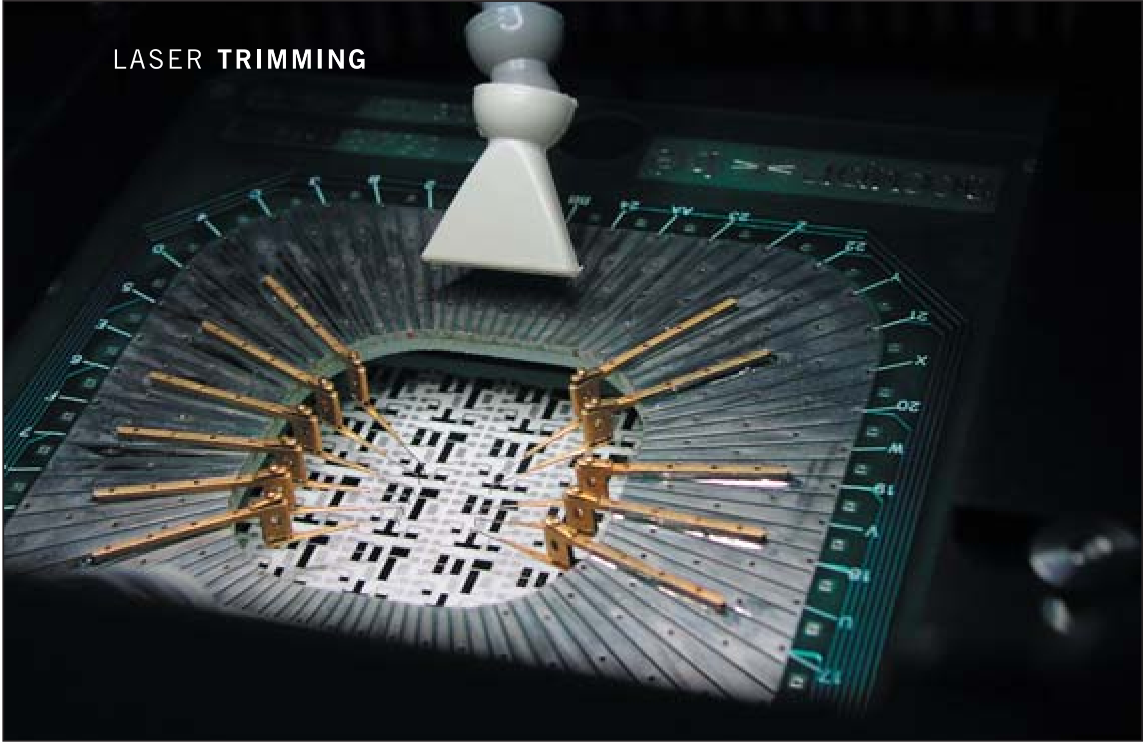

FIGURE 1. Because of their low profile, cantilever type probes are preferred for trimming.

System Considerations for LASER TRIMMING EMBEDDED PASSIVES

Test results on a turnkey, single-button laser trimmer for production, including a novel test probing system. by BO GU, MORDECHAI BRODT, PIERRE-YVES MABBOUX and JEFF WAKE

Demand for better performance and lower cost is leading to the development of technologies that place discrete components on internal layers of multilayer boards.[1,2] A variety of techniques are being proposed to form those embedded components. For resistors, these include screen-printing of thick-film, either organic or inorganic, pastes and sputtering, or electroless plating of thin-film metal alloys.

For tolerances of ±1% or better, embedded components must be trimmed. Laser trimming of thin-film, thick-film and chip resistors is a well-established technology that spans over 20 years. On PCBs, trimming means adjusting passive components on top of the innerlayer of a multilayer PCB. While the passives are on the top surface of the panel, they can be tested and trimmed.[3,4] Subsequently, those trimmed components are embedded as the panel goes through lamination.

When configured for fixed probing, the laser trimmer should accommodate industry standard 165.1 mm (6.5″) probe cards. The probe card should be mounted onto a probe frame with a theta motion axis used to align the probe card to any small rotation of the panel, as well as to enable probing of circuits that are positioned at different angles (0, 90, 180 and 270°). The probe frame should move up and down using a Z motion axis. The probe height is adjustable based on the panel thickness and amount of overdrive chosen.

Finally, all of the sub-assemblies of the system are controlled via software. The software should control the sequence of events, such as panel alignment, probing, measuring, and trimming. It should also provide utilities to convert Gerber or IPC-D-356B file formats to facilitate application setup, and should log the trimming information to a database that can be conveniently queried from a web-based graphical application.

Testing Aspects of Laser Trimming

Testing correctly is of the utmost importance for laser trimming. Major requirements for testing are speed and accuracy. Accuracy in the measurement is obviously required to meet ±1% tolerances. Probing accuracy is also required, as probes need to precisely move in x,y,z in order to make contact to the testing pads.

As for speed requirements, lasers are able to trim at repetition rates in excess of 10 kHz. To make full use of the laser's trimming speed, the measurement system must there-

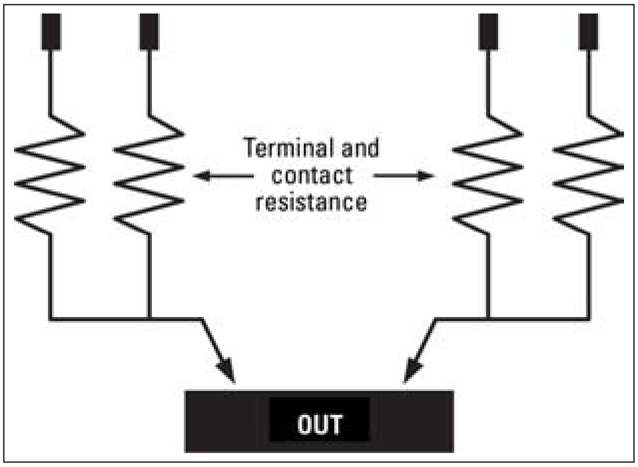

FIGURE 2. Partial 4T Kelvin measurement.

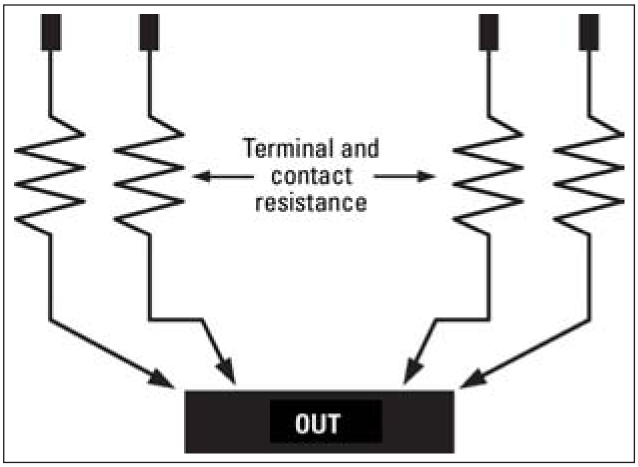

FIGURE 3. Full 4T Kelvin measurement.

fore be designed to make measurements in less than 0.1 ms.

Probing speed is also important as it affects the overall throughput and cost of ownership of the system. In this regard, cost analysis comparison between flying probes and fixed probes systems reveals the notion of a breakeven point. For low volume production, a flying probe system is more economical as it does not incur the fixed costs of having to build probe cards. On the other hand, for high volume production, the ability to probe several components at the same time makes a fixed probe system more appealing as overall throughput per board is higher. Cost analysis shows that the breakeven point is around a few hundred boards.[5]

Another important consideration for any laser trimming application is that probes must be designed such that they do not block the laser beam. In this regard, there are two main types of probe technologies, the first based on cantilever mechanics, the second on vertical probes. Because of their low profile, cantilever type probes are generally preferred for laser trimming applications (FIGURE 1).

Other testing requirements for laser trimming that are unique to the PCB industry are the result of the large panel sizes involved and also the use of copper for trace and pad interconnect.

While flying probe systems can move to any location on a large PCB, this is not the case for typical fixed pattern probe cards, which are optimized for devices up to 10,000 mm^2. This is also not the case for the laser beam, which has a limited range of motion due to optical constraints and is optimized for devices up to 8000 mm^2. The latter two technologies rely on a step-and-repeat motion table to position the device under the probe card and within the laser beam range.

Copper is an extremely good conductor and enhances the electrical characteristics of interconnects, but oxidizes quite quickly and unlike other materials, in which the initial oxidation seals the surface against further oxidation, copper suffers continuous oxidation.

To ensure electrical contact during probing, it is necessary for the probe action to scrub through any surface oxidation in order to reach the underlying base material, reduce contact resistance and ensure reliable measurements. The geometry of cantilever type probes ensures that they scrub forward when a vertical movement or overdrive is applied to the probing system. Typically, a cantilever probe will scrub forward at a rate of 10% of the overdrive applied, and hence a typical 250 mm of overdrive will lead to 25 mm of forward scrub at the point of contact.

Another concept important to probing relates to Kelvin measurements. A single probe in contact with a pad will provide a reasonable measurement interface to the device under test; however, accuracy will be impaired through variations in the electrical characteristics of the leads and other elements in the transmission path to the device (FIGURE 2). Kelvin terminal or four-terminal resistance measurement techniques are used to increase measurement accuracy, particularly when small impedances are being measured (FIGURE 3). Two sets of leads are used at each test point, similar with respect to thickness, material and length; one set carries the test signal and the other connects with the measuring instrument. The effect of resistance in the leads is thus eliminated. Four terminal leads are often specified for low Ohm current sensing applications where lead resistance is a significant factor in total resistance. The Kelvin connection removes the voltage drop error in the current leads, since the sensing leads are attached at a fixed point and carry no large current. The closer the four terminals can get to the actual device under test the more accurate the measurement. This technique affords resistor measurement with an accuracy of better than 0.1%.

A final and important consideration to the achievement of test and measurement efficiency is to ensure that the probes are regularly cleaned and maintained. Oxidation on the surface of the pads attaches to the probe tips, which requires regular cleaning to ensure test accuracy. Beryllium copper (BeCu) probe tips have partial self-cleaning properties and will generally require less cleaning than tungsten and other harder materials that are used in probe needles. Cleaning can be accomplished using abrasive cleaners, which are sometimes incorporated into the probing system, or by the placement of an abrasive film on the chuck in lieu of the substrate. Alternatively, aerosol-based cleaners such as Asahiklin 225 provide excellent cleaning capabilities without degrading the electrical characteristics of the probe card assembly.

TABLE 1. Trimming Results by Panel Type

PANELS	EP MATERIAL	COPPER TREATMENT	AVERAGE (% FROM TARGET VALUE)	STANDARD DEVIATION AFTER TRIMMING (%)	3 STANDARD DEVIATION AFTER TRIMMING (%)
1	NiCr	Plain	-0.1	0.16	0.49
2	NiCr	Reversed treated	-0.1	0.16	0.47
3	NiCrAlSi	Plain	0.2	0.13	0.39
4	NiCrAlSi	Reversed treated	0.0	0.16	0.47

Experiment

We conducted tests to verify some of the unique issues involved in probing PCB materials and to recommend appropriate probing solutions. A test probe card with Kelvin Z-adjustable probes using both tungsten and beryllium copper probe types and different probe needles was constructed. A number of PCBs with embedded resistors (see **TABLE 1**) were manually probed with the test card and measurements made using a precision ohmmeter test set.

Experiments unveiled the criticality of breaking through the surface oxidation on the copper pads for accurate measurements. Too little overdrive – less than 50 mm, which corresponds to a forward scrub of 5 mm – can lead to the probe not breaking through these contaminants, resulting in inaccurate measurements. Additionally, too much overdrive – more than 500 mm – can potentially damage the pad through excessive force and may lead to the probe falling off the pad into other substrate areas or circuit trimming areas. Excessive overdrive can also prematurely wear out the probe tips. Experiments were repeated for tungsten and BeCu probes, with similar results.

Resistor trimming was performed on four different sets of eight panels, all 16 x 20˝, in order to observe the effects of various copper treatments on the capability of the EP laser trimmer. The layout for all panels was identical, the only differences between the four sets being the resistor's material and the copper material used for probing (Table 1).

The PCB was laid out with 156 resistors of various geometries and target values. All the resistors were made of thin-film metal alloys with sheet resistivity of 100W/square.

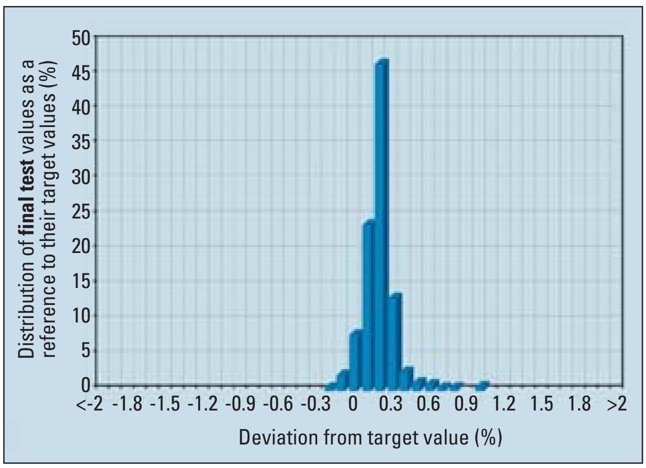

FIGURE 4. Post-trim distribution for panel 3.

Target values ranged from 30W to 2880W corresponding to aspect ratios ranging from 0.3 to 29.

Probing was performed using full-Kelvin probes. The tips of the full-Kelvin probes were made out of beryllium copper and had a diameter of 125 mm. We applied 375 mm of overdrive, to ensure proper scrubbing action and contact. For each of the 1248 trimmed resistors, the nominal value was expressed as a percentage of its respective target value. The distribution of those values for panel 3 is presented in **FIGURE 4**. The average, standard deviation and 3x standard deviations were then calculated and are presented in Table 1.

To complete the first sets of experiments, trimming experiments were also performed on panels with differently treated copper pads (pads underwent plain treatment and reversed treatment for both NiCr and NiCrAlSi panels). There was no evidence that copper pad treatments significantly affects trimming performance provided probes are overdriven properly.

While the laser trimming results of PCBs were very similar to what has been observed with traditional resistor trimming, this is the first known study of probe and pad treatment issues on PCB trimming and their impact on the final results. **PCD&M**

ACKNOWLEDGMENTS

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