Smart Error-Proofing: Intelligent Detection of PuParset Tester Cable Swaps and Process Control at Final Test

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ABSTRACT

Poka-yoke, as one of the pillars of Zero-Defect mentality, promotes Quality Improvement, Cost Reduction, Productivity Increase, Customer Satisfaction, Risk Mitigation, and Adaptability to ever changing and demanding market. Effective use of this technique makes the difference between catastrophic failure to sustainable productivity.
This paper demonstrates the error-proofing technique used by the team to further improve the test-interfacing between its ATE tester (PµPARSET) going to the DUT (Device Under Test). With zero cost involvement, it paved way to zero occurrence of cable swapping upon implementation of the project.
Also, this is to emphasize that Poka-yoke, from simple orientation solution to comprehensive system overhaul, has the same impact when it comes to promoting culture of quality and manufacturing excellence. Embracing it is a powerful tool for achieving competitive advantage in today's dynamic manufacturing landscape.
This report will be focusing on the Poka-Yoke method as a valuable strategy in improving the quality of an operations process.

1. 0 INTRODUCTION

Nexperia is a globally renowned semiconductor company, recognized for its high-quality, reliable products and strong commitment to customer delivery. To meet the diverse product demands, the company employs a structured process flow and strategic planning to ensure timely delivery and customer satisfaction.

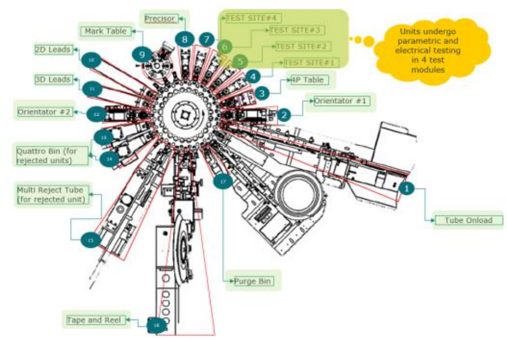

Figure 1: Handler Process Mapping

ASM FT2026 Handlers have 17 modules from Tube Onload to Offload Taping Track each having designated function for Unit Loading, Unit Testing AOI Inspection, Reject Segragator and Unit Taping as shown in Figure 1.

The study will concentrate on the unit testing process in Final Test which is the unit testing involves four distinct test site modules, each with a unique setup to segregate devices that fail the parametric tests. Test Modules are commonly utilized to test a variety of packages requiring low to high voltage supply applications. The test site modules employ two different contact methods: (1) the clamping method, which consists of upper and lower contact fingers, and (2) the plunging method, which uses a cantilever contact finger that makes contact with the leads during device testing.

Test machine comprises a turret-based machine powered with a PµPARSET tester that has modular parameter test system for power discrete semiconductor devices. PµPARSET software gathers data about measured devices and produces various insights for product quality, stability, and yield optimization whereas test machine perform other package inspections.

In this project, a cross functional team was formed to analyze the problem that caused the gross Kelvin /Idss rejection. Through PDCA methodology, the Potential root causes and handler abnormalities will be identified in final test process. The team will also apply the concept of Poka-Yoke to further eliminate the root cause identified and not have any issues in production line in the future.

2. 0 REVIEW OF RELATED WORK

In today's highly competitive world, organizations and companies are expected to deliver reliable products that are of high quality and free from defects, all at a price acceptable to customers. To achieve manufacturing excellence and optimal operational performance, various methods and tools have been used in ATCB, including Six Sigma, RCM, and Poka-Yoke. [1]
The application of the Poka-Yoke approach plays a crucial role in preventing human error and can significantly boost machine utilization and efficiency, thereby reducing breakdowns and product defects. The core principle for the successful implementation of Poka-Yoke lies in the collective prioritization of quality by everyone within the organization. This study aims to assess the effectiveness of the Poka-Yoke method in enhancing quality within the manufacturing and service industries.

2.1 FUNCTIONS OF POKA YOKE

Advanced manufacturing technologies can reduce the likelihood of potential errors, but human mistakes remain prevalent in production environments and can significantly impact costs. The use of Poka-yoke to completely eliminate errors is still not widely adopted, and many managers are unfamiliar with the concept.
Poka-yoke can either identify defects after they have occurred or anticipate errors before they happen. This innovative technique begins with the examination of potential issues, followed by the identification of parts based on their dimensions, shape, size, and weight, and concludes with the analysis of possible deviations from standard processes. Depending on the functionality of the procedure, there are three different types of Poka-yoke: [1]

2.1.1 SHUTDOWN POKA-YOKE

A shutdown is triggered when the Poka-yoke device evaluates several critical parameters and determines that the ongoing process is moving out of the tolerance zone. This indicates that a defective product is either being produced or has already been made. This type of Poka-yoke functions as a preventive mechanism, ensuring that no defective products make it through the production line. [2]

2.1.2 CONTROL POKA-YOKE

The Poka-yoke device, when used as a control method, functions as a regulatory mechanism integrated with the process equipment. This integration ensures that products with nonconformities cannot advance to the next stage of the production line, effectively preventing the manufacture of defective items. This type of Poka-yoke guarantees that every product will be free of defects. [2]

2.1.3 WARNING POKA-YOKE

This Poka-yoke technique alerts the operator in the production area through buzzer sounds or flashing lights when a defect occurs in the manufacturing process. This warning requires immediate intervention from a worker to correct the issue causing the errors, ensuring that subsequent products are defect-free. However, this method does not guarantee the highest product quality due to its dependence on human response. If the Poka-yoke alert is ignored or missed, any resulting defects are the responsibility of the operator. [2]
Among the three types of Poka-yoke mentioned, the control method is the most effective in addressing defects, as it triggers an immediate shutdown of the production line until all errors are resolved. There are three distinct types of control Poka-yoke devices.: [3]

2.1.4 TYPES OF CONTROL POKA-YOKE

A. Contact method
- The Poka-yoke device is able to identify specific abnormal characteristics regarding the shape or dimension of a product. [3]
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B. Fixed-Value Method
- This technique is used when there is a constant repeat of the same activity, giving operators an opportunity to determine the performance of this activity and it ascertains that a certain number of movements is generated. [3]

C. Motion-Setup Method
- This method is utilized when various activities aretaking place in sequence and it regulates that the fixed motions of the production process are followed properly. [3]

3.0 METHODOLOGY

Figure 2: PDCA Methodology

In this study, the problem used the PDCA methodology to futher analyze the unusual gross rejection observed during lot processing in FTAF-017.

3.1.1 PROBLEM DEFINITION

In workweek 2309, Final Test Technician observed a wrong PμPARSET cable configuration setup. Test machine was continuously running with the interchange cable setup of tester encountering gross rejection in Kelvin/Idss.

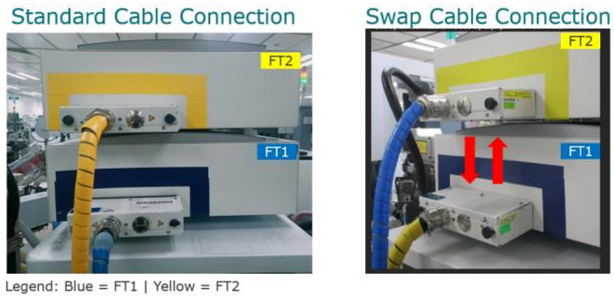

Fig 3. Standard and Swap HD72 Cable Setup

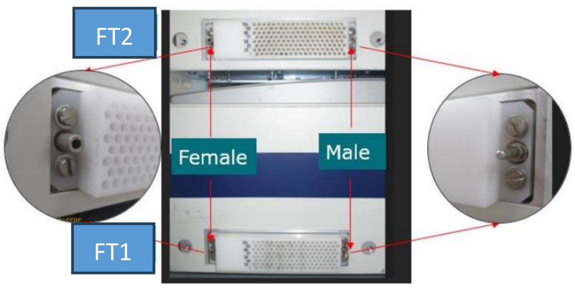

Fig 4. Mechanical Guide Pin Setup (FT1 & FT2)

Fig 4. shows that the cable from FT1 was swapped with FT2 tester. That even in the presence of color coded poka-yoke and mechanical guide pin (worn-out) for cable detection, there is still a possibility of cable swapping because the machine have no detection system in cable swapping for the incorrect setup. In which handler will still have the capability to run with any possible event.
Lot scoping was done to ensure that the processed lots on the test machine will be reviewed and held.

Device	Lot
BUK7Y3R5-40E	MLPC07042200
BUK7Y3R5-40E	MLPC07076400
BUK9Y30-75B/C6	MLPC06252100

3 Lots were identified that were processed with incorrect cable setup.

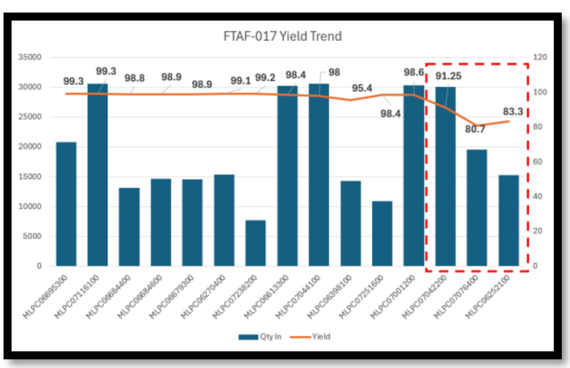

Fig 5. Yield Trend of Lots Processed at FTAF-017

Figure 5 shows the average Yield of the lots processed before the event is 98.5% in FTAF-017 while the average Yield of the 3 Lots affected is only 85%.

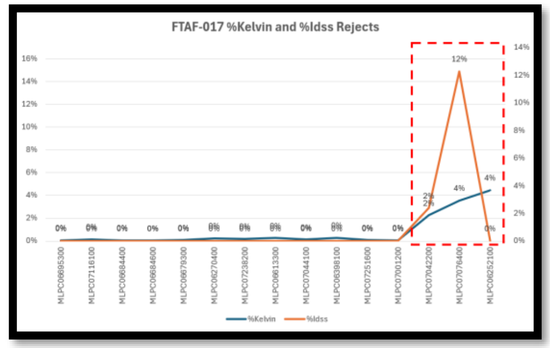

Fig 6. %Reject Trend of Lots Processed at FTAF-017

The average Rejection rate of the affected lots processed is 15% whereas the top rejects are Kelvin and Idss having 3.3% (3 Lots) and 7% (2 Lots) consecutively as shown in Figure 6.

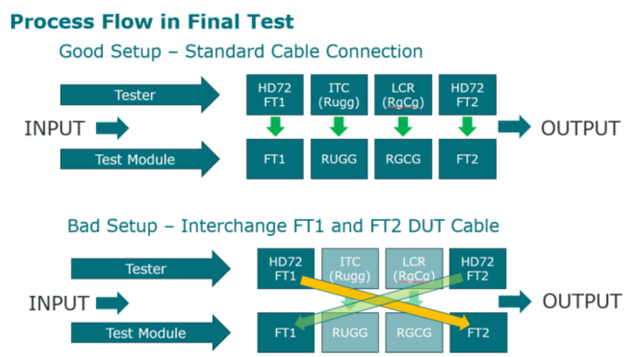

Fig 7. Standard and Swap HD72 Cable Setup

In a standard production run during the Final Test phase, units are tested sequentially at four different test sites: **FT1→ITC→LCR→FT2**. However, in this instance, the lots were processed differently than the usual protocol, with two of the four sites being swapped and the testing conducted asynchronously in the order of **FT2→**ITC**→**LCR**→FT1** as shown in Figure 7

Test Datalog of Affected Lot

BN0422: BUK7Y3R5-40E

Id	Type	Bin	Time	TestBusy	IndexTime_F	tKelvin1	tKelvin2	tKelvin3	tKelvin5	tKelvin6
Low limit						0.01	0.01	0.01	0.01	0.01
High limit						0.06	0.06	0.06	0.06	0.06
Device				s	s	V	V		V	V
1	F02	6	1.68E+09	0.014217	-1269.348	0.3006	0.30008	0.30058	0.30026	0.29926
2	F02	6	1.68E+09	0.113946	8.912333	0.3	0.30002	0.30028	0.29984	0.2999
3	F02	6	1.68E+09	1.549351	0.5456085	0.30004	0.2998	0.30002	0.30032	0.30006
4	P01	1	1.68E+09	0.130326	0.3965741	0.02518	0.02494	0.02544	0.02396	0.02522
5	P01	1	1.68E+09	0.126368	0.1943169	0.02536	0.02488	0.02558	0.02428	0.0254
6	P01	1	1.68E+09	0.126519	1.565701	0.02518	0.02476	0.02542	0.02398	0.02492

BN0764: BUK7Y3R5-40E

Id	Type	Bin	Time	TestBusy	IndexTime	tKelvin1	tKelvin2	tKelvin3	tKelvin5	tKelvin6
Low limit						0.01	0.01	0.01	0.01	0.01
High limit						0.06	0.06	0.06	0.06	0.06
Device				s	s	V	V		V	V
1	F02	6	1.68E+09	0.11379	-1726.18	0.30008	0.30004	0.30058	0.30016	0.29974
2	F02	6	1.68E+09	0.114226	0.130875	0.29982	0.29994	0.30072	0.30008	0.30016
3	F02	6	1.68E+09	0.114204	0.143463	0.3	0.29984	0.3009	0.30024	0.30024
4	P01	1	1.68E+09	0.126611	0.159073	0.02558	0.02424	0.02526	0.0236	0.02542
5	P01	1	1.68E+09	0.126877	0.130707	0.0255	0.02556	0.02536	0.02354	0.02522
6	P01	1	1.68E+09	0.126173	0.131271	0.02544	0.02484	0.02512	0.0241	0.02562

BN2521: BUK9Y30-75B

Id	Type	Bin	Time	TestBusy	IndexTime	tKelvin1	tKelvin2	tKelvin3	tKelvin5	tKelvin6
Low limit						0.01	0.01	0.01	0.01	0.01
High limit						0.06	0.06	0.06	0.06	0.06
Device				s	s	V	V		V	V
1	F02	6	1.68E+09	0.07166	-1269.49	0.30012	0.30006	0.30076	0.30014	0.30008
2	F02	6	1.68E+09	0.135747	-1269.35	0.3006	0.30008	0.30058	0.30026	0.29926
3	F02	6	1.68E+09	0.135992	0.161118	0.30046	0.29974	0.30082	0.29992	0.30062
4	P01	1	1.68E+09	0.136341	0.206818	0.02554	0.02456	0.02544	0.02394	0.0253
5	P01	1	1.68E+09	0.136622	0.271271	0.02542	0.02504	0.02522	0.02406	0.02542
6	P01	1	1.68E+09	0.136275	0.20575	0.02546	0.02492	0.0252	0.02406	0.02506

Fig 8. Test Data Log of affected Lots

The three processed lots observed Kelvin rejection during the initial three units tested suggesting that there was a lack of synchronization in testing right from the beginning of the lot as shown in figure 8

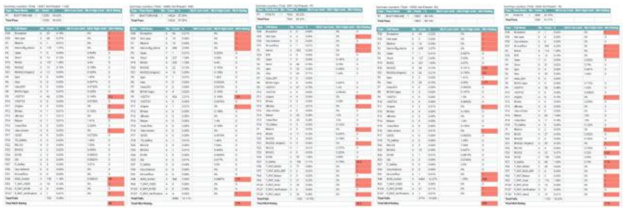

Fig 9. Test Data Summary of affected Lots

Figure 9 shows affected lots encountering unloading and loading of batch due to several rejects detected at test. It was also observed that the overall rejects is averaging 14% on the affected lots.

3.1.2 SOLUTION AND CONTROL

In order to eliminate the problem of cable swapping, it is necessary to implement further Poka-Yoke measures. To assess the effectiveness of PuParset, we are leveraging the Safety Interlock Functionality, which is currently reserved for manual testing, to help reduce electrical risks.

Following discussions with the ITEC Supplier, we have opted to use the X1 (9 Sub Pin Connector) from HD72 and extend it to the DUT cable to enable the Safety Interlock.

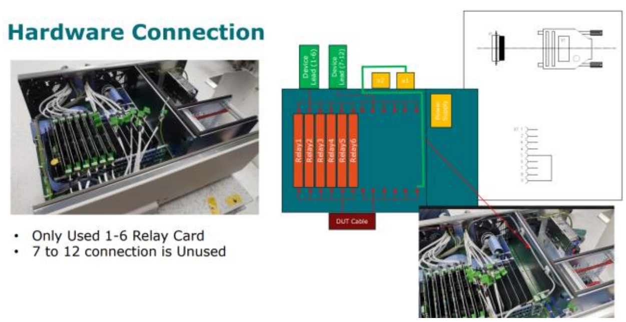

Fig 10. HD72 Hardware Connection

Initially, there are 12 relay card slots inside the HD72 tester. But, only 6 relay card slots are being used for 1 HD72 hardware. Meaning, the remaing relay card are open for use as shown in Figure 10

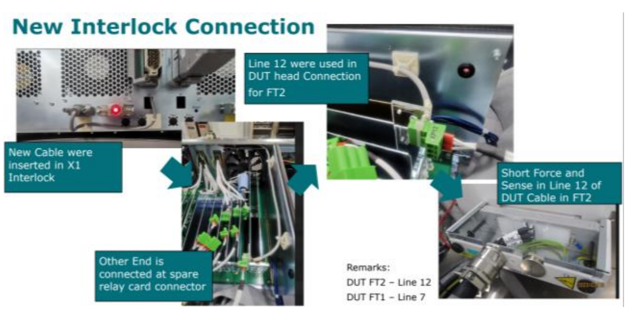

Fig 11. HD72 Interlock Connection

FT1 DUT Cable was used and tapped for Relay card slot 7 whereas FT2 DUT Cable was used and tapped at Relay Card slot 12 as shown in Figure 11

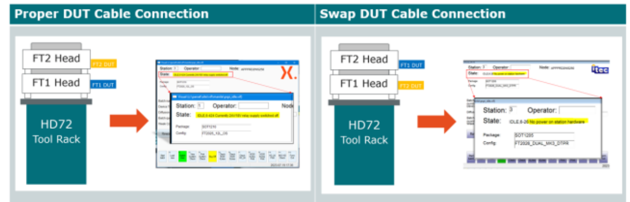

Figure 12: PuParset Setup Pilot Run

Activity	PuParset Status	Validation	Result
Both DUT Cable Connected	Idle State	Can Proceed to Any Transaction	Yes
Both DUT Cable Disconnected	No Power in Station Hardware	Cannot Proceed to Any Transaction	Yes
FT1 DUT Disconnected	No Power in Station Hardware	Cannot Proceed to Any Transaction	Yes
FT2 DUT Disconnected	No Power in Station Hardware	Cannot Proceed to Any Transaction	Yes
FT1 and FT2 DUT Swap	No Power in Station Hardware	Cannot Proceed to Any Transaction	Yes
FT1 Change of New DUT	No Power in Station Hardware	Cannot Proceed to Any Transaction	Yes
FT2 Change of New DUT	No Power in Station Hardware	Cannot Proceed to Any Transaction	Yes
FT1 HD72 Replace	HD72 FT1 Replace, Check Poke Yoke	Cannot Proceed to Any Transaction	Yes
FT2 HD72 Replace	HD72 FT2 Replace, Check Poke Yoke	Cannot Proceed to Any Transaction	Yes

Fig 13. Cable Swapping Validation Table

To further validate the Poka Yoke done by the team, a qualification plan was established. This is to ensure the activity to be done will not cause significant abnormality on the functionality of the machine shown in Figure 13

Fig 13 shows the before and after installation of DUT cable FT1 & FT2 Head while Fig X. Table shows that only when both DUT Cable, with their corresponding connection, are connected to FT1 and FT2 can proceed to any loading transaction in PμPARSET. Any event beyond that, will not allow any user to proceed to machine test operation.

TESTER SIDE Response

HANDLER SIDE Response	FT1	ITC	LCR	FT2	Result
FT1	1	0	0	0	Passed
ITC	0	1	0	0	Passed
LCR	0	0	1	0	Passed
FT2	0	0	0	1	Passed

Fig 14. Logic Test Table result

Using Logic Testing, both tester and test handler was further inspected for communication synchronization. No issue observed during the qualification on the handler and tester side as shown in Figure 14

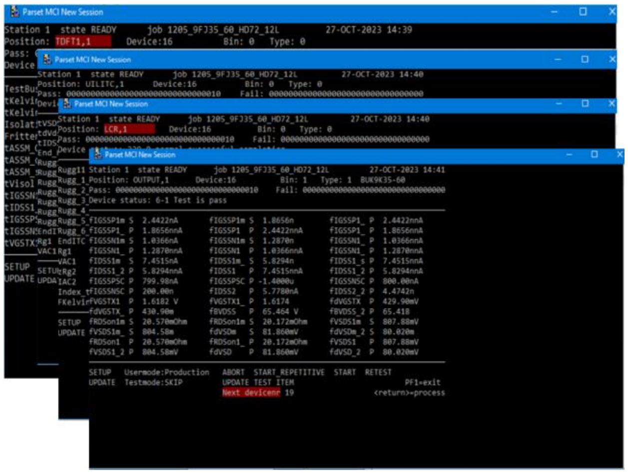

Fig 15. Parset MCI Logic Test Result

PµPARSET Visualization shown Figure 15 shows that there is no communication discrepancy between the handler and the tester as both are connected with all of the test modules as shown in Figure 15.

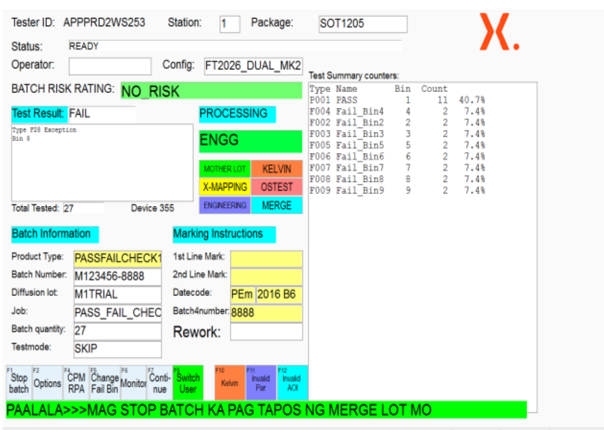

Fig 16. Pass Fail Data Summary Result

All identified good and reject units were binned accordingly as programmed and no mis-binning and fallout encountered. This ensures that the testing proper of units are working accordingly detecting which units falls under the designated bin assignment. 11 good 16 rejects as shown in Figure 16.

4.0 RESULTS AND DISCUSSION

The validation done on the implemented safety interlock poka-yoke proves that the for cable swapping. This also strengthen Poka yoke implemented for the permanent change and safety of cable swapping in Back End Final Test Process. It is clearly shown in Fig. 16 that the swapping of cables did not have any occurrence after the implementation of the identified activities as shown in Figure 17

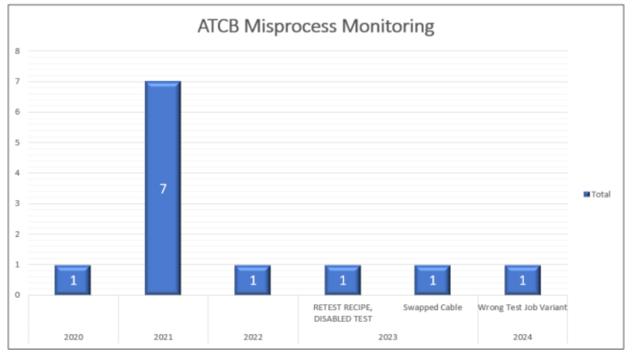

Fig 17. Back End Final Test Misprocess Trend

5.0 CONCLUSION

To ensure safety and quality products produced by Nexperia, the researchers showed that Tester Cable Swapping and Test Sequence are detrimental to the Final Test Process. By applying the Poka-Yoke Principle, incorporating the authors' recommendations, and validating the effectiveness of the changes made, it was concluded that there was no notable impact on the communication between the handler and tester, and no instances of mis-binning were detected. Therefore, the changes can be implemented on the production floor. Utilizing Control Poka-Yoke guarantees that there will be no operational errors during lot processing in relation to accurate testing.

6.0 RECOMMENDATIONS

The goal of implementing Poka-yoke is to reduce, or ideally eliminate, human errors during the manufacturing process, ensuring that defective or low-quality products do not reach customers. The core concept of this system is to prevent potential mistakes in the operation process through continuous monitoring of all production stages. This approach requires collaboration with workers, who can take corrective actions when Poka-yoke detects the potential for defects.

This project was introduced to other sites through the JET team for the opportunity to improve the control of having erroneous testing in Final Test Process, however, other sites have different platform in testing their own products.

7.0 ACKNOWLEDGMENT

The authors would like to extend our greatest gratitude and appreciation to Edwin Ang, Debbie Alcala, and Gareth Hughes for their support, to the authors' family and lastly to Almighty God.

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