LED BIN validation & traceability

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The increased use of LEDs introduces significant new challenges for the electronic PCB assembler. Separate reels containing the same part number may each have a different brightness index number (BIN). The potential for aesthetic defects is introduced if the BIN from one reel to the next is incompatible. Traditional methods for component traceability and line setup validation are not sufficient to assure quality. This paper introduces a new approach that Methode Electronics deployed for a leading automotive OEM. The system delivers a higher level of process control and traceability during PCB assembly and integrates with functional test to enable automatic product calibration.

The electronics industry continues to experience a prolific increase in the use of light emitting diodes (LEDs). Since the 1960s, LED efficiency and light output have doubled every 1.5 years, following a trend similar to Moore's law. Modern LEDs offer many advantages over incandescent light sources including power efficiency, long life, small size, fast switching and robustness. This has resulted in the wide scale adoption of LEDs for vehicle instrument clusters, warning signs, vision systems and other critical lighting applications.

With this trend comes a significant new challenge for the PCB assembler. LED suppliers package surface mount LEDs based on a brightness index number (BIN). This is a multi-digit code indicating the LED's brightness and color. The BIN code is indicated on the reel label. It is a separate data field from the component part number (PN). Two reels containing the same LED PN do not necessarily feature the same BIN. LEDs with the same PN and BIN appear identical when illuminated. However, if the BIN doesn't match the brightness and/or coloring of the emitted light may be noticeably different. Mixing different BINs on the same production unit is often unacceptable. In other cases the product design permits certain combinations of different BINs (color or brightness), or specifies a pairing between the LED BIN and adjacent component PNs (resistors usually). The rules vary from product to product, resulting in a logistical nightmare for the PCB assembler.

Material availability and costs

If the mixing of BINs introduces such a headache on the assembly floor, then why not demand LED suppliers to only provide a specific BIN for each component PN? This is a logical question. The answer is related to three factors that have a huge impact on any PCB assembler's bottom line: material availability, lead time and cost.

For LED manufacturers the goal is to increase end-product consistency, but currently it is impossible to economically

Figure 1. Surface mount LEDs commonly used in instrument clusters.

produce any specific BIN with high levels of consistency from batch to batch. There are several LED manufacturing issues that contribute to this dilemma. These issues are well documented in industry literature, and a detailed explanation is beyond the scope of this article. They include challenges in controlling both the wavelength of the LED die and distribution of the phosphor during the LED manufacturing process[1].

To provide a specific BIN for each LED PN, the LED supplier would have no alternative other than manual sorting. This comes with a surcharge of course. Sole sourcing in this manner can result in a three to four times increase in LED component cost. In one observed example, the additional premium to source specific LED BINs for an automotive cluster assembly was estimated at over $100K per year for a single SMT line. Extrapolate that to a typical factory with four to six SMT lines and the additional material costs become staggering. Another factor to consider: LED suppliers cannot guarantee long term availability of any particular BIN in high volume. As a result of these constraints, PCB assemblers typically cannot afford to source specific BINs. Instead they must strive to establish effective internal procedures for managing different BINs on the assembly floor.

Fortunately there are industry standards, such as NEMA SSL 3-2010, that establish bin structures while promoting continuity amongst suppliers[2]. This helps

Figure 2. LED BIN code included in 1D or 2D barcode on supplier label.

the PCB assembler in that they can at least identify the BIN associated with each reel. On a reel of SMT LEDs, the BIN code is typically included within a barcode or 2D matrix on the supplier label, to facilitate data acquisition by a material tracking system (*Figure 2*).

Automotive OEM requirements

To meet automotive OEM traceability and quality specifications, Methode sought a higher level of SMT line setup validation than traditionally available. Instead of simple validation based on component PN only, Methode specified the additional requirement to validate based on the LED BIN, to ensure that only compatible BINs are placed onto any given PCB in accordance with design specifications. Traditional validation solutions compare the actual line setup to a static recipe (i.e. the PNs and assigned feeder slots in the placement machine program). The additional requirement to validate based on BIN introduces a new requirement; dynamic setup validation. Why dynamic? Because the correct BIN to load into the machine at any given time may depend on the other BINs presently loaded on the machine, or whether there are partially populated PCBs in the placement machine during reel replenishment. The required solution would also include control systems for physically preventing the machine from placing components whenever the risk of a BIN mismatch or component PN error is present.

Methode's customer also demanded Traceability for every component Lot Number (LN) for each serialized PCB. Again, traditional methods would fall short of expectations. To provide proof of compliance to the customer's design specifications, Methode specified that the traceability data must also include the BIN code for every LED placed onto each PCB. Their customer's traceability specifications also require data storage and accessibility over a 15 year period.

An additional goal was to eliminate variability between individual product units. Accomplishing this would require a traceability system that could integrate with their functional test equipment to enable automatic product tuning and calibration.

After a thorough analysis of potential suppliers, Methode Electronics partnered with a leading supplier of track-trace-control (TTC) solutions for the electronics manufacturing industry. The partner delivered TTC software modules for line setup validation (*Figure 3*) and lot code traceability that account for the LED BIN codes used during SMT assembly.

Ensuring data integrity

"Garbage In, Garbage Out" is a catch phrase that definitely applies to TTC systems. Methode understood it would be pointless to implement TTC SW without checks and balances to ensure 100% data capture and accuracy[3]. For this reason, sources of data loss and error were eliminated wherever possible.

When tracking serialized products, a common source of data loss comes from the need to capture each PCB serial number at scan points along the assembly line. In such applications, the PCB S/N is typically denoted by a barcode or 2D data matrix symbol. The PCB S/N can easily be missed due to quality issues associated with the creation and placement of the S/N identifier, or if scanners along the line are not properly adjusted during product changeover. The risk of data loss is greater in higher mix environments with frequent product changeovers and a wide variety of PCB form factors.

Product flow controllers (PFCs) were implemented to control the SMEMA handshake between conveyors and placement equipment. The PFC only allows product transfer when the TTC SW confirms a successful scan of the product serial number (*Figure 4*). Thus, Methode can assure their customer a 100% read rate of PCB S/N. The PFCs are also used to prevent product transfer when the TTC system detects a downstream line set-up discrepancy, or potential BIN mismatch, thereby preventing defects.

Another typical error stems from mistakes made by production operators when manually associating feeders with feeder locations on the placement machine. To poke yoke the setup and replenishment processes, Methode deployed RFID technology to convert their placement equipment into the smart feeder variety. A low cost RFID tag was attached to each feeder and an RF antenna array was installed on each feeder bank, to automatically detect and identify the feeder at each slot (*Figure*

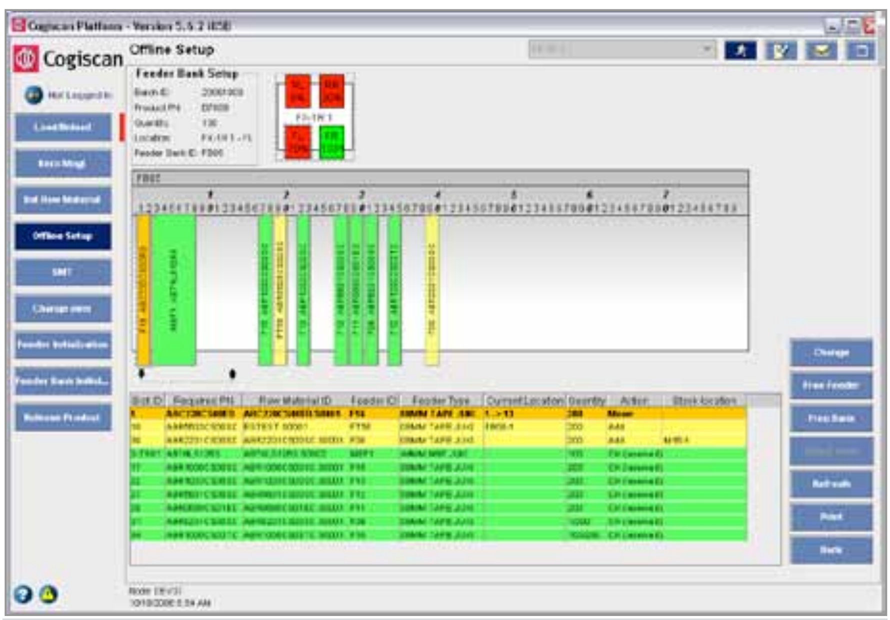

Figure 3. Line setup validation SW accounts for LED BIN as well as PN.

Figure 4. Product flow control (PFC) assures data integrity while preventing defects.

5). In addition to defect prevention, the smart feeder system automatically collects accurate traceability data during machine setup and replenishment. The deployment of smart feeders also increased productivity by replacing manual validation of line setup. By automating what was previously a manual procedure, Methode shaved 12 minutes off the average line changeover time. With three changeovers typical over a 21-hour work day, this efficiency gain equates to 36 additional minutes of productive line runtime per day.

Machine monitoring: low level alarms

The TTC system is directly integrated with the placement machine's software. This allows critical real-time production data to be shared between both systems yielding numerous benefits. For example, the machine will stop whenever there is a PN related setup error. Holding the machine in cycle stop until the fault is

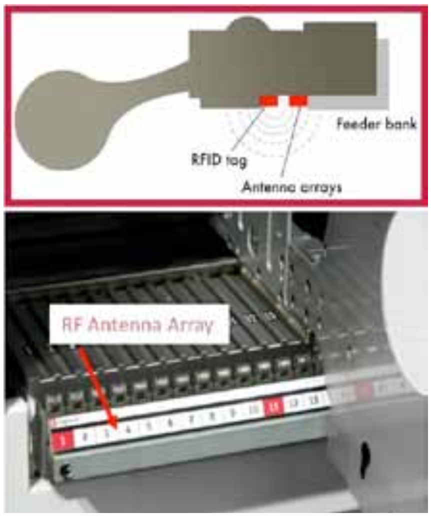

Figure 5. RFID smart feeders to poke yoke setup and reduce changeover time.

cleared. Integration with the machine's SW also allows the TTC system to accurately track component consumption, including all miss picks and rejected components, enabling proactive material management. The system issues an alarm when the remaining quantity of components on any reel becomes lower than a set threshold.

When a low quantity alarm is issued for an LED, the PFC upstream from the placement machine prevents additional boards from entering the machine. The operator is prompted to choose between replacing the low reel immediately, or resuming production with the current setup:

- If the operator chooses to resume production using the current setup, the system allows one additional

Figure 6. Detailed traceability report including LED BIN code data for every reel.

PCB to enter the machine.
  — This choice makes sense when there are enough LEDs remaining in the low reel for one more PCB, or if the operator has a replacement reel in hand that contains a compatible BIN to the one that is low.
- The error will come back for each subsequent PCB, until the Low LED Qty alarm is cleared.
- The Low LED Qty alarm is cleared when the low reel is removed from the machine and replaced with a new reel.

If there are PCBs within the machine when a reel of LEDs is replaced, the system will confirm that the new reel's BIN code is compatible to the one it replaced. If by accident the operator used an incompatible BIN, the TTC system will issue an error and trigger the machine's cycle stop circuit. This makes it impossible for the machine to place any incompatible BINs onto partially populated PCBs.

If there are no PCBs within the machine when a reel of LEDs is being replaced, the system will permit any allowable BIN for that product, provided of course that the PN is also correct.

Complete traceability

For each PCB S/N, a traceability report (*Figure 6*) may be generated that includes the following information:

- Time stamp for start and end of SMT placement process.
- Operator ID
- PN and LN for each reel used.
- BIN for each LED reel used

Conversely, for any given reel, a traceability report may be generated that lists all affected PCB S/N.

Automatic product calibration

The system described above ensures that any particular product only contains correct PNs and compatible LED BINs.

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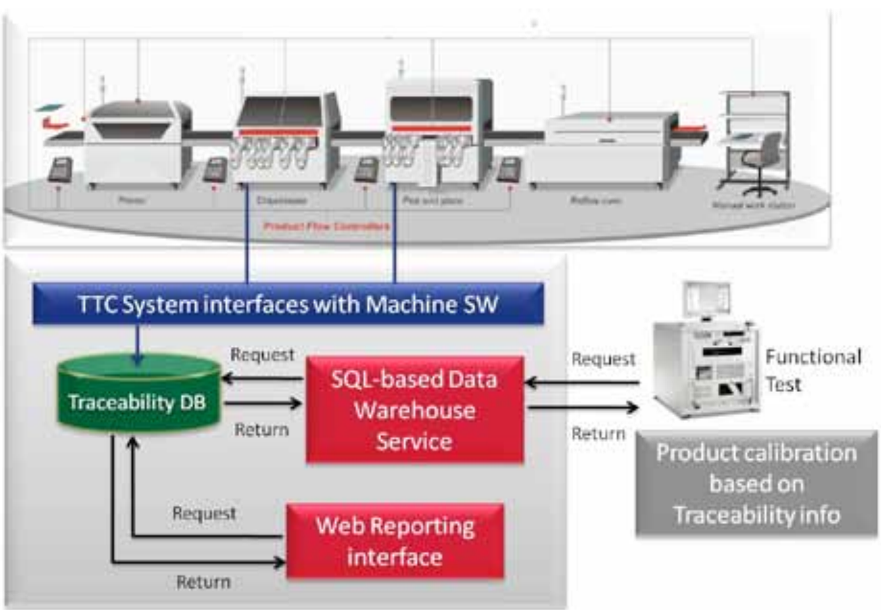

Figure 7. Automated calibration eliminates product variability.