

Application note

“ETEL solution for IC turret handler”

Keywords:

Integrated Circuit (IC), Automated Test Equipment/System (ATE/ATS), packages (QFN,FO-WLP, DIP, SOT, SOIC), reel, tray, tube, chip handling, PCB, cost of test, tester, interface or DUT board, dwell time, force control, soft contacting, conversion time, test time, test socket, short stroke actuator, theta motion, turret handler, known good dies (KGD), Z axis, servo cam.

Abstract

This application note describes the IC package handler ecosystem (market drivers, machine architectures, technical challenges...), and sets a specific focus on the IC turret handler category. With its range of products, ETEL S.A. can propose competitive solutions that match with the specific needs from this market and is already prepared for its future challenges.

Introduction

There are hundreds of different IC package types available on the market, coming from different technologies, and developed over the past decades. Based on the final application, these IC packages are also calling for specific final test recipes (QFN, DIP, SOT, SOIC, wafer-level, etc.)

The IC handlers execute the final test on the integrated circuits. This final test is usually performed through a combination of several test methods using vision and electrical contact, in ambient, cold or hot conditions. These tests are performed in the same machine which is loading the ICs into some form or transfer media (it can be through a reel, a tube or a tray) before they can be sent for assembly into a final product (typically a PCB). Among the different IC package handler architectures available on the market, the IC turret handler raise particular

technical challenges:

- High throughput (up to 60 kUPH).
- High handling care (latest generation of ICs requires soft contacting handling).
- Harsh environment conditions (the machine is subject to vibrations, and operating around dust and metal residues due to laser marking operation).
- High number of axes and modules in a minimum footprint.

All those specifications make the IC turret handler one of the most challenging application from a motion control point of view.

Elements composing an IC handler

As shown in Fig.1, IC handlers are made of three different elements: the tester, the interface board or DUT board (Device Under Test) and the handler itself).

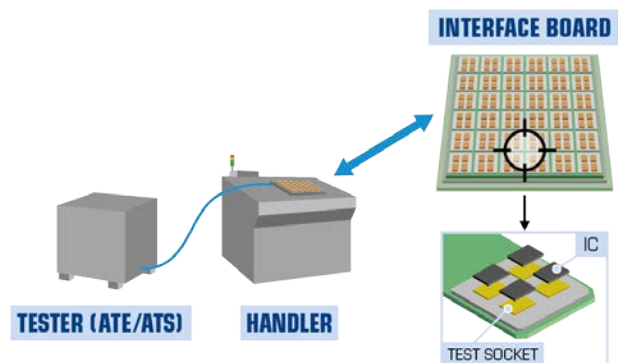


Fig.1 Elements composing an IC handler.

The handler

The handler is used to manipulate packaged devices from a loading station to the different test stations, up to the final media transfer. The handler provides a temporary connection to the test station and is responsible for sorting the good ICs from the bad ones. IC handler manufacturers have built their core competencies around:

- Chip handling at high dynamics.

- Chip contacting into test socket or under camera focus.
- Mechanical integration of all modules equipping the machine.

The tester

The tester, also called Automated Test Equipment (ATE) or Automated Test System (ATS), can be a simple computer, or a complicated system containing dozens of complex test instruments (real or simulated electronic test equipment) capable of automatically testing and diagnosing faults on integrated circuits. The tester defines the test strategy (send the test commands, receive and analyze them).

The interface board or DUT board

The interface board is the link between the component to be tested, the ATE or ATS, and the handler itself. The interface board transmits the electrical signal received from the component to the tester, through a test socket. The test socket is a consumable part (typically few millions insertion lifetime).

Bringing down the cost of test

While the IC packages are getting more and more complex, smaller and delicate to handle, final tests are becoming always more challenging. Indeed, smaller chips do not transfer into faster test times. As chip complexity increases, so does test time. Studies have shown that packaging and test now account for an average of 50% of the total product cost for an IC; and this number is projected to rise to over 75% within the next few years [1]. The rising cost of semiconductor device testing is now one of the main challenges to manufacturers. As a consequence, solutions must be found to limit, or even better, decrease the cost of test.

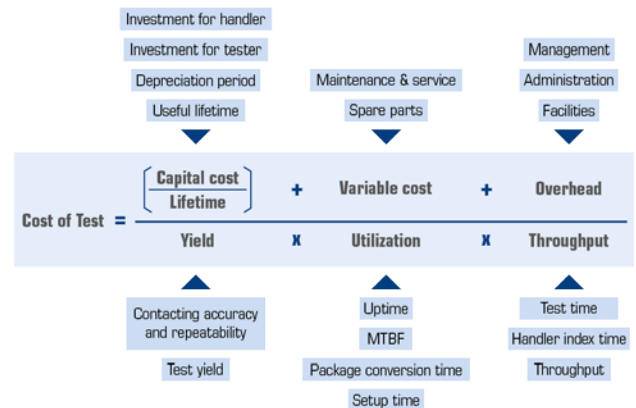


Fig.2 Parameters affecting the cost of test.

Fig.2 makes clear that the machine cost itself is not the only parameter defining the cost of test. With its product offering, ETEL S.A. can significantly help the OEM IC handler to decrease its cost of test through:

- A unique product reliability: drive technology, combined with ETEL's manufacturing quality, extend machine lifetime and increased utilization rate. Some IC handlers equipped with ETEL products have been running in the field for more than 15 years.
- Unmatched soft contacting capabilities and control of trajectory: with its range of dedicated features, ETEL S.A. helps increasing yield (better contacting accuracy, longer socket lifetime, limitation of jammed components). Moreover, with its new Force Control feature [2] available in its AccurET family of controllers, ETEL S.A. is able to carefully monitor the contacting force without any force overshoot at landing.
- Faster index time: ETEL S.A. provides high performance products and can help OEMs setting up their machine to improve throughput. In many cases of benchmark against competition, ETEL S.A. was able to demonstrate a significant increase of machine throughput.

Three IC handler categories

Three categories of IC handler machines are currently available on the market: gravity feed, pick & place and turret handlers. Each architecture is designed to minimize the cost of test for a specific range of application, based on the requested test recipe (test time) and the package characteristics (media transfer, package size, component fragility, variety of tested components), see Fig.3.

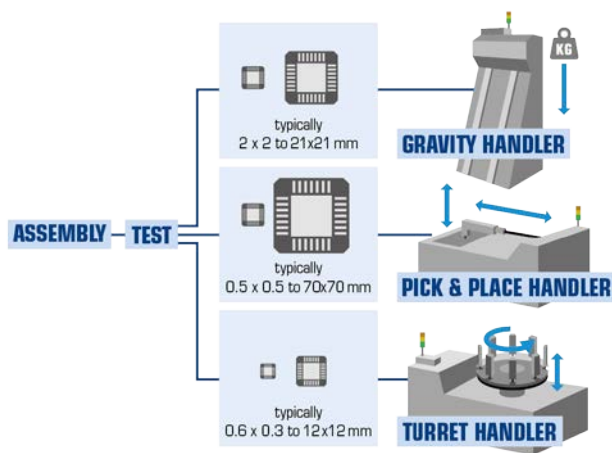


Fig.3 Three categories of IC handler.

Gravity handlers

Gravity feed handlers are based on a package sliding down through gravity and inclined rail up to a test socket. They work best for packages that are quite solid and can withstand friction on a sliding surface (TO, DIP, SOIC) since they provide low capital investment and can do the job at a good yield. However, when the chip becomes smaller and fragile, gravity feed loses its advantages since decelerator are needed to protect component landing, reducing significantly throughput.

Pick & Place handlers

In a pick & place handler, components are typically entering into the handler through a tray, which is moved to a Z pick position, from where an array of components is then picked and placed to the test station. Pick & place handlers are more complex

than gravity feed and therefore more expensive. But, for complex chips and long test times, thanks to their multisite testing capabilities, pick & place offer finally a better cost of test than gravity feed handlers. In addition, with a high parallelism approach and for long test time (> 100 ms), the component handling time becomes irrelevant in the throughput computation. This allows to transport ICs carefully at reasonable speed. Most of the time, pick & place handlers do not use direct drive technology unless the component handling require a tight motion profile control like MEMS (to not damage the moving structures). In some cases this call for the use of linear motors.

Pick & place handlers are today widely used in the automotive industry since this market requires high-end chips and long test times at three different temperatures (cold, ambient, hot). The high parallelism approach from pick & place is then well adapted.

Turret handlers

The third category, turret handlers, are built around a carousel (turret) on which components are loaded and indexed at high speed to individual test stations. They have the lowest cost of test among IC handlers when it comes to short test time applications (serial testing). Because of serial testing, the component handling time (meaning the overall machine motion control performance) is a big contributor to throughput and cost of test. However, handling the chips at high speed raises proportionally the challenge of handling carefully the components. With its advanced soft-contacting technology, ETEL S.A. gives a perfect answer to this second challenge. Turret handlers are particularly well adapted to the growing mobile device market which requires small components with ultra-short test times (typically 20 ms).

IC handler market

As the package design evolution goes towards a miniaturization, with more and more embedded functions to test, there is consequently a progressive loss of market share for gravity feed handlers while turret and pick & place handlers are sharing each other most of the market. Fig.4 shows the package market evolution together with typically used test handlers.

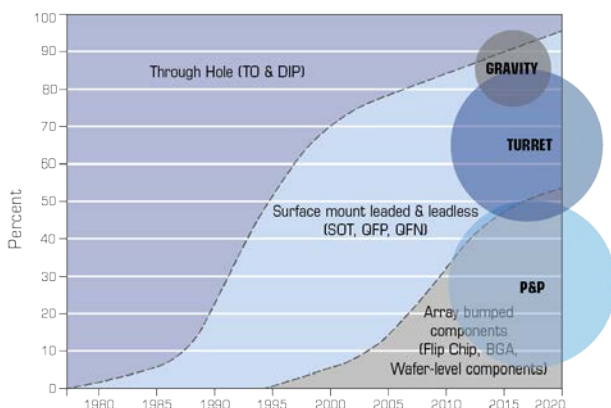


Fig.4 Market share evolution for the different IC packages (trend inspired from several sources [3] and [4], built by ETEL).

Among these two machine architectures showing the highest growth, the turret-type architecture is progressively adopting the Direct Drive technology for all its motion axes. The following section describes in deeper details this particular architecture, and the associated ETEL S.A. solution.

Turret handler in a nutshell

As shown in Fig.5, the motion's cycle of an IC turret handler is based on three steps, repeated continuously:

1. A rotary (theta) motion to index components loaded on a disc to the next test station
2. A linear (Z) motion to press pick-up heads which load the component to test station (clamp the chip mechanically into a test socket, or move it into vision DOF, or load it into laser marking

station, or release it in a bin, or load the component into the reel...)

3. Dwell time (test time or process time), before re-starting from step 1.

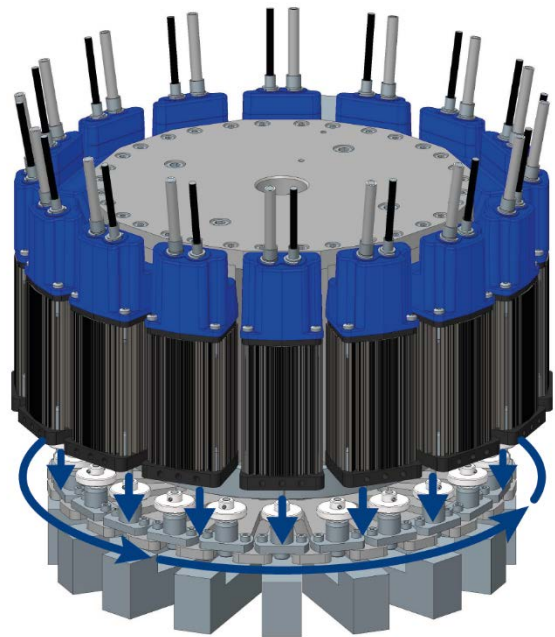


Fig.5 IC turret handler's main carousel.

ETEL S.A. is typically supplying the following core elements on these machines:

- The rotary table for theta motion (RTMBi).
- The Z axis for the Z motion (TMMA).
- The full electronic architecture for the control and synchronization of all axes at high dynamics (AccurET family of products).

Two turret handler types

Among the different IC turret handlers available on the market, two categories can be described as they slightly differ in terms of specifications.

Turret handlers for conventional packages

This category of IC turret handlers tests "basic" electronic components such as discrete components (resistors, diode, capacitor packaged into SOT) or simple ICs. The input format is usually "bulk" from a

bowl feeder or a tray. In output, the tested component is usually loaded into tape through a reel. The main driver for the design of such machines is throughput. Electrical and vision tests are limited to basic checks, allowing a very short component test time. In addition, package robustness allows to handle the chip at maximum speed with limited risk of damage.

Since these handlers are testing the ICs that are still the most popular on the market, they naturally dominate the turret handler market (around 80% of total machines), with a machine-price set according to the throughput.

16 - 20 stations / 18°- 22.5° index angle
Theta Index time: 18 – 20 ms
Down/up Z axis typical move time: 10 ms / 10 ms
Disc inertia: between 0.003 and 0.010 kg.m ²
Test time: 20 – 30 ms
Throughput: 50 – 60 kUPH
Repeatability @ tool point: < 5 µm

Table 1 Typical handlers requirements for conventional packages.

Turret handlers for wafer dies

These IC handlers deal with wafer-level dies and although they share the same cinematic turret mechanism, they have quite different characteristics than IC handlers dealing with conventional packages. The typical tested components on these machines are LED, bare die, and all related ICs built on a wafer-level package. In wafer-level packages, the bare die is processed to have solder balls attached directly to the printed circuit board, removing the need for external casing and wiring, which enables to reduce the footprint. These handlers operate from dies picked from a wafer, right after wafer dicing.

As shown in Fig.4, wafer-level packages are among the ones showing fastest growth on the market, contributing to a steady growth of this handler category over the years.

These handlers have limited throughput because of longer test times and more precaution taken during chip handling (typically around 30 kUPH). The tested components are also more expensive than traditional packages which drive machine makers to focus on yield rather than throughput, implementing high-end optical inspections like 3D topography or infra-red inspection. After inspection, rejected dies are sorted out while good dies are packaged into a tape or reloaded into a reconstructed wafer made of only known good dies (KGD).

Typically 32 stations / 11°- 25° index
Index time: 35 ms
Down/up Z axis move time: 8 ms / 8 ms
Disc inertia: From 0.03/0.05 kg m ² up to 0.35/0.6 kg m ² for biggest disk (700 mm diameter)
Test time: 50 – 100 ms
Throughput: 20 – 30 kUPH
Soft contacting (wafer level)

Table 2 Typical handlers requirements for wafer dies.

Typical ETEL solution

IC turret handlers combine a series of technical challenges on the motion handling part: throughput, accuracy, but also communication time to synchronize the different axes, oscillations at the end of the motion, disturbing frequencies from customer mechanics, etc.

With its global solution (see Fig.6) and its deep market expertise, ETEL S.A. can bring to its customers more than the simple sum of the contributions from a motor and an electronic supplier. ETEL S.A. is the only supplier able to provide a forward integration solution made of rotary

table, Z axes and electronics, in a global approach, integrating the different ETEL products together to reach the best performance. Another step of optimization can then be realized, helping its customers saving the last and hardest milliseconds that allow them to bring a 60 kUPH equipment on the market.

A second advantage relies on ETEL's long market expertise. ETEL S.A. entered this market 15 years ago and has built over the years a unique expertise which brings today the following results:

- Highest product performance thanks to an unique HEIDENHAIN group expertise on all components integrated in ETEL products (encoder, bearings, Direct Drive motors).
- Unique reliability in the field thanks to years of continuous improvement.
- Market knowledge which helps anticipating market needs.
- Field support experience which allows to quickly set a machine equipped with ETEL products to the market's state-of-the-art.



Fig.6 ETEL global solution for IC handler.

The following section describes in details the different parts of ETEL's solution for the turret handler market.

Theta motion with ETEL's RTMBi

Indexing the component by 11.25°, 18° or 20° to bring it to the next test station might look trivial, especially when the required bidirectional repeatability is around +/- 5 µm. To do it in less than 20 ms, with a component at end of the motion idle within few millidegrees, is quite a technical challenge. With its RTMBi range of rotary tables [5], ETEL S.A. has designed a family of products specific to the IC turret handler market. These rotary tables have the highest angular acceleration capability on the market for a given footprint. They combine ETEL's high efficiency torque motors and HEIDENHAIN's high resolution encoder technology in a very compact package.

In a recent demonstration performed by ETEL S.A. at an IC turret handler manufacturer's site, ETEL's RTMBi, driven by AccurET controller, demonstrated 17 msec move time to perform the typical market requirement of 20° index within +/- 5 mdeg at the end of the motion, which is remarkable for the market. These 2 or 3 milliseconds saved on the rotary indexing for a total cycle of around 60 ms typically increase the machine throughput by 5%.

Beside to its pure performance level, with more than 10'000 rotary tables currently operating in the test handler market, ETEL S.A has built over the years an outstanding market expertise and product robustness. Finally, when laser marking operations are integrated into the turret IC handler and load the ambient air with dust and microscopic particles, RTMBi's with elevated protection IP50 instead of IP40 can be utilized.

Z motion with ETEL's TMMA

For the Z motion, the requirement seems trivial as well: pressing down a spring for a few millimeters. But performing this move in less than 10 ms, in a controlled way, at an average of 1 million cycle a day during years of operations raise some significant technical challenges.



Fig.7 ETEL's TMMA short stroke actuator.

ETEL's TMMA short stroke actuators (see Fig.7), direct driven, have been designed especially for this application, where high dynamics and a small footprint are key requirements [6] and [7].

ETEL's TMMA exceeds in many aspects the conventional Z axis solution currently used on the market. This conventional servo cam solution is made of a servomotor coupled with a cam as shown in Fig.8.

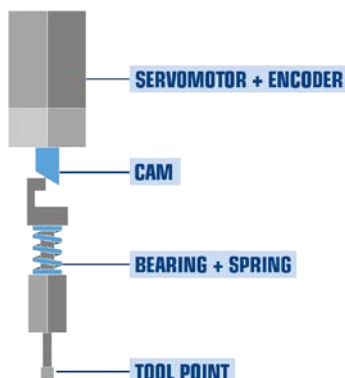


Fig.8 Schematic of the conventional servo cam solution.

This is a "non-direct solution" for lower performance, with all its known limitations (higher friction, backlash, degradation of performance over time, lower dynamics, lower accuracy, wear...). ETEL's TMMA's advantages are described in the next section.

More throughput with TMMA

The TMMA products allow ETEL S.A.'s customers to perform the typical 2.5 mm move in 6.6 ms within +/- 5 µm position window at end of motion. This is a 30% improvement compared to traditional servo cam solution.

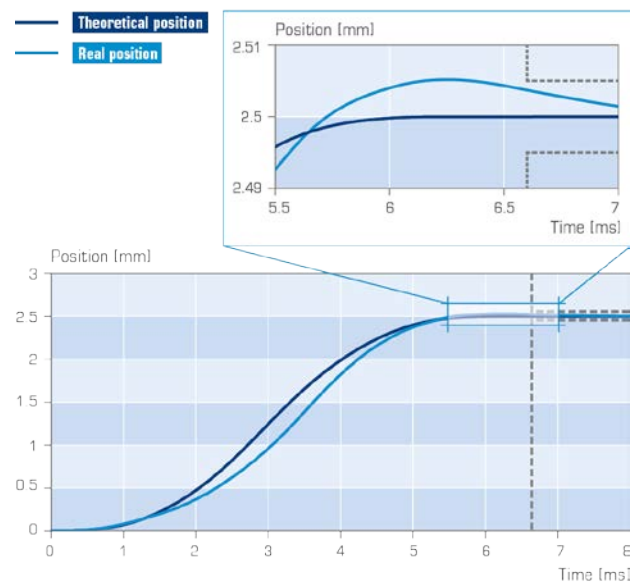


Fig.9 ETEL's TMMA high dynamics.

As shown in Fig.9, the TMMA provides ultra fast move with extremely low tracking error during motion and at landing position.

More care when contacting the component

The use of a servo cam solution for Z actuator does not allow a controlled motion during its full Z trajectory until contacting with the chip, since the position feedback is then located far from the tool point at the back of the servomotor. In addition to this, as the cam is designed for a given motion profile, there is no possibility to adjust/optimize the

motion trajectory in function of the expected touchdown or required contacting softness, resulting in “bumpy” component landing. And finally, with a servo cam solution, since there is no direct position feedback along Z stroke, customers cannot monitor what is happening during Z motion. Settling time at the end of motion is then unknown. How does the customer know when he can safely start its test? Therefore, significant margin has to be accounted for before starting testing the device. This deteriorates significantly the throughput.

These drawbacks are overcome with ETEL’s TMMA solution, which finally provides the capability to optimize trajectory, as well as contact quality with a full monitoring at any time of its Z trajectory.

Faster conversion time

Another advantage of the TMMA solution compared to traditional servo cam solution is its flexibility to adapt to any component to be tested, hence significantly reduce the conversion time. Indeed, with its 10 mm max stroke, the user can easily reconfigure, via software, its Z stroke according to the component position. At the opposite, when using a cam for the Z motion, the cam is machined for a given stroke and motion profile. As a result, any change of component requires a change of the cam or a mechanical re-adjustment.

Transfer axes

In more and more IC handler machines, auxiliary transfer axes are required to load or unload the components from the turret handler. These axes can move a wafer in X and Y position for die picking in input or wafer rebuilt in output with known good dies only. Some new hybrid handlers are also emerging on the market which combine turret handler and pick & place architectures requiring transfer axes to bring the components from the turret to the pick & place

handler. With its wide linear motor portfolio, ETEL S.A. can answer to these needs and size the right set of motors to maintain the given machine throughput.

AccurET motion control

ETEL’s AccurET product family [8] allows to connect and synchronize the different axes of the machine. Its architecture is made of several layers to support the customer in all aspects of its machine control design from dedicated DLL library to position controller and powerful commissioning software.



Fig.10 AccurET position controllers family.

With typically more than 20 axes to control and synchronize, the motion control architecture of an IC turret handler poses numerous challenges. The ETEL’s AccurET and UltimET motion control solutions (see Fig.10) benefit from ETEL’s long experience in IC turret handler market and provides dedicated features to setup the machine. The ETEL’s dual expertise in both motion control and motion systems design allows machine builder to quickly come to a robust and high performing solution.

Among the many advantages of ETEL motion control solution, the following key features that are commonly used by IC machine builders can be highlighted:

- ETEL's EDI library with dedicated DLL created for the specific needs of IC turret handler market.
- ETEL real-time communication TransnET bus @ 1 Gbps for high-speed communication.
- High bandwidth control loop (20 kHz) to reduce settling times.
- Possibility to create an asymmetric move profile to optimize throughput or soft landing during Z motion.
- Various force control modes to ensure a soft landing and a full monitoring of the force during insertion of the components into the test socket (avoid dual stacks phenomenon).
- Identification tools for fine tuning and management of disturbing mechanical frequencies.

Conclusion

Among the different categories of IC handlers available on the market, turret handler is probably the most challenging from a motion control point of view.

ETEL S.A. can propose cutting-edge solutions to cope with the specific requirements linked to this market, such as throughput, accuracy, soft contacting, robustness and immunity to harsh environment. This is made possible thanks to a wide range of ETEL's products, designed according to market needs and built with the highest standards of quality.

With more than 20 years of expertise acquired in this market, an highly qualified staff of ETEL S.A. (available through the worldwide HEIDENHAIN sales network) is partnering with OEM

manufacturers on a daily basis to turn their IC handler into state-of-the-art equipment, within a very short timeframe.

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