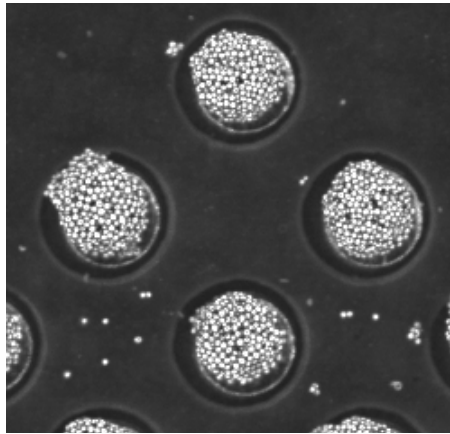


## 1 INTRODUCTION

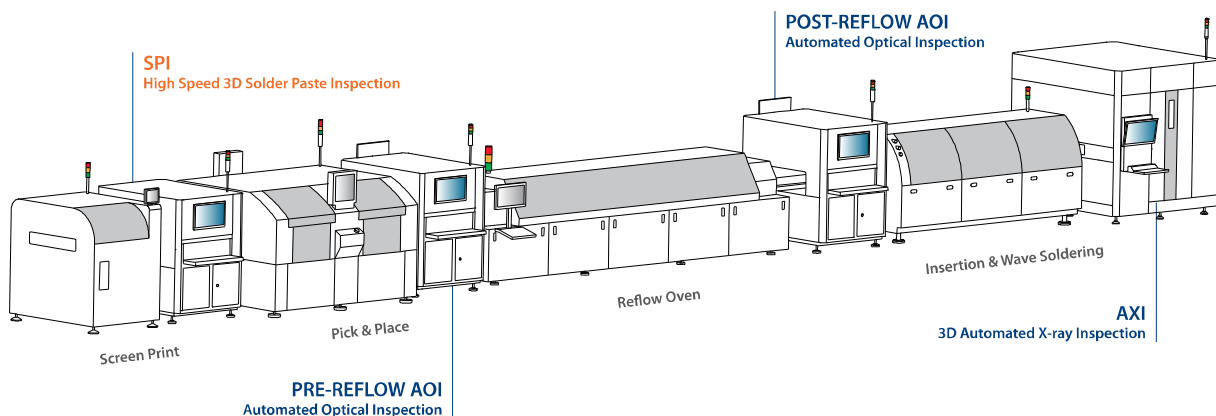
Test Research Inc. (TRI) designs, manufactures and markets precision test equipment for the world's leading electronics manufacturing service (EMS) companies. Product lines include Automated Optical Inspection (AOI) and Automated X-Ray Inspection (AXI), In-Circuit Testers, Board Testers, Solder-Paste Inspection (SPI) and Manufacturing Defects Analyzers (MDA).

The purpose of this White Paper is to give a brief introduction to the SPI technology with information feeds to other manufacturing equipment in printed circuit board assembly lines.



*Solder paste deposits on grid array of soldering pads.*

Solder Paste Inspection (SPI) is one of key Quality Control components designed to minimize production losses by identifying solder paste printing defects in the early stages of production. In addition to defect detection, SPI can integrate with the Printer and other equipment in the production line to optimize quality, automate cleaning and identify the defective boards in placers, buffers and other in-line equipment. TRI's SPI Closed Loop solution delivers these advantages to help minimize line stops, reduce material costs and minimize operator interventions.



*SPI system integration in a PCB assembly production line*

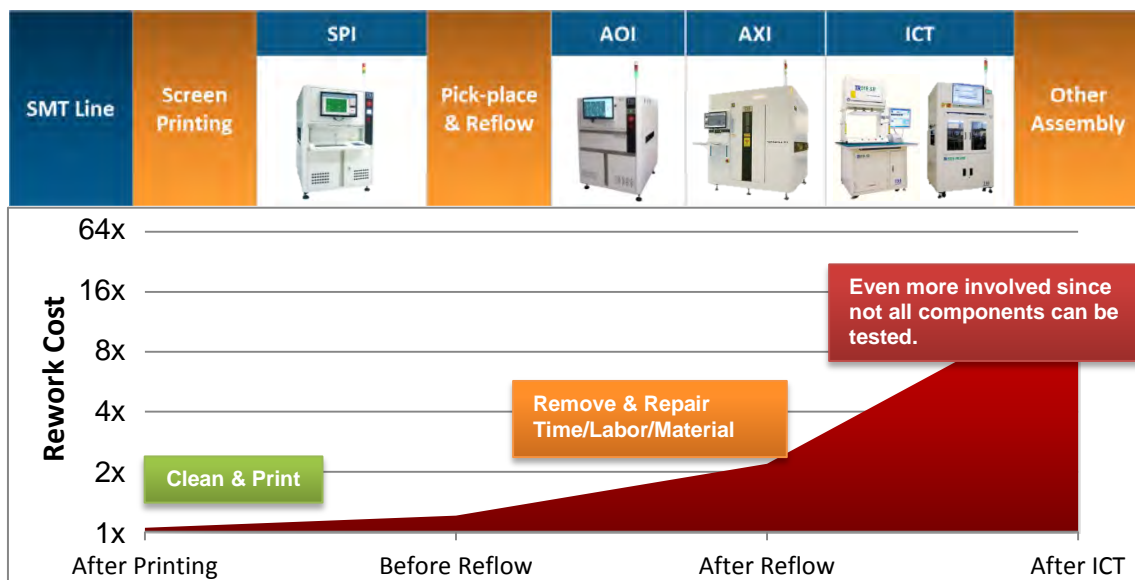
## 2 SPI BASICS

Solder paste inspection (SPI) is one of the first inspection processes employed in production of PCB assemblies, and takes place after a stencil printer lays a precisely aligned matrix of solder paste deposits on top of soldering pads on the PCB. Further in the production process, a pick and place machine places SMT components on top of these solder paste deposits and the entire board moves to a reflow oven, where it is heated in a controlled environment and the solder paste changes into solder, attaching the components to the board. Problems with the quality, accuracy or shape of the paste deposits can negatively influence the resulting solder bond and create many problems during solder reflow, including bad connections, no connections, voids, short-circuit bridges, tombstone and billboard defects.

SPI measures the quality of the paste printing process, and signals any problems with volume, height or area of each of the paste deposits, as well as the misalignment of the PCB and the printing stencil.

### 2.1 SOLDER PASTE INSPECTION VS. SOLDER JOINT INSPECTION

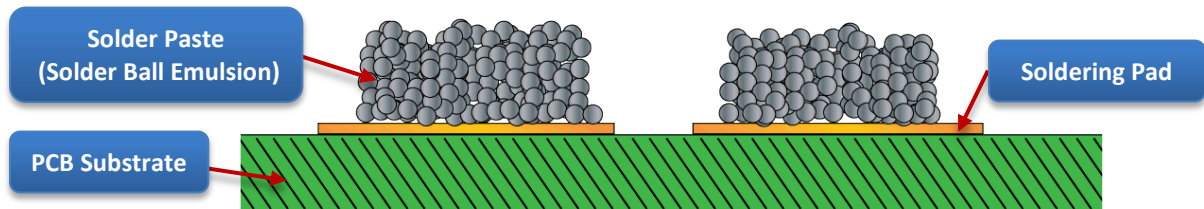
One of the key benefits of solder paste inspection is easy and inexpensive correction of any detected defects by simply wiping and re-printing the solder paste again. In contrast, any defects found by later solder joint inspection (AOI or AXI) require expert rework and are exponentially more expensive to correct.



***Rework costs for manufacturing defects rise exponentially after every stage of the production line, making early defect detection a vital cost-cutting measure.***

## 2.2 SOLDER PASTE DEFECTS

The quality of solder paste printing process is influenced by many conditions, including the configuration of the printer, state of the stencil, solder paste, wiper blade, conveyor, etc.

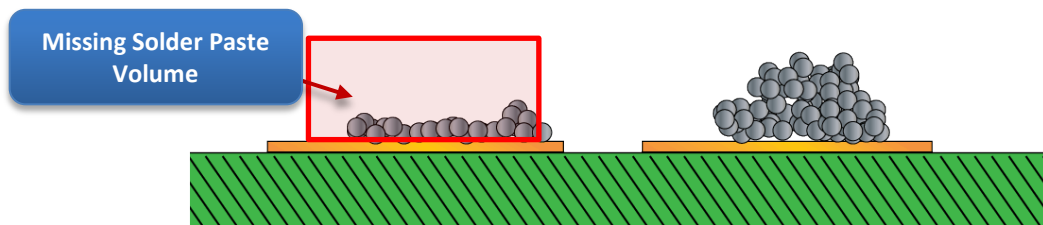


***Ideal printed solder paste deposits have a flat top and nearly vertical sides.***

3D SPI detects four main characteristics to determine if a printing defect occurred: Height, Area, Volume and Offset.

### 2.2.1 INSUFFICIENT VOLUME/NO PASTE

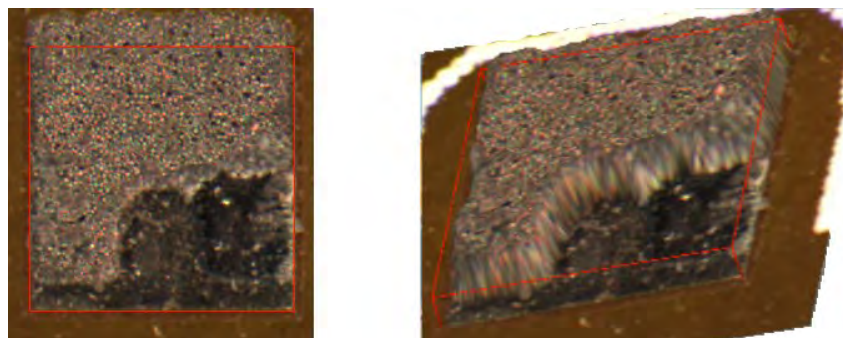
Typically occurs when the stencil in the printer gets clogged and requires cleaning. This affects solder height and area.



***Clogged stencil openings do not allow enough solder paste through.***

### 2.2.2 SHAPE ABNORMALITIES

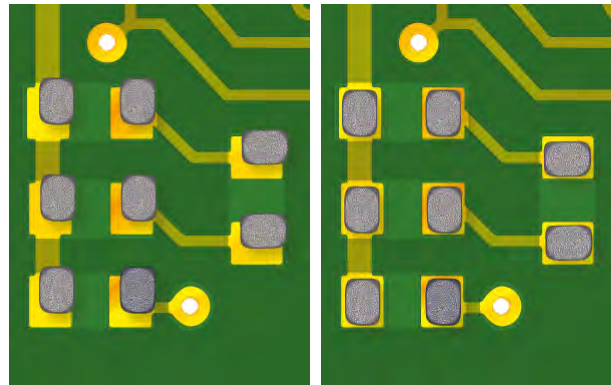
A combination of printer configuration, wiper blade angle, and solder paste composition may affect this issue. Resulting defects may include solder too high/low, area too large/small, and , smearing, bridging and other shape deformities.



***Various solder paste shape deformities can cause solder joint defects during reflow.***

### 2.2.3 SOLDER SHIFT

This defect is typically a result of conveyor tolerance and inaccurate board registration in the printer.

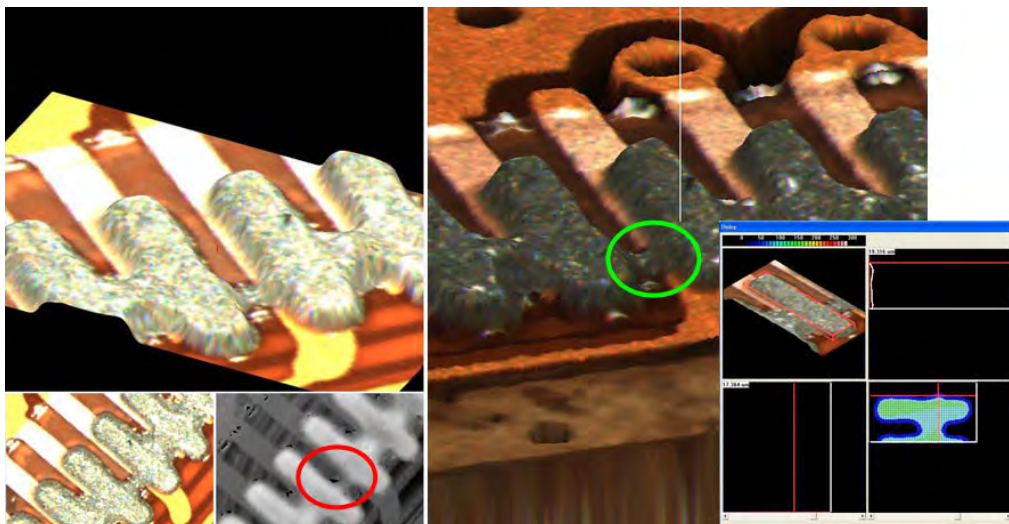


*Shifted solder paste (left) and correctly aligned paste (right).*

## 2.3 3D SPI TECHNOLOGY

Well-defined solder paste deposits have nearly vertical sides and relatively flat top surfaces that are perpendicular to an optical viewing axis (i.e., an axis is generally perpendicular to a plane of a circuit board). In theory, good solder paste deposits can be reliably inspected using optical imaging with on-axis illumination, but any shape irregularities significantly influence the amount of reflected light and make optical inspection using on-axis light impractical.

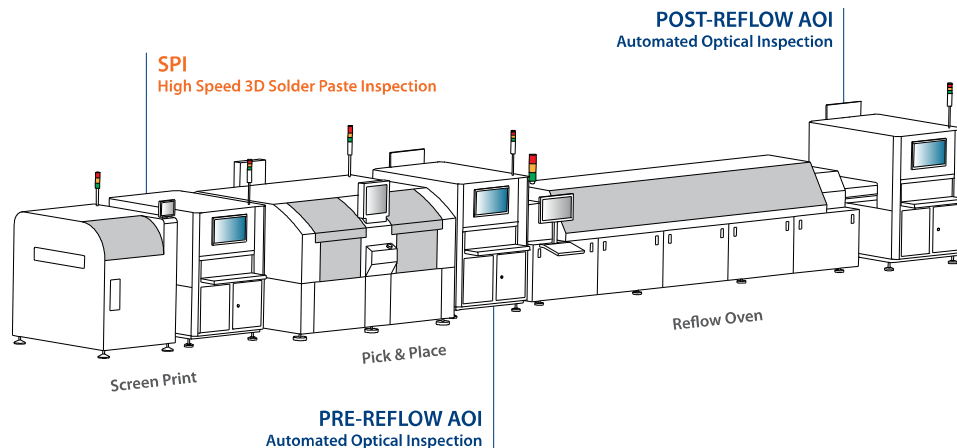
TRI has developed an advanced inspection technology combining 3D shape inspection and 2D imaging to reliably detect all common solder paste defects.



*Example of 3D solder paste inspection result on TRI SPI systems.*

### 3 PRODUCTION LINE INTEGRATION

Solder paste inspection is one of the first automated inspection systems deployed in a PCB assembly production line. It receives printed boards from the Screen Printer and forwards inspected boards to a Pick and Place machine, which places components onto the solder deposits. Further down the line, the entire PCB assembly is heated in a reflow oven until the solder paste melts and forms solder joints between soldering pads and components.



#### ***SPI system and surrounding manufacturing equipment***

Owing to its unique position, SPI can provide valuable information to monitor and improve production quality. In a typical production environment, SPI collects information that can be used for both immediate adjustment and long term statistical evaluation of production yields.

#### 3.1 STATISTICAL PROCESS CONTROL

Statistical Process Control (SPC) is a method of Quality Control which uses statistical data, approximation, and charts to analyze and improve a process, typically a production process. In a production process, several key factors control and affect the final product quality level such as: raw material, process variations, operation procedures, and machine parameters. SPC is applied in the production process to collect data, measure differences, monitor and control those process variations to ensure the process produces as many conforming products at final output as possible. Generally speaking, SPC is a very common tool used in the industry to monitor and control the process variations in order to uplift the final product quality in a continuous improvement loop.

In TRI SPI, an SPC software tool is integrated in the main inspection result window. Our clients can use this SPC tool to collect and analyze the SPI inspection results in any desired timeframe, i.e. discrete and continuous data by Hour, Day, Shift, Working Order, Batch No, Machine No., ... etc.

By comparing the historical inspection results in different key categories, the Quality Engineers are able to find out the preliminary causes to a particular defect symptoms. With aids from SPC and other QC tools, Quality Engineers are able to drill down further and confirm the real root causes leading to a particular defect symptom. Repeating the SPC problem solving techniques the overall process improvement plan can be outlined and then



the short term, long term and preventive actions can be implemented in the process, finally improving overall production quality. Other SPC function such as real time monitoring charts (C Charts and P Charts) can be found in TRI SPC software package, and they are used as an early warning when sequential inspection results begin rising against the Upper Control Limits (UCL) or lowering against the Lower Control Limit (LCL) in a certain timeframe.

Overall TRI SPI not only provides accurate and fast solder paste inspection results, but its SPC functions also help Quality Engineers identify the root causes, implement the corrective actions and preventive solutions, as well as monitor and control the refined process to output the better quality products.

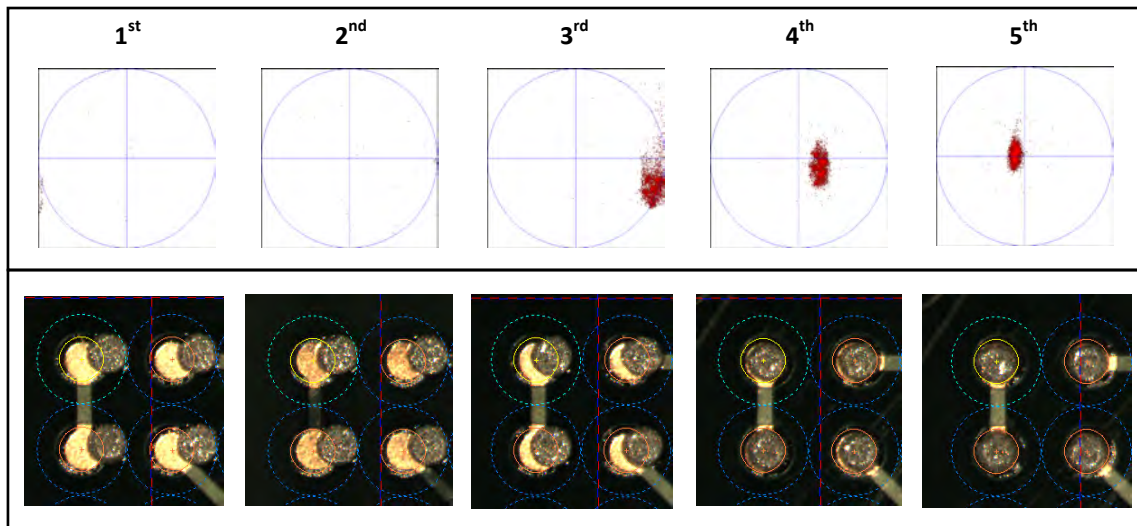
### 3.2 AUTOMATED PROCESS OPTIMIZATION

Specific parameters detected by the SPI system can be used as guidance by manufacturing equipment to automatically adjust production parameters to maintain stable high quality, cut production costs and reduce operator workload.

In TRI's closed loop implementation offers information feeds in two directions: feedback loop to the solder paste printer, and feed-forward loop, which sends inspection results and skip-board information down the production line.

#### 3.2.1 FEEDBACK LOOP

Typical example of information feedback used by the stencil printer is the detected printing offset, solder paste volume and stencil cleaning warning, which triggers an automated cleaning process.



***Solder paste printer uses SPI offset information to gradually realign the stencil with the soldering pads and stabilize production quality.***

Most solder paste printers are configured to periodically clean the stencil to maintain stable printing quality. However, a rigid cleaning schedule may result in excessive consumption of cleaning agents.

By incorporating SPI volume data, the printer can dynamically extend the cleaning schedule to minimize cleaning costs and optimize the printing parameters while maintaining stable quality.

### 3.2.2 FEED-FORWARD LOOP

Production and inspection equipment down the production line may accept inspection results and skip-board data from the SPI system to adjust operation or skip defective boards from further processing.

Automated process control (APC) link with a component placer may utilize SPI offset data to match the position of placed components and actual printed solder paste.

Due to the physical characteristics of the reflow process, heated solder paste melts and forms a joint between a component and a solder pad underneath. While melting, solder paste will adhere and realign itself with the solder pad, also changing the position of the placed devices.

This auto-correcting property of solder reflow makes accurate positioning of SMD components and solder paste before reflow critical for preventing reflow defects.

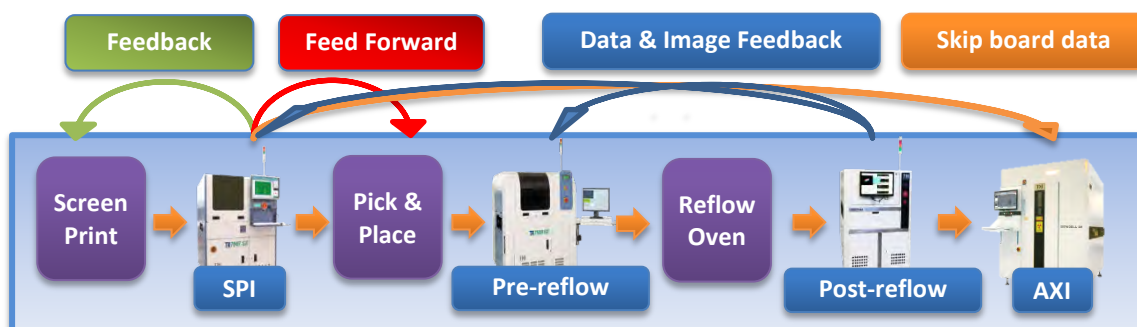


*Component placers may optimize placement of chips onto printed solder paste to use the auto-corrective effect of solder reflow.*

### 3.2.3 TRI SPI SMT LINK LOOP

In addition to sharing data with immediate production line neighbors, TRI inspection equipment can communicate with inspection and production equipment to reduce production costs and collect diagnostic information to analyze root causes of production defects.

The figure below illustrates the data flows in a sample production line environment.



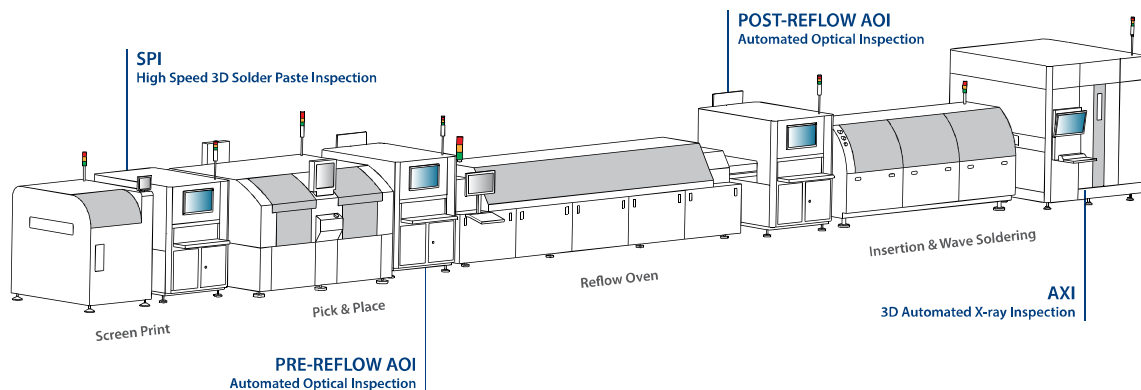
*Data flows between TRI SPI and other production line equipment.*

## 4 CONCLUSION

Solder Paste Inspection (SPI) is one of key Quality Control components designed to minimize production losses by identifying solder paste printing defects in the early stages of production. In addition to defect detection, SPI can integrate with the Printer and other equipment in the production line to optimize quality, automate cleaning and identify the defective boards in placers, buffers and other in-line equipment. TRI's SPI Closed Loop solution delivers these advantages to help minimize line stops, reduce material costs and minimize operator interventions.

TRI's One Stop Solution offers the most robust product portfolio in the industry for Automatic Test and Inspection solutions. From Solder Paste Inspection (SPI), Automated Optical Inspection (AOI), and 3D Automated X-ray Inspection (AXI) systems to Manufacturing Defect Analyzers (MDAs) and In-Circuit Test equipment, TRI provides the most cost-effective solutions to meet a comprehensive range of manufacturing Test and Inspection requirements.

### TRI's One-Stop Solution for PCBA Test and Inspection



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***TRI's One Stop Solution offers a complete inspection portfolio for PCBA production.***

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To find out more about TRI's inspection solutions, visit [www.tri.com.tw](http://www.tri.com.tw) or write an email to [sales@tri.com.tw](mailto:sales@tri.com.tw)



**TRI White Paper  
Introduction to SPI Closed Loop  
ver. 1.0.0**

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