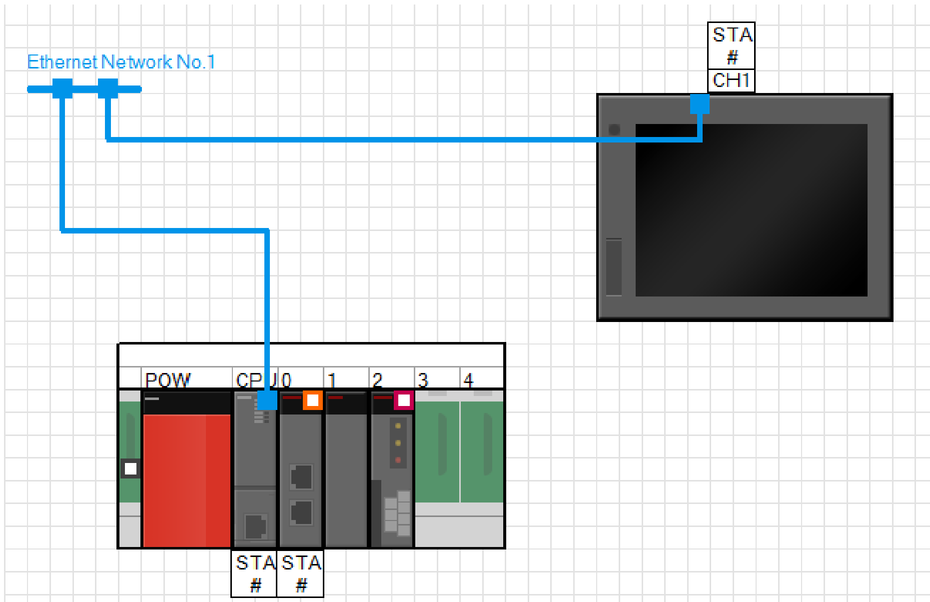


Figure 3 Manual Workstation Control

An example of manual workstation for control system consists of following components

- iQ Series PLC system, includes base rack, power supply, PLC with Built-in Ethernet port, Fieldbus Master module, Input module and Output module and RFID Module based on the Customer specification.

The MEL-FACS typical IP 67 enclosure is shown below

Note:
The hardware configuration and enclosure style may vary based on customer's specification.

1.3 MEL-FACS Software Functionality

The Mitsubishi MEL-FACS contains a software library which provides a complete framework for a typical assembly line manual workstation.

The functionality features of the software library include:

- Support for “stop in station” assembly line concepts
- Support of pre stop areas for “stop in station assembly” lines
- Support of “Dual-GOT” – two GOT’s on either side of the Assembly Line station
- Support of Multi-Foot Print stations – Multiple Work Stations share single PLC and GOT
- Handling of part reject
- Handling of station and task bypass configuration
- Model specific build data (up to 200 build configuration)
- Direct control of all sensors and actuators connected via physical I/O channels
- Managing of RFID systems in different configurations
- Support for typical assembly tools (e.g. error proofing sensors, stitching and multi spindle controller, vision systems and barcode reader)
- Support of indicator lights in different configurations
- Standard sequencing of a typical assembly station operations (e.g. read RFID, determine prerequisites, lookup model build data, enable tools and operations, write RFID)

1.3.1. Device Integration and Adding Functionality

The Mitsubishi MEL-FACS software library also controls all devices which are connected via physical I/O channels to the MEL-FACS control system.

All other devices (e.g. vision systems, multi spindle controller) have to be integrated by means of additional user application. The software library provides standard data interfaces for these devices with predefined parameter input and output areas.

The software library function blocks are sequenced by means function block input and output parameters. The standard sequence of function block is capable to control a typical manual workstation. It is possible to integrate additional functionality in order to control “special purpose” assembly stations (e.g. pallet load or unload station) or manual workstations with additional assembly devices. The interlocking (sequencing) of the operations is open to the user application.

2 Assembly Process Description

2.1 Task Based Assembly Process

The Mitsubishi MEL-FACS software library implements a task based controls concept. The entire assembly process is subdivided into individual tasks (e.g. error proofing task, pick sensor task).

Each task is identified by a unique number which represents the RFID tag address in which the task status is stored.

The tasks are assigned to the individual assembly line stations via a FACS configuration system.

Every assembly line station is capable to perform a predefined number of tasks by means of standard PLC logic.

2.2 Basic Program Flowchart

The basic program flowchart of the Mitsubishi MEL-FACS is shown in the following figure.

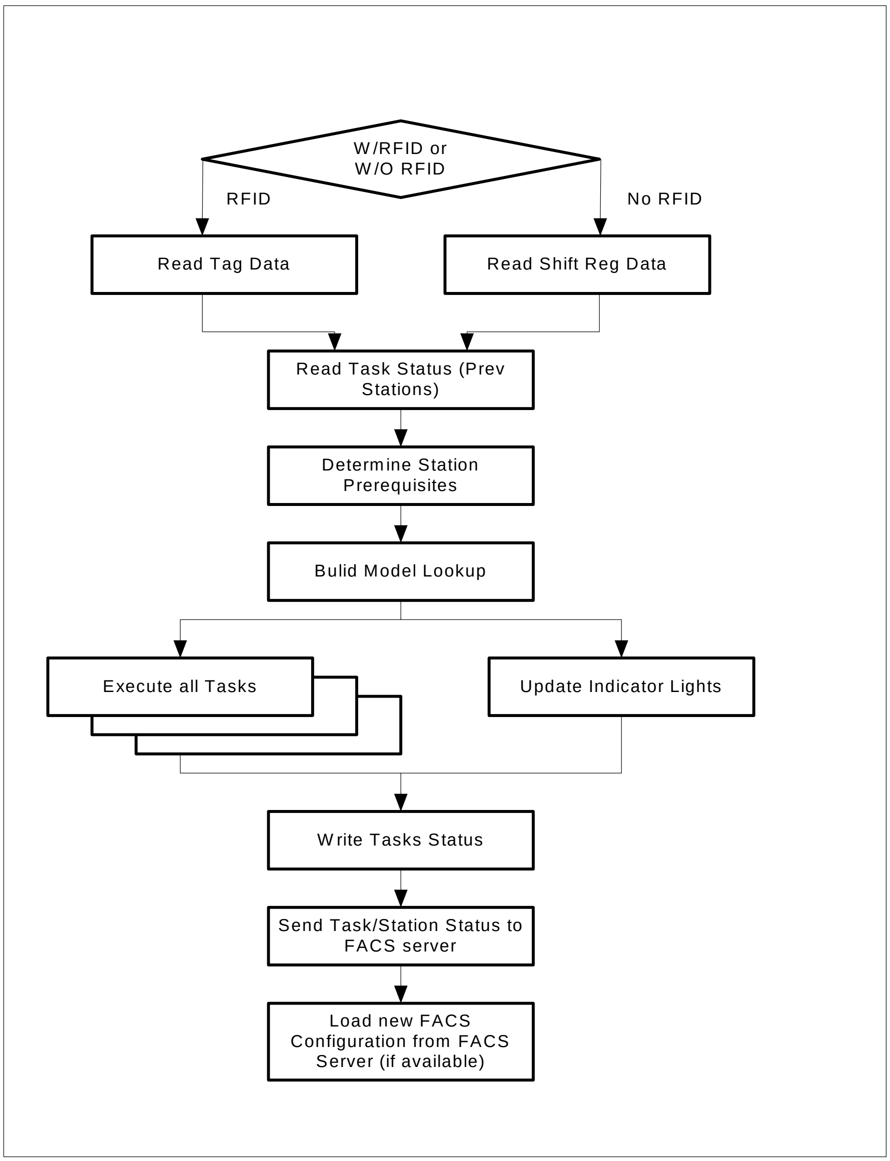


Figure 4 Basic Program Flow Chart

The process starts as soon as a new workpiece enters the assembly station. A new workpiece can be detected by either a proximity switch or an encoder system.

1. Read Task status

All task statuses are stored on an RFID tag. The read operation is executed at the entrance of the assembly station (see “Continuous Moving Line”), at the pallet pre-stop position or in the station (see “Stop In Station Line”). The complete defined RFID tag memory area is read and stored in a local memory buffer in the PLC (data block) for further processing.

2. Determine Station Prerequisites

Station prerequisites are defined as tasks, which have to be completed with an “accepted” status. The tasks assigned to an assembly station are only activated if the station prerequisites are fulfilled. All tasks are assigned the status “Prerequisite(s) not met” if the prerequisites are not fulfilled.

3. Read Global Status

Global status determines whether or not the workpiece is workable.

4. Read Model Specific Task Parameter

Up to 200 different model specific build data can be configured. The required build data set is determined based on the part identification code stored on the RFID tag. The build data are processed by the station tasks.

5. Execute/Monitor Tasks

During this process the different tasks are activated if the following requirements are fulfilled:

- Prerequisites are fulfilled and workpiece is workable
- Station is not bypassed
- Task is not bypassed
- Task enabled for the specific model

All tasks produce result codes on completion (see “Task Status Codes”). The result codes are tracked and stored in a local memory buffer in the PLC.

Continuous Moving Line

The conveyor will be stopped if a task did not report an “accepted” status code within the available tool work footprint area. The conveyor will be resumed if the operator rejects the workpiece.

Stop In Station Assembly Line

A pallet can only be released if all tasks reported an “accepted” status code or if the operator rejects the workpiece.

6. Write Task status

The stored task status results are written to the RFID tag before the workpiece leaves the station. The write operation is executed at the exit of the station (see “Continuous Moving Line”) or in the station (see “Stop In Station Line”).

7. Send Task/Station Status

The task and status information are sent to the FACS configuration for backup.

8. Load New Configuration Data

The configuration data are stored in File Registers (ZR registers) in the PLC. New configuration can be downloaded from the FACS configuration server to the station controller via an Ethernet network connection. The data are loaded into the configuration registers (activated) only after the current active workpiece is completed.

2.3 Tasks Type

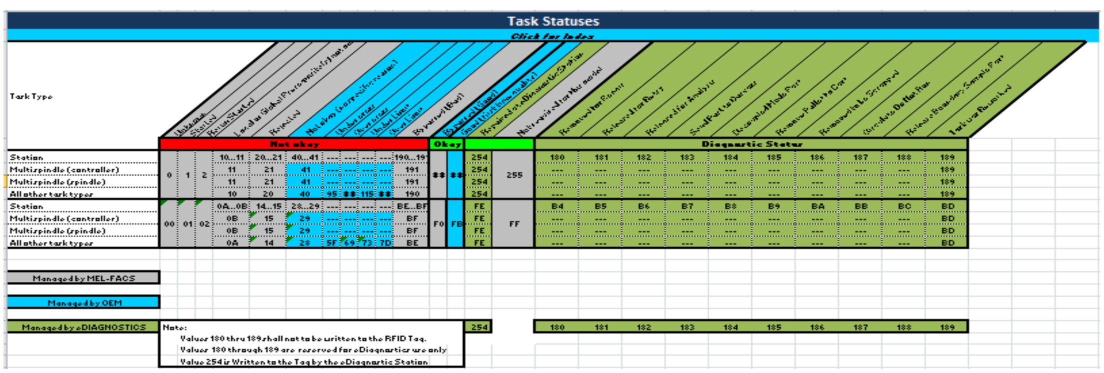
The assembly process tasks are differentiated by tasks types. The following table lists the predefined task types and the quantity of task which can be assigned to a typical single assembly station. The task types and the quantity of task may vary based on the customer/OEM requirements.

Task Type	Max Number of Tasks for **Manual Station**	Max Number of Tasks for **Auto Station**
Stitching Tool	8	8
Stitching Tool as Backup	2 x 32 (Sub)	2 x 32 (Sub)
Stitching Tool w/Socket Tray	8 x 8 (Sub)	8 x 8 (Sub)
Multi-Spindle Tools	4 x 32 (Sub)	4 x 32 (Sub)
Pick Lights and Sensors	16 (32 I/O Points)	16 (32 I/O Points)
Error Proofing Sensors	16	16
Vision system error proofing	4 x 16 (Sub)	10 x 16 (Sub)
Bar Code Readers	2 x 10 (Sub)	2 x 10 (Sub)
Test	4 x 8 (Sub)	8 x 8 (Sub)
Press	4	8
Lubrication	8	8
Robot/Servo	4	4
Generic Backup	2	2
Universal	4	4

The additional task type "Station task" represents a summary of all tasks assigned to a single station. A maximum of one "Station task" can be assigned to a station. The "Station Task" can be referenced by subsequent stations as part of the prerequisite conditions.

2.4 Tasks Status Codes

The status of the tasks is tracked throughout the assembly system by means of task status codes. The following table lists all defined task status codes.



- At the beginning of the assembly process the task status code 0 is assigned to all tasks ("task not started" - "task status unknown").
- All other task statuses are assigned as soon as a task is completed.
- Task status codes 251 … 255 are assigned to each task which is completed with an "accepted" ("good") result.

- Task status codes 10 … 200 are assigned to each task which is completed with a “not accepted” result (“bad” status).
- The “Station Task” summarizes all task statuses assigned to an individual station.
- An “accepted status” is only assigned if all tasks are completed with an “accepted” status.
- Accordingly, a “not accepted status” is assigned as soon as one or more tasks are completed with a “not accepted” status.

2.5 Station Prerequisite Management

The Mitsubishi MEL-FACS software library provides a configurable assembly station prerequisite functionality. Station prerequisites are defined as tasks which have to be completed with an “accepted” status.

Up to 10 prerequisite conditions can be defined per station. Each prerequisite condition can consist of up to 10 alternative tasks, of which, at least one has to be completed with an “accepted” status in order to meet the prerequisite condition.

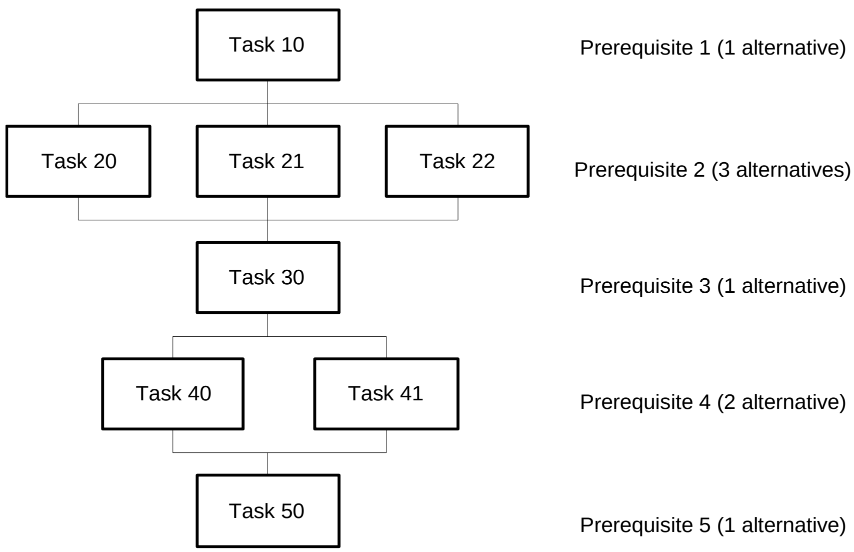


Figure 5 Sample Prerequisite Configuration

- The above figure shows a station prerequisite configuration that defines five prerequisite conditions (prerequisite 1 … prerequisite 5).
- The prerequisite condition 2 and 4 consist of multiple alternatives.
- The station prerequisite is fulfilled if all prerequisite conditions are met.

The following task status results would cause a “prerequisite not met” condition because the prerequisite condition 4 is not met.

Task	Status
10	251
20	0
21	0
22	251
30	251
40	0
41	21
50	251

Neither task 40 nor task 41 has an “accepted” task status (none of the alternative prerequisite paths has an “accepted” status).

2.6 Model Management

The Mitsubishi MEL-FACS software library supports configurable build data for up to 200 different models. The following graphic shows the basic build data concept.

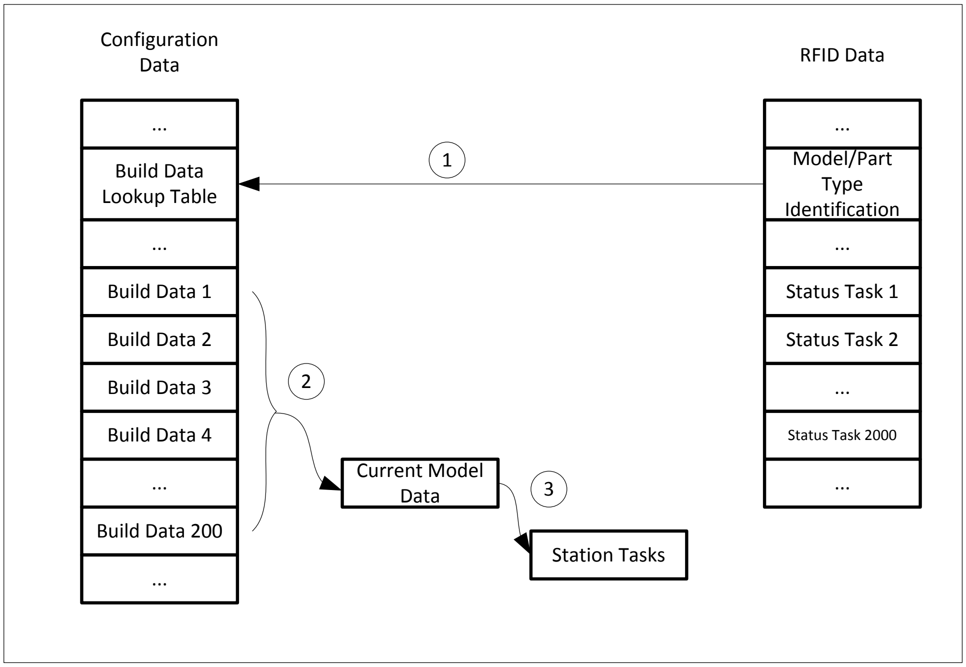


Figure 6 Build Data

1. ***Lookup Build Data Index***

   The model specific identification code is extracted from the Model/Part type identification code. The extracted model code is searched in the build data lookup table.

2. ***Select Build Data Set***

   The matching build data configuration set is copied into the “Current Model data” memory area.

3. ***Process Build Data***

   The build data are passed on to the stations tasks.

2.7 Station Types

The Mitsubishi MEL-FACS software library supports both “continuous moving” and “stop-in-station” assembly concepts in different configurations. The station type is configured by means of the FACS configuration software.

2.7.1. “Continuous Moving” Assembly Line

Continuous moving assembly lines are based on a constant footprint size.

Tasks are executed within the work area. The pallet position (e.g. pallet entering or leaving the station) is determined based on an encoder system or by means of proximity switches.

<u>Continuous Moving Line with RFID</u>

This station type requires an encoder system. The RFID read and write antennas are mounted at the entrance and the exit of the assembly station. The station controller sends a “STOP” signal to the conveyor controller if one or more tasks does not report an “accepted” status code before the work area ends. The operator has to press the reject button in order to resume the conveyor.

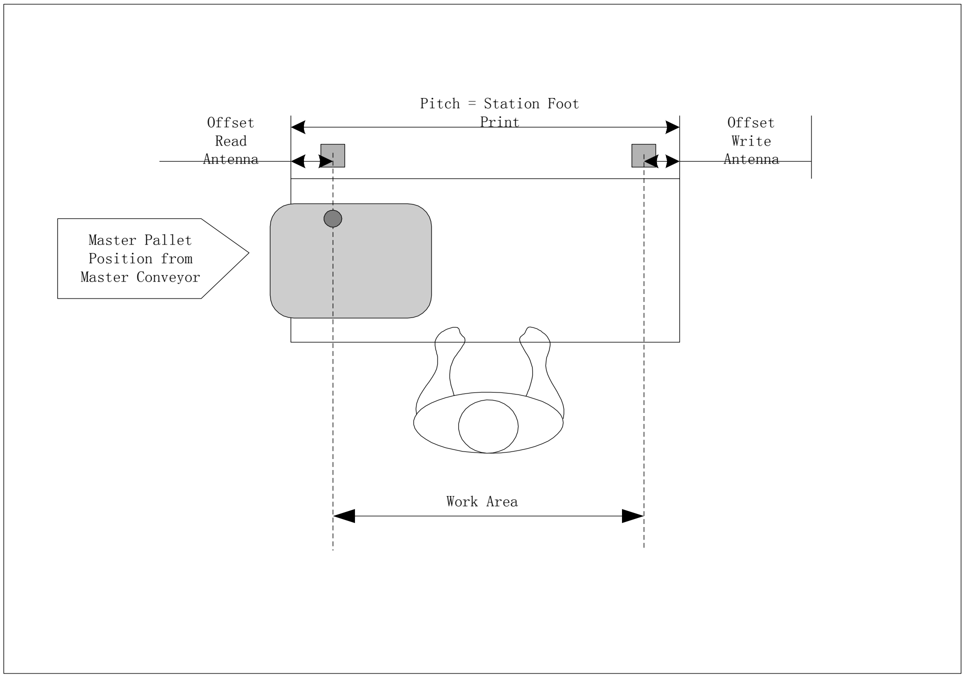
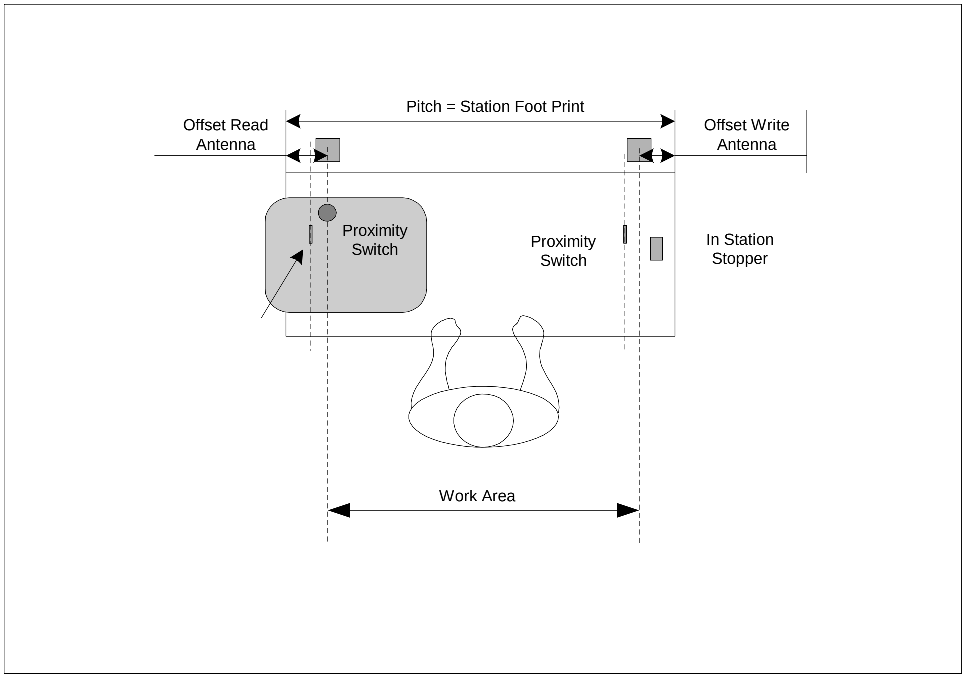


Figure 7 Continuous Moving Assembly Line with RFID

Continuous Moving Line with Stopper

The continuous moving line with stopper is based on a conveyor system which allows stopping the workpiece pallets without stopping the conveyor system.

The tolerated slip between the conveyor system and the pallets makes the use of an encoder system impossible. Tracking of the workpieces (e.g. workpiece entering / leaving the work area) must be accomplished by means of in station proximity switches. All tasks are active within the work area. The station controller sends a “STOP” signal to the conveyor controller if one or more tasks do not report an “accepted” status code before the work area ends (indicated by the second proximity switch). The conveyor controller has to evaluate the “STOP” signal from each station and control the in station stopper accordingly.



The operator has to press the reject button in order to resume the conveyor.

Figure 8 Continuous Moving Assembly Line with Stopper

Note
The station stoppers are controlled by the conveyor controller and not by the individual station controllers.

2.7.2. "Stop-In-Station" Assembly Line

Stop-In-Station assembly lines are based on a pallet stopping in a station and remaining in the station while tasks are performed. The pallet position (e.g. pallet in the station) is determined based on detection by proximity switches.

The RFID read and write antennas are mounted in the assembly station.

Stop-in-Station with Pre-Stop

The stop-in-station with pre-stop is based on a conveyor system which allows stopping the workpiece pallets without stopping the conveyor system. Tracking of the workpieces (e.g. workpiece present in the work area) must be accomplished by means of in station proximity switches. The pre-stop area has an RFID antenna in addition to the RFID antenna at the station stop. All tasks are active within the station work area. The Mitsubishi software library provides a signal to "lower pre-stop" after the task status information is read successfully. The software library also provides a signal for "lower station stop" when all tasks report an "accepted" status code or the operator rejects the workpiece.

> ***Note***
>
> *The station stoppers are controlled by the user application. The Mitsubishi software library only provides an indication to lower station stops only from the perspective of the tasks complete.*

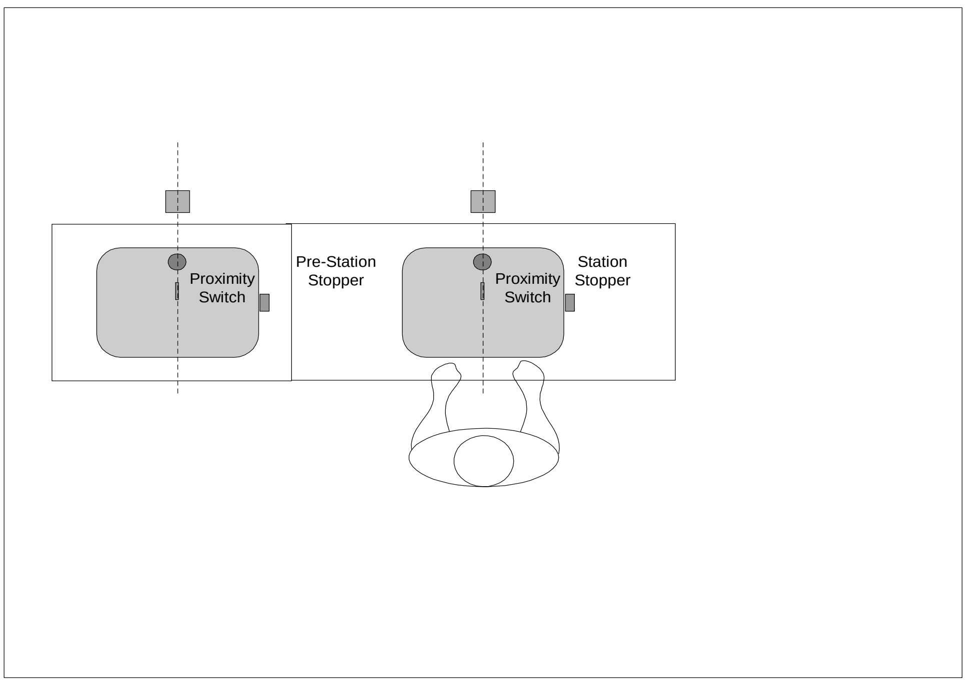


Figure 9 Stop-In-Station with Pre-stop Assembly-Line

Stop-in-Station

The stop-in-station is based on a conveyor system which allows stopping the workpiece pallets without stopping the conveyor system. Tracking of the workpieces (e.g. workpiece present in the work area) must be accomplished by means of in station proximity switches. The station stop area has an RFID antenna for reading and writing task statuses. All tasks are active within the station work area. The Mitsubishi software library provides a signal for “lower station stop” when all tasks report an “accepted” status code or the operator rejects the workpiece.

> ***Note***
>
> *The station stoppers are controlled by the user application. The Mitsubishi software library only provides an indication to lower station stops from the perspective of the tasks complete.*

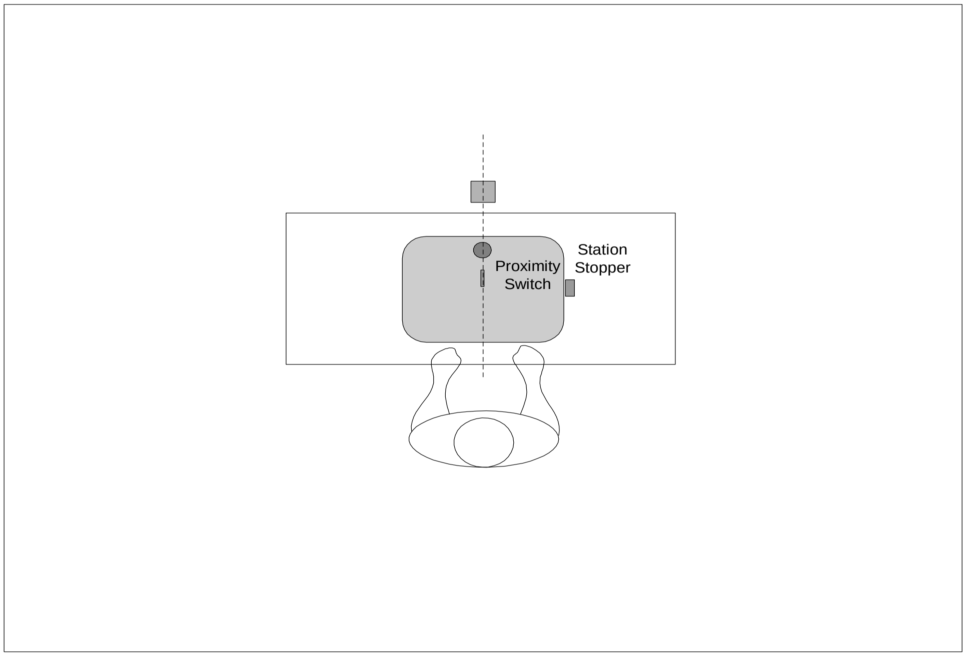
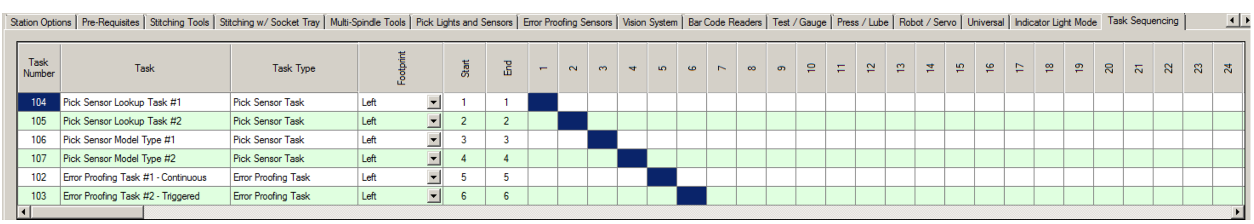


Figure 10 Stop-In-Station without Pre-stop Assembly-Line

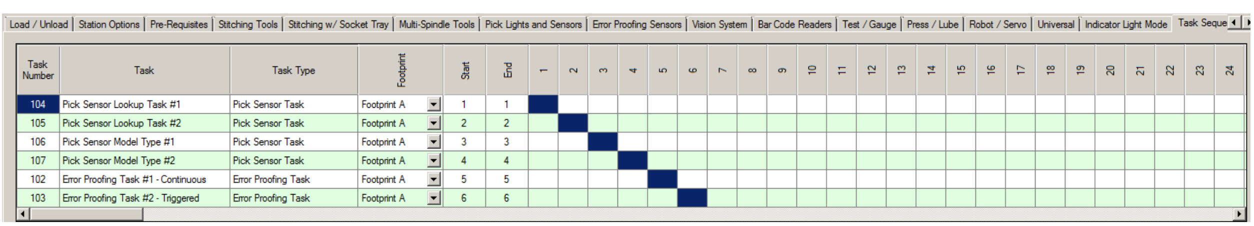
In FACS Configuration Software, Work Areas of Stop-in-Station has to be configured as

Manual Station - Left -– 0 for Work Area #1 / Automatic Station – Foot print “A” -– 0 for Work Area #1 and Set “i_uMultiFootPrintPos” = 0.

The eFlex Manual and Automatic Station configuration screen is shown below.



Task Number	Task	Task Type	Footprint	Start	End	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
104	Pick Sensor Lookup Task #1	Pick Sensor Task	Left	1	1																								
105	Pick Sensor Lookup Task #2	Pick Sensor Task	Left	2	2																								
106	Pick Sensor Model Type #1	Pick Sensor Task	Left	3	3																								
107	Pick Sensor Model Type #2	Pick Sensor Task	Left	4	4																								
102	Error Proofing Task #1 - Continuous	Error Proofing Task	Left	5	5																								
103	Error Proofing Task #2 - Triggered	Error Proofing Task	Left	6	6																								



Task Number	Task	Task Type	Footprint	Start	End	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
104	Pick Sensor Lookup Task #1	Pick Sensor Task	Footprint A	1	1																								
105	Pick Sensor Lookup Task #2	Pick Sensor Task	Footprint A	2	2																								
106	Pick Sensor Model Type #1	Pick Sensor Task	Footprint A	3	3																								
107	Pick Sensor Model Type #2	Pick Sensor Task	Footprint A	4	4																								
102	Error Proofing Task #1 - Continuous	Error Proofing Task	Footprint A	5	5																								
103	Error Proofing Task #2 - Triggered	Error Proofing Task	Footprint A	6	6																								

2.8 *“Dual GOT” on either side of the Assembly Line*

Dual GOT feature of the MEL-FACS gives the ability to mount two GOTs/eHMI on either side of the Assembly Line in the same Stop-in-Station. With this feature, two operators are able to stand on either side of the work piece and work simultaneously on the same work piece. Tasks configured for the station can be shared between two operators. Tasks can be individually configured with independent sequencing by Configuration software. These tasks are displayed on the each GOTs/eHMIs. The Dual GOT Stop-in-station has only one PLC communicating to two GOTs. This feature allows combining independent tasks into one MWS area by reducing the foot print of the line and the tac time. The Task status from both work areas are written into one RFID tag in the stop-in-station.

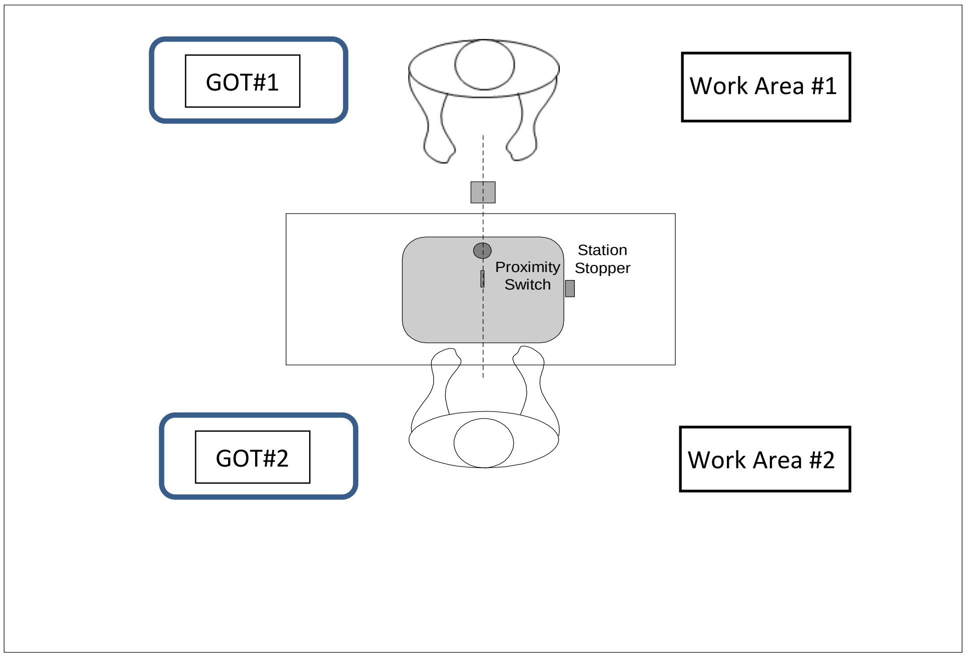


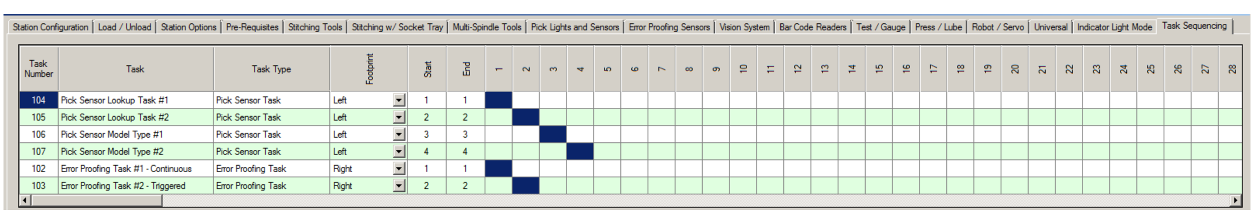
Figure 11 Stop-In-Station with Dual GOTs on either side of Assembly-Line

In FACS Configuration Software, Work Areas of Dual GOT station has to be configured as

Left – 0 for Work Area #1

Right – 1 for Work Area #2

The eFlex Dual GOTs configuration screen is shown below.



Task Number	Task	Task Type	Footprint	Start	End	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
104	Pick Sensor Lookup Task #1	Pick Sensor Task	Left	1	1																												
105	Pick Sensor Lookup Task #2	Pick Sensor Task	Left	2	2																												
106	Pick Sensor Model Type #1	Pick Sensor Task	Left	3	3																												
107	Pick Sensor Model Type #2	Pick Sensor Task	Left	4	4																												
102	Error Proofing Task #1 - Continuous	Error Proofing Task	Right	1	1																												
103	Error Proofing Task #2 - Triggered	Error Proofing Task	Right	2	2																												

2.9 *Multi-Foot Print Stations*

Multi-Foot Print stations are two/three independent stop-in-station cells share one PLC and one GOT based on station design. Each stop-in-station will have their own RFID. Tasks configured for the station are shared between two or three cells. Each cell will have their own task sequencing. After all of the tasks completed in each cell, the status of each cell tasks, time taken for each tasks and RFID data will be sent to FACS server. Statuses of tasks in each cell are written into the RFID tag in each cell.

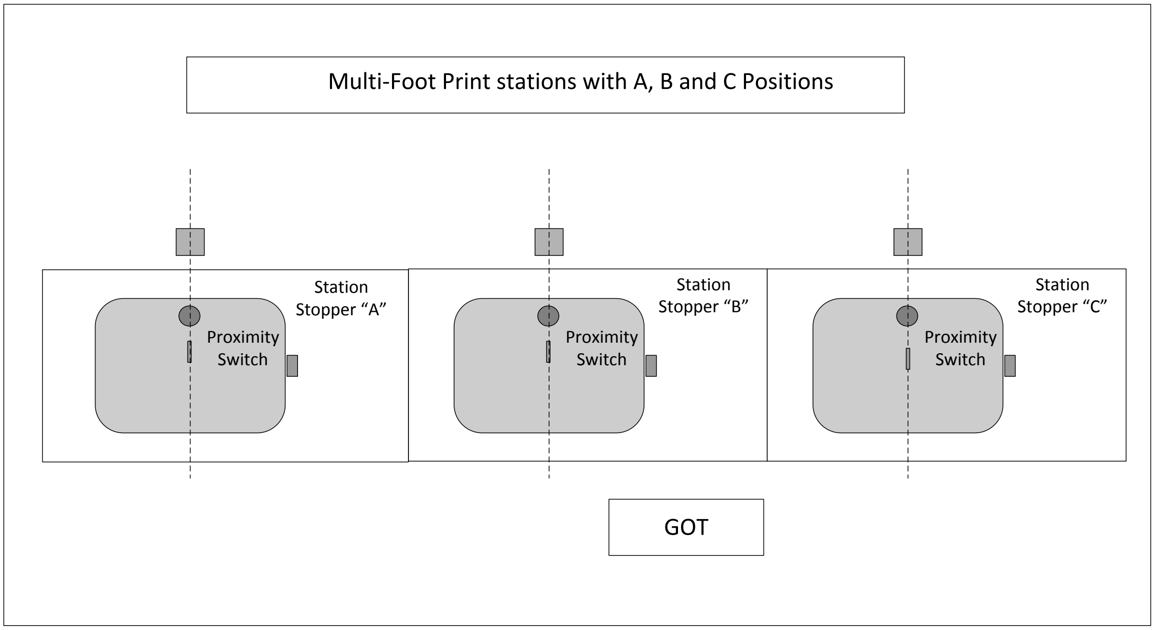


Figure 12 Multi-Foot Print stations with Single GOT

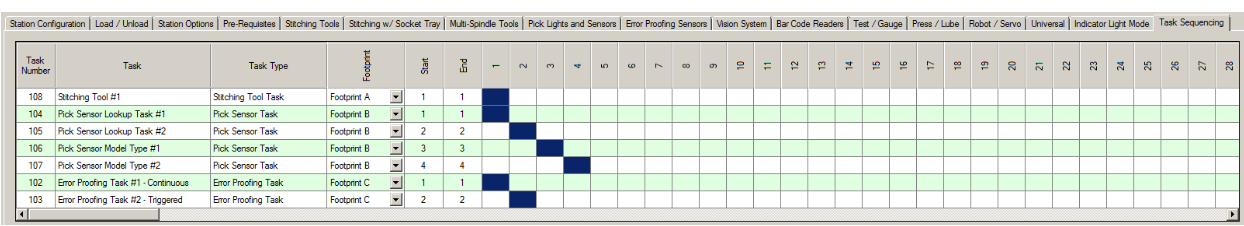
In FACS Configuration Software, Multi-Foot Print Positions A, B and C have to be configured as

Foot Print – 0 for Multi-Foot Print Positions A

Foot Print – 2 for Multi-Foot Print Positions B

Foot Print – 4 for Multi-Foot Print Positions C

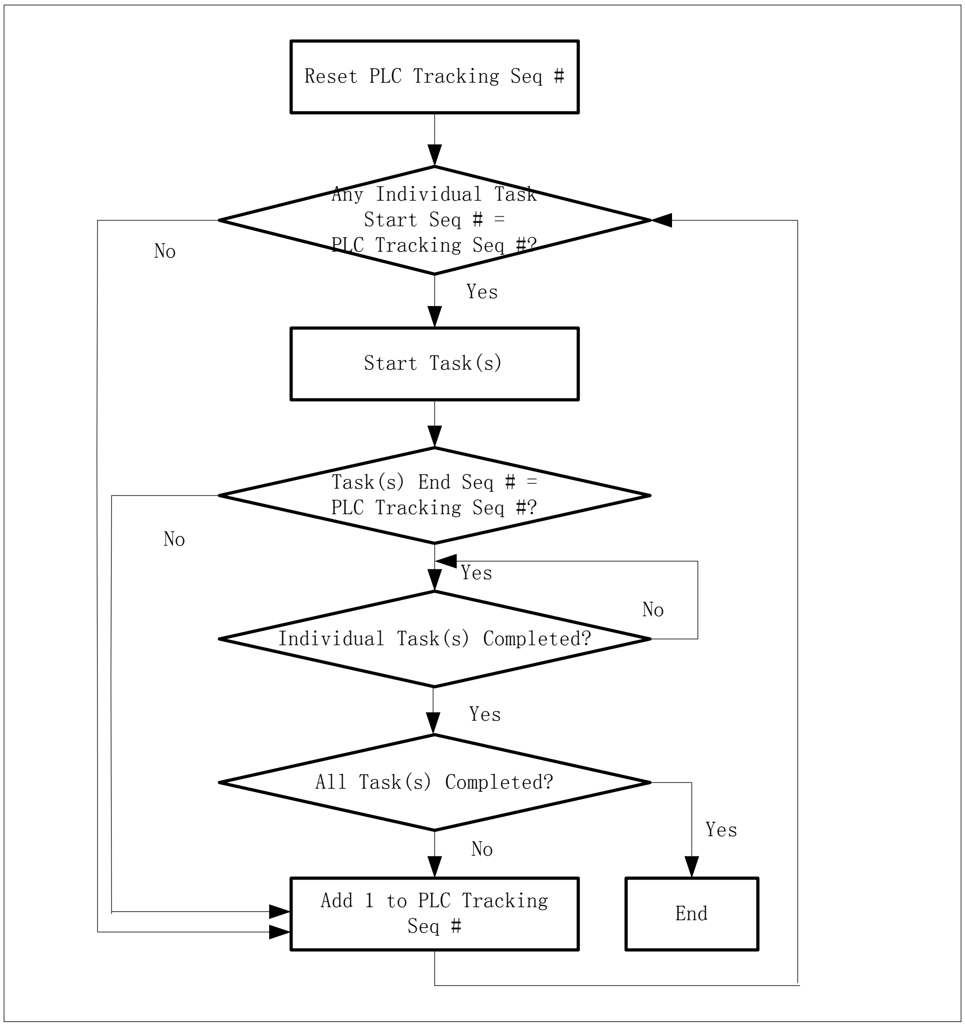
The eFlex Multi-Foot Print station is shown below.



Task Number	Task	Task Type	Footprint	Start	End
108	Stitching Tool #1	Stitching Tool Task	Footprint A	1	1
104	Pick Sensor Lookup Task #1	Pick Sensor Task	Footprint B	1	1
105	Pick Sensor Lookup Task #2	Pick Sensor Task	Footprint B	2	2
106	Pick Sensor Model Type #1	Pick Sensor Task	Footprint B	3	3
107	Pick Sensor Model Type #2	Pick Sensor Task	Footprint B	4	4
102	Error Proofing Task #1 - Continuous	Error Proofing Task	Footprint C	1	1
103	Error Proofing Task #2 - Triggered	Error Proofing Task	Footprint C	2	2

2.10 Task Sequencing Management

All the master tasks and certain sub tasks (Stitching Tool with Socket and Bar Code Reader) support task sequencing configuration. The tasks are individually assigned with a Start and End sequence number. A task will be activated only when all the previous task(s) is completed.



The flowchart of Task Sequence Management is shown in the following figure.

Figure 13 Task Sequencing Management Flowchart

> ***Note***
>
> *The Mitsubishi MEL-FACS software library manages Task Sequencing internally.*

2.11 Workpiece Re-Run Management

The master tasks support Re-Run configuration. Any workpiece will be Re-Run if "Always Re-Run" is configured. A workpiece with current status code as "Not Accept" will be Re-Run if "Re-Run Rejects" is configured. The new status code will overwrite the previous status code of the workpiece.

The workpiece will not be Re-run if "Never Re-Run" is configured.

> ***Note***
>
> *The Mitsubishi MEL-FACS software library manages Re-Run internally.*

2.12 Task Bypass Management

Individual tasks and station can be bypassed by means of configuration parameter. The bypass configuration is handled as follows:

Station Bypass

All tasks are automatically assigned the "bypassed" status code. The tasks are not activated.

Task Bypass

All bypassed tasks are automatically assigned the "bypassed" status code. Bypassed tasks are not activated.

> ***Note***
>
> *The Mitsubishi MEL-FACS software library* manages station and task bypass configuration internally.

2.13 "Workpiece Reject" Management

For manual station, reject is required, if one or multiple tasks can not be completed with an "accepted" status after retry. The "reject" status (result code 20…21 depending on the task type) will be assigned to all tasks which did not report any status at that point.

For automatic station, if one or multiple tasks cannot be completed with an "accepted" status, the "reject" status (result code 20…21 depending on the task type) will be assigned to all tasks which did not report any status at that point.

Already existing result codes (accepted" and "not accepted" task result codes) are not overwritten by the "reject" result code.

The reject process procedures are depending on the station type.

Continuous moving assembly line

If a task did not finish within the available footprint of the task, the "STOP" signal has to be sent to the conveyor controller in order to stop the conveyor system.

A manual "reject" by an operator causes the task to signal a "task done" and resets "stop request". The conveyor controller restarts the conveyor system.

The conveyor system of a "continuous moving line with stops" is actually not stopped. Station stops prevent the workpieces (pallets) to leave the stations. The station stops are controlled (or synchronized) by the conveyor controller.

Stop in stations assembly line

The workpieces (pallets) in a "stop in station" assembly line are individually released by the stations. A workpiece is only supposed to be released if all tasks assigned to the station are completed with an "accepted" status.

A workpiece release request has to be blocked if any of the tasks have not completed with an "accepted" status.

A manual "reject" by an operator causes all tasks to signal a "All_Task_Completed" and a subsequent "release" request can be executed.

2.14 "Workpiece Release" Management

The workpiece (pallet) will be released after all tasks are done.

Furthermore the following workpiece releasing strategies are also available in FACS configuration system.

> ***Note***
>
> *The "workpiece release" functionality is only available for "stop in station" assembly stations.*

Release workpiece after cycle time expired

A workpiece (pallet) is automatically released after a configurable cycle time expired and all tasks are done.

Release workpiece after all tasks are done

A workpiece (pallet) is automatically released as soon as all tasks are done and a configurable hold time expired.

Manual early release

A manual "early release" can be initiated by an operator by means of a push button. The "early release" can be enabled for both release strategies by means of a configuration setting.

> ***Note***
>
> *Tasks report the status "done" if either all tasks finished with an accepted status or if the workpiece was manually rejected by an operator.*

A manual "early release" can be initiated by an operator by means of a push button. The "early release" can be enabled for both release strategies by means of a configuration setting.