SMART ENERGY STRATEGY: ENHANCING ASM FT2026 FINAL TEST HANDLER EFFICIENCY THROUGH INTELLIGENT MOTOR, AIR AND VACUUM SUPPLY CONTROL

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ABSTRACT

Global energy demand is rising rapidly, making energy conservation a major challenge—especially when trying to maintain operational efficiency. This issue has become a key focus in the industrial sector, particularly in the semiconductor industry. Efforts are aimed at optimizing processes to reduce energy waste, improving efficiency through advanced technologies, and implementing effective energy management systems.

Global semiconductor sales have declined steadily since FY2022, leading to lower demand for semiconductor products and reduced production volumes. As a result, machines are spending more time in standby mode. However, even when not in use, these machines continue to consume compressed air, vacuum pressure, and electrical power, which adds to overall facility energy costs.

This paper presents the structured and detailed study of Auto Cut-off control system design and integration to automatically stop or cut off the power supply of electrical motors and pneumatic supply under specific time-based conditions. This automated control system supports the Energy conservation initiatives which remained non-existence in the machine across Semiconductor Manufacturing industry.

By implementing the Enercon project in ASM FT2026 handlers, it provides automated control to cut-off the compressed air, vacuum pressure and motor supply that results to facilities energy savings amounting to $59,000 USD.

1. 0 INTRODUCTION

Nexperia is a global semiconductor company specializing in the high-volume production of diodes, bipolar transistors, ESD protection devices, MOSFETs, and more. These products undergo a series of processes, from assembly to final testing, using various machine platforms. Essential operational requirements such as pneumatic and electrical supplies are supported by the Facilities group.

These fundamental resources are extensively used in tape and reel machines in the Final Test Area, playing a critical role in operations—for example, vacuum pressure is used to hold the units in place, and air assist is used to move them. These utilities are required to operate different handler models, including the Cohu NY20, Nortech NTH24, ASM FT2030, and ASM FT2026.

PROBLEM STATEMENT

During low-volume production, some machines experience standby downtime while waiting for the next lot for the Final Test process. In FY2023, Clipbonded Final Test utilization dropped by 8%, while standby downtime increased by 9.7%, based on a comparison of data from Q1'23 to Q4'23.

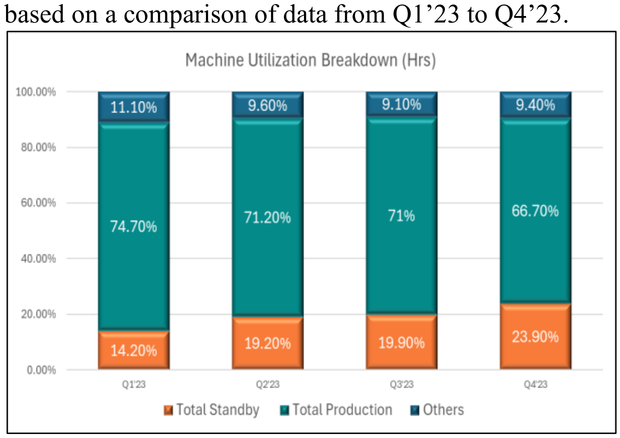


Figure 1. FY2023 Machine Utilization Breakdown

1.1.1 Project Objective

The project's objective is to design and implement an An automated system has been developed to cut off machine supply during standby or idle status. This system incorporates the following key features:

1. Time-Based Auto Cut-Off

- Automatically disables the compressed air, vacuum pressure, and electrical supply to specific motors within identified modules after a predefined period of inactivity.
- Triggers a warning message when the auto cut-off is activated.
- Ensures that no safety risks are introduced before or after the activation of the Auto Cut-Off Control.

These features are designed to enhance energy efficiency, extend the lifespan of machine components, and maintain a high level of operational safety.

2.0 METHODOLOGY

In this project, DMAIC approach was utilized as methodological structured analysis on how the Automatic Cut-off Control was integrated as handler feature without risking the machine operating function once transition from Standby to Production mode.

2.1 *DEFINE* PHASE

The feasibility study was initiated to support the Company's Energy Conservation Initiative. The research team identified potential facility savings in electrical and air supply based on handler usage patterns. The pilot implementation was conducted on the ASM FT2026 handler model, which accounts for 69% of the total Final Test handlers, as shown in Figure 2.

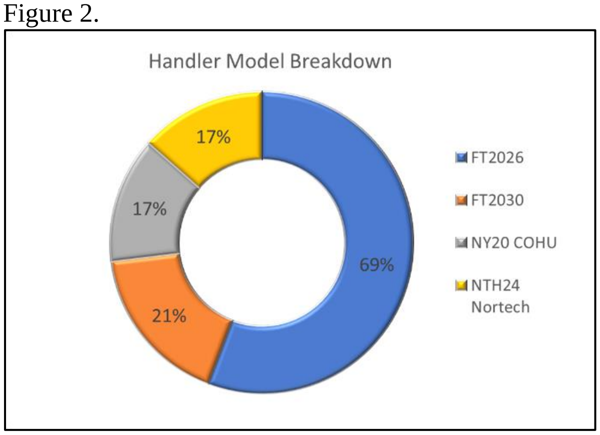


Figure 2. Final Test Handler Breakdown

2.1.1 ASM FT2026 Handler Standby Contribution

In FY2023, the Final Test Area recorded an average standby downtime of 19.30%. The ASM FT2026 platform accounted for 12.13% of this total, representing the largest contribution by a single model. Given its significant share of overall standby time, the FT2026 was selected as the pilot model for the Energy Conservation Initiative, with the goal of reducing idle power consumption and enhancing operational efficiency.

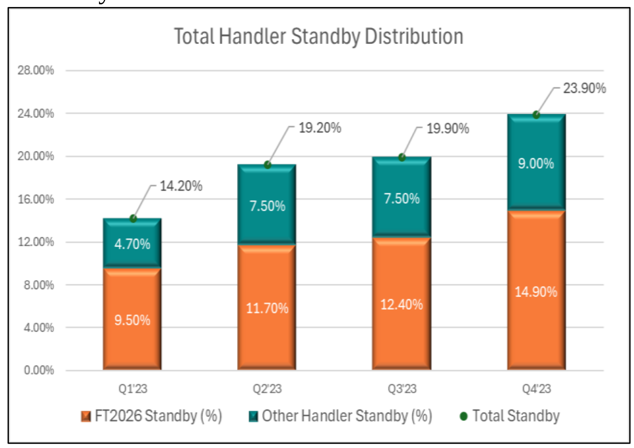


Figure 3. Total Handler Standby Distribution

2.1.2 ASM FT2026 Module Comparison during Production and Standby

The supply utilization of the ASM FT2026 handler was analyzed, revealing that each module consumes compressed air, vacuum pressure, and electrical power for motors in both Standby and Production modes. Despite the machine producing no output during Standby, all these supplies remain active. Refer to Figure 4 for details.

Machine Modules	PRODUCTION		STANDBY	
	AIR SUPPLY	ELECTRICAL	AIR SUPPLY	ELECTRICAL
Tube Onload	ACTIVE	ACTIVE	ACTIVE	ACTIVE
Linear Track	ACTIVE	ACTIVE	ACTIVE	ACTIVE
Separator	ACTIVE	ACTIVE	ACTIVE	ACTIVE
Orientator 1/2/3/4	NON-ACTIVE	ACTIVE	NON-ACTIVE	ACTIVE
4P Table	ACTIVE	ACTIVE	ACTIVE	ACTIVE
Test Module	ACTIVE	ACTIVE	ACTIVE	ACTIVE
Precisor	NON-ACTIVE	ACTIVE	NON-ACTIVE	ACTIVE
Mark Table	ACTIVE	ACTIVE	ACTIVE	ACTIVE
Multi Bins	NON-ACTIVE	ACTIVE	NON-ACTIVE	ACTIVE
Reject Elevator	ACTIVE	ACTIVE	ACTIVE	ACTIVE
Taping Module	ACTIVE	ACTIVE	ACTIVE	ACTIVE
Up/Down Motor	ACTIVE	ACTIVE	ACTIVE	ACTIVE

Figure 4. Machine Modules Comparison

2.2 MEASURE PHASE

The researchers initiated the data gathering based on applicable tools to determine the correct consumption focuses on two main parts as the baseline data of the study.

2.2.1 Compressed Air and Vacuum Pressure Usage: Production versus Standby Mode Comparison

The baseline data for the main input supplies of compressed air and vacuum pressure in this study were collected using a flow meter, which provided real-time measurements of the handler's actual consumption. The researchers demonstrated that the total consumption levels during both Production and Standby modes were similar across three pilot ASM FT2026 handlers. The average consumption was approximately 432 L/min for compressed air and 430 L/min for vacuum pressure in both modes, as shown in Figure 5.

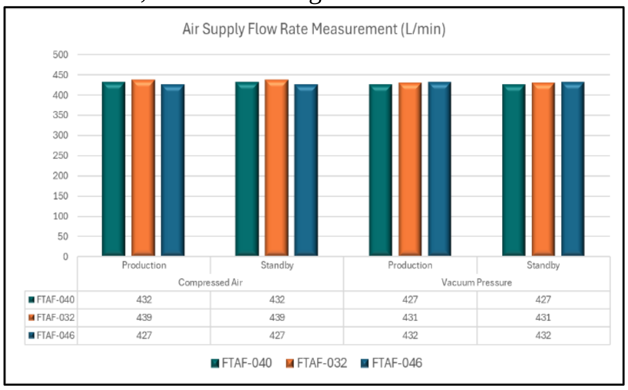


Figure 5. ASM FT2026 Flow Rate Measurement

2.2.1 Module Motor Supply Measurement

The ASM FT2026 consumes electrical power to operate motor drivers, boards, I/O modules, solenoid valves, and motion controllers during production mode. Researchers measured the actual current using an electrical clamp meter, recording an average of 8.5 A during production. In Standby mode, the average current drops to 4.5 A, corresponding to a power consumption of approximately 0.99 kWh.

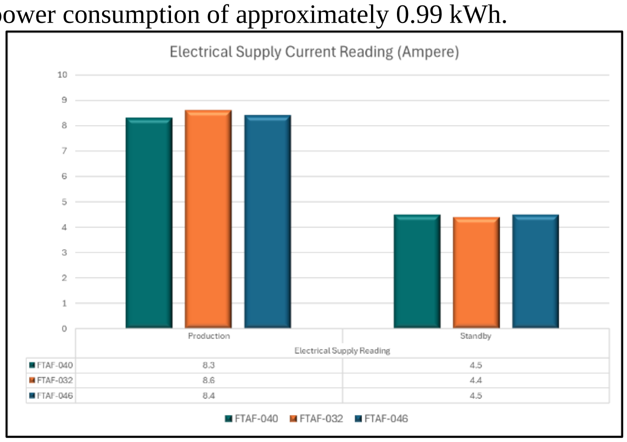


Figure 6. ASM FT2026 Current Measurement

Production Power Consumption

$$Power\ (kWh) = \frac{Voltage(V) x\ Current(A)}{1000}$$

$$Power\ = \frac{220V\ x\ 8.5A}{1000} = \mathbf{1.87\ kwh}$$

Standby Power Consumption if all motor is ON

$$Power\ (kWh) = \frac{Voltage(V) x\ Current(A)}{1000}$$

$$Power\ = \frac{220V\ x\ 4.5A}{1000} = \mathbf{0.99\ kwh}$$

Despite the lower current consumption observed in Standby mode compared to Production mode, the researchers explored opportunities to further reduce energy use during Standby by identifying critical modules and applying process elimination.

2.3 ANALYZE PHASE

2.3.1 Machine Utilization Analysis for Main Supply Flowrate and Electrical Usage

To develop the concept and optimal design of the Auto Cut-off Control system, it is important to understand the utilization of machine supplies. This understanding helps validate which components and conditions should trigger system activation.

During Production mode, machines operate optimally by continuously utilizing air supply to perform their functions.

In idle standby mode, the machine's primary airflow pathways are generally restricted or closed to minimize activity. However, if there are no controls in place and an open vent or unintended exit point exists in the system, air will continue to flow due to the pressure differential. Notably, this issue is not addressed by existing handler machines.

Continuous airflow (open-exit points) can occur through vacuum suction, vacuum generators, air curtains, motor cooling systems, and unnecessary air leaks, as illustrated in Figure 7.

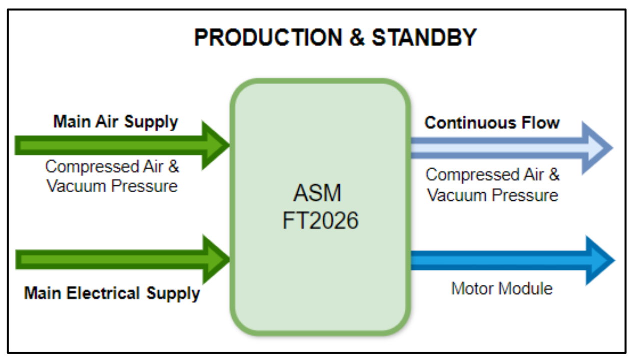


Figure 7. Production versus Standby Supply

The motor operates according to its configured parameters, executing the required positions based on the handler setup during production. In Standby mode, the motor remains in its homing position, idling while awaiting the next processing lot. Despite the lack of active motion during Standby, the motor's electrical consumption remains at nearly the same level as during Production mode, indicating that energy usage is not significantly reduced during idle periods.

2.3.2 Module Fail Safe Mechanism

Understanding how the machine and its modules respond to sudden changes in operational sequences is crucial for designing an effective control system. The researchers identified the fail-safe mechanisms within machine modules, which are essential safety features that ensure the system automatically reverts to a safe state in the event of sudden changes, malfunctions, or failures. This reduces the risk of injury, equipment damage, or operational disruptions.

Consequently, this ensures that no safety risks arise following the manual validation of supply cut-offs.

● *Compressed Air, and Vacuum Pressure Risk Analysis*

The handler uses air supply to transport units from the onload stage through to the tape and reel module. To move units between modules, the machine employs 26 turrets that hold the units using vacuum during rotational movement. These air supplies continue to consume energy even when no units are being processed during machine standby.

The researchers conducted a risk analysis to evaluate the machine's response when manually turning the main supplies of compressed air and vacuum pressure ON and OFF, as well as when both are turned OFF simultaneously. Repeated simulations showed no potential for product loss or mechanical damage. Observations of the single- and double-acting cylinder functions confirmed optimal performance, with no early signs of wear or deterioration after the ON/OFF cycles.

Additionally, the machine monitors system pressure to ensure controls are in a ready state and within required levels before resuming operation. A negligible startup delay of approximately 2 seconds was noted to stabilize compressed air and vacuum pressure. Refer to Figure 8 for details.

Main Supply	Main Air Supply ON and OFF				Product Risk	Single and Double acting Cylinder Risk
Compressed Air	✓	⊗	✓	⊗	No risk	No risk
Vacuum Pressure	✓	✓	⊗	⊗	No risk	No risk

Figure 8. Compressed Air & Vacuum Pressure Risk Analysis

● *Module Motor Risk Analysis*

Cutting the main electrical supply directly may cause prolonged machine initialization downtime. Therefore, the researchers identified specific modules suitable for inclusion in the Energy Conservation strategy and conducted risk analyses on various parts, modules, and motors that might pose risks during Auto Cut-off.

The motors classified for Auto Cut-off control are the module motors. The handler consists of 14 independent modules, each equipped with electrical motors that remain powered during machine standby. To evaluate risks, the researchers manually toggled the ON/OFF status of each motor via the handler's GUI and assessed the impact on product quality and motor function. They observed that the measured current decreased by approximately 0.1 A for every motor turned off. Based on this assessment, the researchers concluded that all module motors can be turned off during standby, reducing the total current from 4.5 A to 3.1 A, as shown in Figure 9.

Motor per Module	Motor Power ON and OFF																Product Risk	Motor Risk
Turret Motor	✓	⊗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	⊗	No risk	No risk
Mark Table Motor	✓	✓	⊗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	⊗	No risk	No risk
Up/Down Motor	✓	✓	✓	⊗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	⊗	No risk	No risk
Test Clamping Motor	✓	✓	✓	✓	⊗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	⊗	No risk	No risk
Precisor Motor	✓	✓	✓	✓	✓	⊗	✓	✓	✓	✓	✓	✓	✓	✓	✓	⊗	No risk	No risk
Onload Separator Motor	✓	✓	✓	✓	✓	✓	⊗	✓	✓	✓	✓	✓	✓	✓	✓	⊗	No risk	No risk
Orientator Motor	✓	✓	✓	✓	✓	✓	✓	⊗	✓	✓	✓	✓	✓	✓	✓	⊗	No risk	No risk
Tube Offload Motor	✓	✓	✓	✓	✓	✓	✓	✓	⊗	✓	✓	✓	✓	✓	✓	⊗	No risk	No risk
Multibin 1 Motor	✓	✓	✓	✓	✓	✓	✓	✓	✓	⊗	✓	✓	✓	✓	✓	⊗	No risk	No risk
Multibin 2 Motor	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	⊗	✓	✓	✓	✓	⊗	No risk	No risk
Reject Tube Index Motor	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	⊗	✓	✓	✓	⊗	No risk	No risk
TnR Index Motor	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	⊗	✓	✓	⊗	No risk	No risk
TnR Heater Motor	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	⊗	✓	⊗	No risk	No risk
Orient Check Table Motor	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	⊗	⊗	No risk	No risk
Current Reading (A)	4.5A	4.4A	4.4A	4.4A	4.4A	4.4A	4.4A	4.4A	4.4A	4.4A	4.4A	4.4A	4.4A	4.4A	4.4A	3.1A		

Figure 9. Module Motor Risk Analysis

2.3.3Identifying Standby Category for Activation of Conditions for Auto Cut-off

Figure 10 illustrates the standby downtime contributions from No Material, No Dedicated Device Available, and Planned Machine/Event Shutdown. These factors account for 66.06% of the total standby downtime, totaling 19,654.05 hours, representing a significant opportunity for implementing the control system.

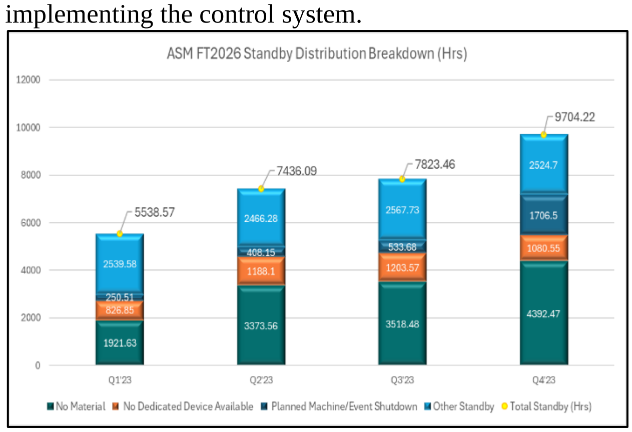


Figure 10. ASM FT2026 Standby Category Distribution

Using the Process Elimination method, the researchers identified specific Standby mode categories to be addressed by the Auto Cut-off Control: No Material, No Dedicated Device Available, and Planned Machine/Event Shutdown—periods during which no units are being processed.

2.3.4Proposed Process Flow Chart of Auto Cut-off Control

The Process flow on Figure 11 shows how the Auto Cut-off control will function will initiate and work be executed in the handler.

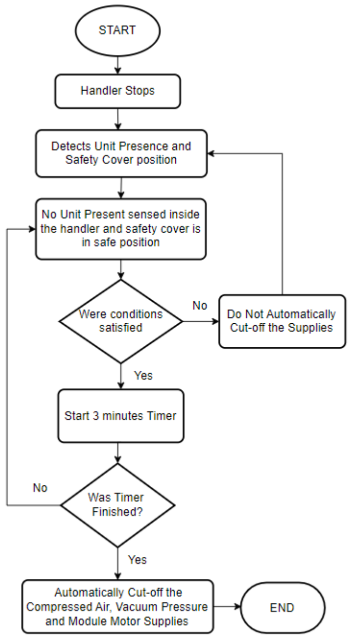


Figure 11. Auto Cut-Off Control Process Flow

2.4 IMPROVE PHASE

2.4.1Project Concept of Auto Cut-off Control

As a result of manually cutting off the supply, identifying the machine module's fail-safe mechanisms, and considering the Standby categories where Auto Cut-off Control may activate, an initial system concept was developed. This concept requires a controller to create a closed-loop system that receives an input signal from the machine, indicating that all conditions have been met before cutting off the machine's supply. Implementing this also requires a software patch to enable communication between the handler and the controller. See Figure 12.

The closed-loop system must meet the following conditions before activating the Auto Cut-off Control:

- No unit is present in the turret system, and the safety hood cover is in the safe-down position.
- A timer starts when no unit is detected, and the safety hood remains in the safe position.
- An alarm and error message prompt a warning before cutting off the supply.
- The supply is immediately restored when the machine's Reset/Start button is pressed.

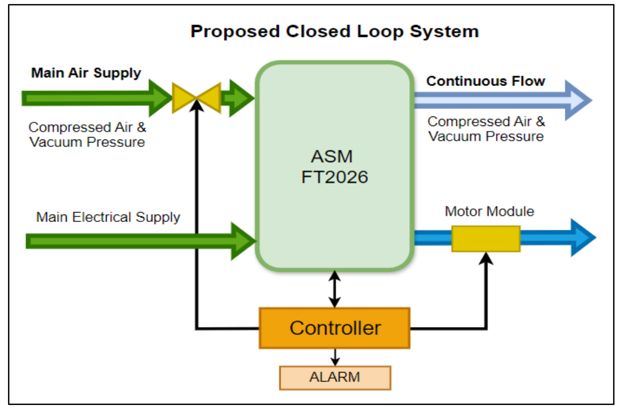


Figure 12. Proposed Auto Cut-off Closed Loop System

2.4.2Machine Set-up with Auto Cut-off Control System Integration

During the evaluation of the software patch required for Handler-Controller interlink communication, the researchers reassessed the feasibility of directly integrating the Auto Cut-off Control into the machine, eliminating the need for an external controller. They determined that the machine is capable of supporting this feature, as it already includes an available I/O module, existing Andon lights that can be used for alarms, and pressure gauges for monitoring the main supplies. See Figure 13.

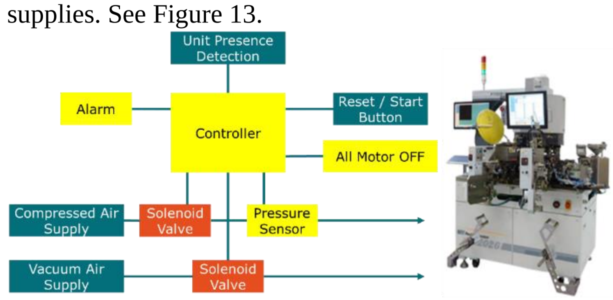


Figure 13. Machine Hardware Validation

By integrating these key machine components along with additional solenoid valves, the functionality of the closed-loop system is strengthened. This new approach not only removes the need for an external controller but also offers a more sustainable and effective long-term solution for the Auto Cut-off Control.

2.4.3Integration of Auto Cut-off Control

An additional solenoid valves were installed in machine's main air supply and insert its power supply in designated I/O module as shown in Figure 14.

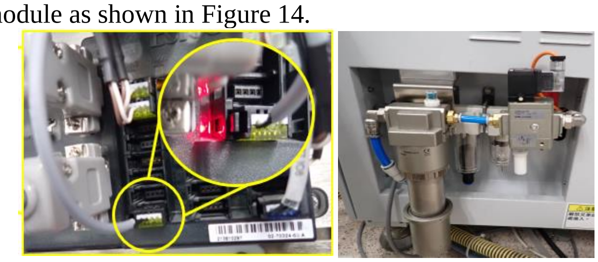


Figure 14. Installation of Additional Solenoid Valves

A Software patch was requested from Original Equipment Manufacturer (OEM) to apply the Auto Cut-off Control for compressed air, vacuum supply and motor electrical power. This software upgrade gives the machine a capability to automatically cut-off its own supplies and monitor them when set conditions are met during Standby mode. See Figure 15.

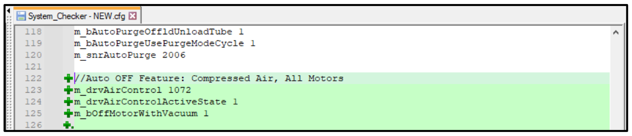


Figure 15. Software Patch of Auto Cut-Off Control

2.4.4Time-based Auto Cut-off Control Realtime Error Warning

During the time-based triggering validation, the Auto Cut-off control timer was set to 180,000 ms (equivalent to 3 minutes). The machine stopped at 7:30 am, and at 7:33 am, the system automatically cut off the supply of compressed air, vacuum pressure, and module motors. Corresponding error messages appeared on the machine's GUI: "System: Vacuum Blower Off," "Motors are turned Off," and "Compressed Air is turned off."

When the machine's reset/start button was pressed, the supply was immediately restored, and the machine confirmed that its internal settings remained intact, displaying the message "System: Vacuum Blower On," along with indications for motor and compressed air reactivation. See Figure 16.

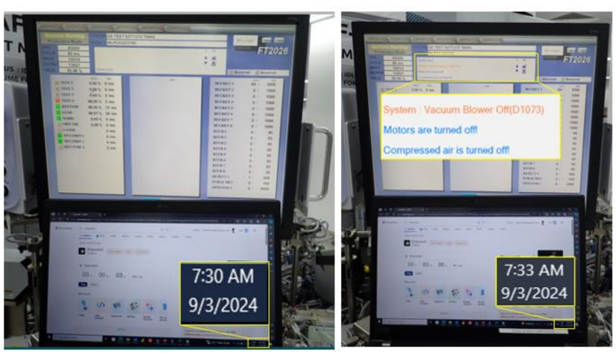


Figure 16. Time-based Activation Validation

2.4.5Auto Cut-off Control Functionality Test

During the functionality test, the researchers conducted trials at various time intervals—3 minutes, 8 hours, 24 hours, and 1 month—to activate the Auto Cut-off feature on the pilot machine. After reactivating the main air supply, no issues were observed, and the module's operation was successfully verified by completing three TD bin insertions, as illustrated in Figure 17.

Figure 17. Auto Cut-Off Activation Time -Interval Validation with Machine Response

3.0 RESULTS AND DISCUSSION

3.1 Fan-out Integration of Auto Cut-off Control in All ASM FT2026 Handlers

After applying the necessary testing, validation and effectiveness of the Auto Cut-off Control System, it was applied in all ASM FT2026 handlers in total of 31 handlers starting from WW2401 to WW2411 as shown is Figure 18.

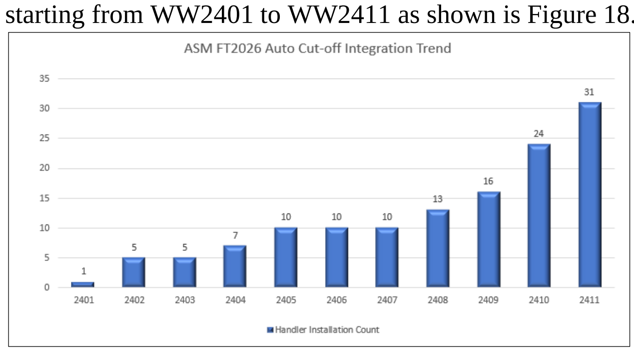


Figure 18. Integration of Auto Cut-off Control in all FT2026 Handlers

Using the Consumption Cost Computation, the average per machine is at 15 cubic meter per hour for Compressed Air and a Vacuum Pressure respectively on the existing Normal machine setup for ASM FT2026.

FY2023 Cost Computation:

Compressed Air and Vacuum pressure:

$$Compressed\ Air\ and\ Vacuum\ Pressure\ Consump$$

$$= (Ave.Flowrate\left(\frac{m^3}{hr}\right) x\ Machine\ Standby\ (Hrs.)\ x\ Consumption\ Cost)^2$$

$$= (Ave.Flowrate\left(\frac{m^3}{hr}\right) x\ Machine\ Standby\ (Hrs.)\ x\ PHP\ 6.8534)^2$$

$$= \left(\frac{9.18\left(\frac{m^3}{hr}\right) x\ 19{,}654.05(Hrs.)\ x\ PHP\ 6.8534}{\$58}\right)^2$$

$$= \$\mathbf{42,638.48}$$

The Standby initial current measured is 4.5A which is equivalent to 0.99 kwh while the measured after Turning off the module motor is 3.1A equivalent to 0.682 kwh therefore:

Module Motor:

$$Electrical\ Consump = 0.99\ kwh - 0.682kwh$$
$$= 0.308kwh$$
$$= Electrical\ Consumption(kWh)\ x\ Machine\ Standby\ (Hrs)\ x\ Consumption\ Cost\ (PHP/kWh)$$

$$= \frac{0.308\ kWh\ X\ 19{,}654.05\ (Hrs) x\ 8.26 \frac{PHP}{kwh}}{\$58} = \$\mathbf{862.09}$$

3.2 Auto Cut-off Control System Savings

This project has an initial savings of $41,153 from January 2024 to August 2024 and Projected FY2024 savings of $59.1K for ASM FT2026 handlers as shown in Figure 19.

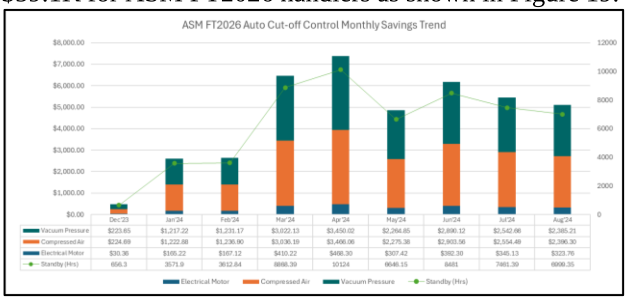


Figure 19. Enercon Savings for Compressed Air, Vacuum Pressure and Module Motor

3.3 Control Phase

3.3.1 Manufacturing Risk Assessment

Manufacturing Risk Assessment Tool under MC-20231123-164 and FMEA is essential for systematically identifying, evaluating, and mitigating potential risks in manufacturing processes. It was employed to deliver a detailed analysis of potential issues that could be encountered during the pilot phase of the Auto Cut-off control system, ensuring alignment with machine operating parameters and specifying the system's detection thresholds.

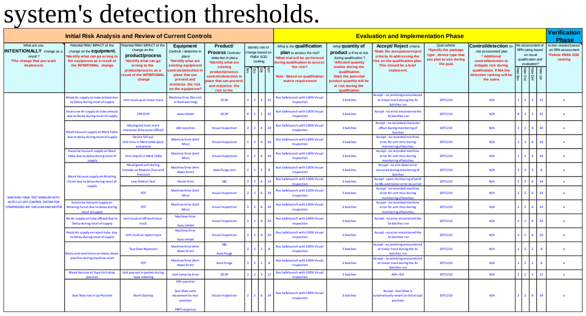


Figure 20. Manufacturing Risk Assessment Table

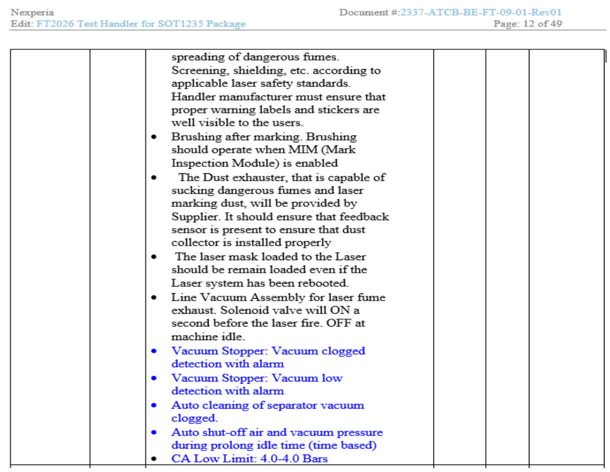
3.3.2Auto Cut-off Control Setting Protection

Auto Cut-off Control System has a timer control setting and Turn ON and OFF feature protected by a higher-level admin password.

Figure 21. Auto Cut-Off Control Password Protection

3.3.1 Inclusion of Auto Cut-Off Control in ASM FT2026 Purchase Order Specification

The identified improvement for the cost savings initiative, the Auto Cut-off Control feature in ASM FT2026, was included in the Purchase Order Specification for future buy-off of new FT2026 machines.


Nexperia
Edit: FT2026 Test Handler for SOT1235 Package
Document #:2337-ATCB-BE-FT-09-01-Rev01
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spreading of dangerous fumes. Screening, shielding, etc. according to applicable laser safety standards. Handler manufacturer must ensure that proper warning labels and stickers are well visible to the users.

- Brushing after marking. Brushing should operate when MIM (Mark Inspection Module) is enabled
- The Dust exhauster, that is capable of sucking dangerous fumes and laser marking dust, will be provided by Supplier. It should ensure that feedback sensor is present to ensure that dust collector is installed properly
- The laser mask loaded to the Laser should be remain loaded even if the Laser system has been rebooted.
- Line Vacuum Assembly for laser fume exhaust. Solenoid valve will ON a second before the laser fire. OFF at machine idle.
- Vacuum Stopper: Vacuum clogged detection with alarm
- Vacuum Stopper: Vacuum low detection with alarm
- Auto cleaning of separator vacuum clogged.
- Auto shut-off air and vacuum pressure during prolong idle time (time based)
- CA Low Limit: 4.0-4.0 Bars

Figure 22. Auto Cut-off Control in PO Specs

3.3.3 Maintenance Task Instruction for Auto Cut-off Control

Include the Auto Cut-off Control in Maintenance Task Instruction to provide step-by-step procedure in checking the solenoid valve conditions.

7.51 SOLENOID VALVE CONDITION AND INSTALLATION IN MAIN SUPPLY FOR ASM FT2026	
7.51.1 All FT2026 handler (OS and Final Test) have solenoid valve installed align with the software update for motor, vacuum and air supply auto cut-off.	7.51.2 Check the condition of the solenoid valve during PM activity (quarterly) if functioning, replace if not.
7.51.3 Current Setting of Auto Cutoff feature is 180,000 ms or 3 mins. Setting can be adjusted only by Sustaining Engineering and Higher Password is needed to change.	1. System : Enable Vacuum Blower Ctrl — True; 2. System : Machine Idle Time(ms) — 180,000

Figure 23. Documented Maintenance Task Instruction for Auto-Cut off Control

4.0 CONCLUSION

In response to the global semiconductor volume downtrend this year, the researchers identified an opportunity to optimize operations. Following ATCB's directive to idle machines during periods of low volume, the implementation of the Auto Cut-off Control System for the ASM FT2026 has demonstrated significant technical benefits, including enhanced sustainability, improved energy efficiency, and reduced facility costs.

The system maintains operational efficiency while enabling the handler to automatically cut off supplies during standby conditions such as No Material, No Dedicated Device

Available, and Planned Machine/Event Shutdown. As a result, this project has achieved cost savings of $41,153.

4 Recommendations

The project proponents strongly recommend conducting a benchmarking and feasibility study for implementing the Auto Cut-off Control System across various handler models within different departments of ATCB

This project was also shared in JETs meeting along with ATSN and ATGD as recommendation to conduct feasibility study to adopt this Auto Cut-off Control System in their handler

Additionally, it is advised to incorporate a monitoring system to track machine flow rate consumption for both existing machines and those for acquired during the buy-off process.

5 Acknowledgment

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