PNL-SA--18184

DE91 004077

DEVELOPMENT OF A SEMI-AUTOMATED
WORKCELL FOR REPAIR OF PRINTED
CIRCUIT BOARDS

DW Bennett
MS Evans

August 1990

Presented at the
Institute of Electrical and
Electronics Engineers Conference
on Systems Engineering
Pittsburgh, Pennsylvania
August 9-11, 1990

Work Supported by
the U. S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, WA 99352

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

CP2

Doc ID: A18184

DEVELOPMENT OF A SEMI-AUTOMATED WORKCELL FOR
REPAIR OF PRINTED CIRCUIT BOARDS

David W. Bennett AND Mark S. Evans

Pacific Northwest Laboratory(a)
POB 999
Richland, Washington 99352

ABSTRACT

Printed circuit boards that comprise U.S. Army electronic systems are repaired at Army depots. An existing automated diagnostic system determines the area of failure; either by identifying failed components or failed board traces. Currently, repairs are performed manually by trained technicians. A system is being developed for repair of through-hole printed circuit boards. It is comprised of many automated and operator-assisted functions to perform the multiple operations related to replacement of failed components. When completed, this system will demonstrate economic payback by reducing skilled labor requirements and decreasing rework. The semi-automated system integrates human operators into the process while maintaining high productivity. After several fully automated systems were conceived and modelled, it was found that the configuration that provided the best return on investment was comprised of a mix of autonomous and operator-assisted functions.

BACKGROUND

While printed circuit boards are routinely manufactured using automated methods, their repair creates unique challenges. Extreme flexibility in autonomous repair is required because repair lot sizes vary from quantities of 1 to 75 maximum for printed circuit boards of a given type, each with different component replacement requirements. During initial manufacture, lot sizes of over 1000 are common, utilizing a fixed assembly program. Approximately 2000 component types are inventoried to support the repair activity as compared to 40 component types for a typical printed circuit board assembly campaign. Circuit boards still exist in the Army inventory that were originally assembled manually. Dimensional tolerances of these boards vary widely and design layouts obviously did not consider intervention of autonomous equipment.

It was found that autonomous replacement of all failed through-hole components was not cost effective. Economic justification for the system was achieved by selecting only the components with the highest failure rates and common physical configurations to alleviate automated handling requirements.

The existing component replacement activity was characterized revealing the following mix of failed components over a period of several months:

- 25% dual-in line packages (DIPS)
- 17% capacitors (axial lead)
- 13% radial lead cans (transistors)
- 12% resistors (axial lead)
- 12% relays
- 8% transformers
- 7% switches
- 5% diodes (axial lead)
- 1% miscellaneous.

Autonomous replacement of DIPS and all axial lead components proved to provide the desired return on investment. This system capability services 63% of the failed components.

SYSTEM DESCRIPTION

The variability in feed, both from the standpoint of printed circuit boards and repair components, places extreme demands on tooling and programming flexibility. Approximately half of the boards studied had two or more failed components; at times requiring that a combination of manual and autonomous repair processes be applied. The system configuration that was derived (Figure 1) permits highly productive interaction of autonomous repair processes with enhanced operator/manual repair stations.

The following functions are performed by the "automated" repair system:

- identify printed circuit board
- accept replacement component information
- locate failed component(s) and determine replacement access requirements
- remove conformal coating
- remove failed component
- remove solder and prepare holes for replacement component
- determine lead spacing
- receive new component and prepare leads
- insert new component
- solder new component
- inspect solder joints.

In the semi-automated repair system, printed circuit boards are fixtured and placed on a positioning system driven by linear stepper motors in the X and Y axis. The various repair and inspection

(a) Operated for the U.S. Department of Energy by Battelle Memorial Institute.

Figure 1

Printed Circuit Board Repair Station Arrangement

unit operations are arranged on a support beam over the X-Y positioning system. Repeatability of the X and Y axis positioning system is 0.0001 inches. The fixturing arrangement permits the system to automatically invert the board to expose the back side for inspection and processing. Each fixture is identified by a unique bar code that relates to the current board in process and its repair status. Z axis positioning of various repair and inspection devices is provided by the individual unit operations. Necessarily, Z axis forces are limited to prevent significant printed circuit board deflections and subsequent positioning errors.

The repair system accepts component replacement data from the automated diagnostic systems and then calls up board demographic information from an on-board file. This information includes board layout and component type and location. Optimized tool paths for the component removal operation are preprogrammed. The envelope representing the tool path is overlaid on the image of the component to be replaced and the system verifies that no adjacent component infringes in the affected zone. If adjacent components interfere, the system notifies the operator who makes the decision to either replace the interference component or to replace the failed component manually. Where digitized board physical data is not available, the operator identifies components to be replaced by locating them on a video image using a mouse. If necessary, the operator can also generate new tool paths for removal of the component. This information is then added to the data base for re-application. Because of this "learning" feature, board repair operations will evolve toward less operator involvement as the system becomes acquainted with the printed circuit board population.

Two television cameras are utilized to provide images to the machine vision system and to the

operator. The printed circuit board and the operator produces a 1-cm square image for hole and solder inspection. Both normal and black lighting provide illumination for the inspection processes.

Edge-finding algorithms locate the exact position of the component and, for through-hole components, lead locations are identified automatically using an image of the back side of the board where the lead locations are clearly visible.

Post component removal images of the board in the vicinity of the repair operation are subtracted from pre-removal images and the "difference" image is displayed to the operator who, in turn, determines if the removal task has been correctly completed and inspects adjacent components for displacement or damage.

Images of the lead holes are acquired after component and solder removal to automatically determine dimensions and roundness in preparation for insertion of a new component.

Conformal coating is automatically removed from the repair area using an abrasive blast with real-time feedback for coating removal based on the fluorescent properties of the coating.

Removal of failed components is accomplished with a milling machine that physically removes the component leads. Machining debris is controlled by a vacuum shroud that encloses the milling cutter and the failed component.

Lead forming and insertion of new components is performed robotically with commercially available tooling that accepts lead spacing information from the vision systems. Rather than feeding replacement components on tapes as is done during initial board manufacture, replacement components are presented to the repair system in hand-prepared kits. Because of the huge inventory of repair parts required, automatic tape feeds are not viable for the repair activity.

Soldering and de-soldering are autonomously accomplished with a CO₂ laser controlled by a real-time infrared sensor. Laser positioning is based on interpretation of the board images.

Present military standards [1] require that solder inspection be performed visually. The repair system will employ enhanced visual inspection utilizing a projected image, three-dimensional zoom microscope. Several solder inspection approaches are being investigated for possible application at a later time. These include thermal decay and real-time radiography.

A hierarchical control and data acquisition system is employed. Individual microprocessors directly control the unit operations. These devices communicate through a local area network with a host controller that, in turn, originates high-level commands, coordinates activities between the various unit operations, provides system status information, accepts commands from the human operator, and archives and retrieves data. The operator's console

language and menu-driven commands. During normal operation, the operator typically is overseeing system function and making decisions based on information presented at the operator's station. A set up or manual operation mode is also provided allowing the operator to address individual sensors and actuators in the system for diagnostics and calibration without overriding interlocks. By employing a portable computer, individual unit operation controllers can be addressed by the operator for diagnostic purposes.

Because all components cannot be economically replaced using autonomous methods, a combined operator's console and manual work station is provided. Trace repairs can also be accomplished at the manual work station. Trace repair requires excavation of the board base material, probing traces for electrical continuity, and solder repairs. The manual work station is co-located at the operator's console and allows printed circuit boards to be rapidly moved to the manual station. Three-dimensional magnification systems, micro-positioners, special tools, and test probes are available to perform precise work in a productive fashion. Manual work can be performed as required and the board can be returned to the automated system to resume processing. Productive mix of manual and autonomous operations in a work cell while maintaining operator safety is a unique achievement of the system design.

CONCLUSIONS

Cost-effective automated repair/replacement activities differ significantly from initial manufacture. The characteristic low throughput and variability of repairs places extreme demands on system designers to fully characterize repair streams and to use discretion in automation investments so that return on investment is not compromised.

ACKNOWLEDGEMENT

This work is sponsored by the U.S. Army DESCOM, Sacramento Army Depot, Sacramento, California under contract DE-AC06-76RLO 1830.

REFERENCE

- [1] MIL-STD 2000, "Requirements for Soldered Electrical and Electronic Subassemblies," 1990.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

END

DATE FILMED

12 / 13 / 90