Automated Camera Module Assembly in the Automotive Industry

A fully automated solution

Autonomous driving is the way of the future. Driver assistance systems with numerous sensors are already state of the art in today's modern vehicles. It is becoming increasingly important that camera modules provide cars with the power of "human eyesight". Sensor manufacturers, camera integrators and automotive developers are working under great pressure to achieve or even surpass the resolution, field of view, colour perception and dynamics of the human eye with camera modules. At the same time, the transfer of human "sight" to camera modules also means a transfer of responsibility for the safety of the vehicle's passengers and other traffic participants to technology.

The lawmakers are currently working on creating the legal framework for autonomous driving. This means de facto that camera modules will be developing into car systems relevant to safety in the coming years. In addition to the demands on quality, the camera modules must be able to be mass-produced economically for the car manufacturers. This places very high demands on the production lines of such modules.

Various production-line concepts exist for the manufacture of camera modules. Two core processes here are crucial for the product’s subsequent quality: The first is the active alignment and assembling of the optics unit to the sensor unit. The second is the final quality test with calibration of the camera data. Concepts for single-space solutions for predominantly manual assembly of the camera modules and the subsequent final test are widely implemented primarily in Asia and in the mobile-telephone and consumer-camera market segments. In contrast, most of the European production sites of automotive suppliers are equipped with partial and fully automated production lines with the integrated core processes of the currently popular state of the art.

A fully automated solution

A fully automated production line for camera modules starts with the PCB assembly, and includes the fully automated incoming test of critical components,
the cleaning and activation of component surfaces, the application of adhesives, the active alignment and UV attachment, the curing in the oven, the subsequent assembly of the housing parts and ultimately the final quality test and calibration of the camera parameters.

An important feature of the camera module production is that the produced camera module is not passive during "assembly." The activated sensor of the component itself is used to mutually align optics and sensors in sub-micrometer and arc-second resolution.

A multi-axis system is used to align either the optics or the sensor in real time based on test-image data in up to 6 degrees of freedom. High precisions are achieved by using collimators to project test patterns onto the camera module.

These patterns are used at several points in the image to simultaneously compute the image contrast and determine the best image plane location.

Active alignment has become necessary for various reasons: on the one hand, as a result of increased demands on the camera's resolution - car cameras are also technically developing towards 4 megapixel sensors. On the other hand, the smaller aperture of the lens leads to correspondingly smaller depths of field. Passive production processes purely based on mechanical tolerances reach their limits here.

**The production process**
Measurement parameters are collected during the entire production process. This begins with the tests of the individual parts (sensors, optics) before they are assembled and continues to the ejection of defective parts. Tests then follow after the assembling for process monitoring and finally, an end-of-line test for ensuring consistent quality and/or for calibrating the camera parameters. The following parameters are recorded for this:

- The optical properties (e.g. distortion, focal length, relative illumination, image quality, MTF)
- The opto-mechanical properties (e.g. alignment of the optics to the sensor, focussing, angle of view, roll angle)
- The opto-electrical properties (e.g. linearity, signal-to-noise behaviour, dynamic range, colour reproduction)

One or another of the parameters are required, depending on the application in the automobile. For example, the calibration of the distortion and relative illumination is important for the wide-angle rear view cameras, while, in contrast, the uniform MTF and the mutual alignment of the cameras takes centre stage for the stereo cameras used to record distance information.

In the manufacturing process, the measuring technology must be selected in a way that enables reproducible, absolutely comparable measurement results. Camera modules in the car (with the exception of the rear view camera) do not produce any images in the actual sense, but rather data and key figures for the on-board electronics.

A major challenge is translating requirements on driver assistance systems such as "the double-line street marking must be reliably distinguished from the dashed line street marking in all lighting situations and for all conceivable curve radii" into measurement parameters such as MTF (modulation transfer function), OECF (optical electronic conversion function), distortion, etc.

These system requirements on the measurement parameters must not only be carried down to the camera module but also broken down into the parameters of the individual parts. The measuring technology must be able to continuously measure the different components along the entire supplier chain.

**High efficiency**

Measurement precision and the traceability of measurements to international standards is becoming more and more important in the context of "safety relevance". Since driver assistance components will become standard in cars of all price segments in the future, economical production for the mass market must be
ensured. For this reason, concrete production costs per camera module play a major role. An important key figure here is the UPH (units per hour) data of a production line. The time-intensive work steps in the process must be identified to estimate the cycle-time problems of a system. In fully automated production systems, all single processes are generally run in parallel. The "bottleneck" process is the active alignment, which is connected with UV attachment process step. Active alignment involves several processes which are relevant for the cycle time: the supply of the optics to the sensor, the sensor initialisation, the image rate, the determination of the image position - typically carried out by a focusing procedure - the actual alignment of the 6 axes and the final UV attachment. The current state of the art is 15-20s cycle time for this process, whereby doubling of this process by parallel operation is possible but does not necessarily improve the key figure Euro/UPH. The properties of the adhesive (UV bonding time) and the specimen itself (sensor initialisation, image rate) have a great impact on the cycle time in addition to the process itself. The next generation of camera production systems will enable drastically reduce cycle times due to optimised automation and new measurement technologies. In this process, the camera-production lines will directly interlink the production with the system calibration, ensure the traceability of the production and measurement results and provide these to software algorithms of the driver assistance system as a data base – completely in line with Industry 4.0.

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