# Dual Camera Technology with Mediatek

**MediaTek White Paper**

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# Introduction

Human beings, like other creatures with forward-facing eyes, explore the real world with the benefit of stereo vision. Monoscopic vision provides images from only one eye, while stereoscopic vision simultaneously obtains image information from two different points of view. Although the two-eye views have plenty in common, each eye obtains some visual information the other doesn't, and the additional information allows the brain to yield depth perception. Inspired by the natural binocular vision, the MediaTek dual camera system is designed to capture stereoscopic images simultaneously and retrieve the lost information of a single camera.

**Dual camera technology** encompasses a wide range of imaging system and vision analysis research and development. Imaging systems, like two eyes, synchronize the dual sensors to capture stereo images. Stereo-vision analysis plays a similar role as that of the human brain, which retrieves perceptual information via complex computational processing. By comparing image content from two vantage points, depth information can be extracted by the examination of the relative positions of objects in the two panels, known as stereopsis.

MediaTek Native 3D architecture has steadily improved, as shown in Figure 1 and Table 1 . The Mediatek smartphone SoC MT6575 is the first generation that supports a dual camera solution. More particularly, the IC consists of a camera interface for dual camera sensor input connected to Image Signal Processing (ISP) block, and integrates the Sensor Synchronization module. In addition, an embedded rectification module is designed to compensate the geometry relationship of the stereo camera system. The main limitations of MT6575/77 include identical symmetric YUV sensors and fixed-focus camera module.

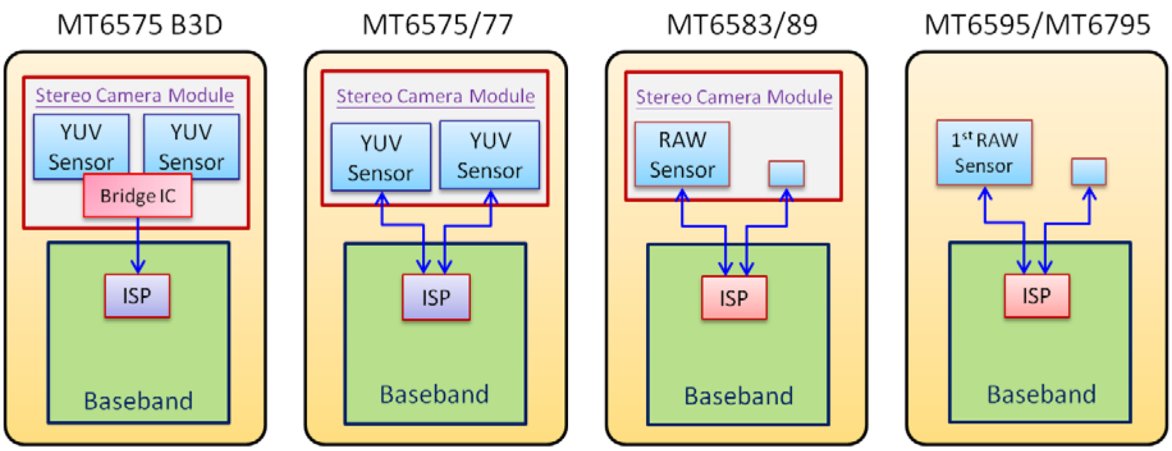



***Figure 1. Native 3D Technology Architecture within MediaTek ICs***

***Table 1. Mediatek N3D Solutions***

| | MT6575/77 | MT6583/89 | MT6595 |
|---|---|---|---|
| **Spotlight** | - First non-bridge N3D<br>- Online rectification (2D)<br>- Support 3rd party solution | - Asymmetric dual sensors<br>- Support raw sensors<br>- One-shot calibration<br>- Photometric correction | - Two single camera module<br>- Self-learning calibration<br>- Different FOV<br>- Autofocus |
| **Limitations** | - Symmetric YUV sensors<br>- Fixed focus | - Similar FOV<br>- Fixed focus | |

MT6583/89 N3D further supports asymmetric dual sensors, which generally contain a main camera, composed of a lens module of higher resolution, e.g. 8 megapixel sensor, and an auxiliary camera of a lower resolution, e.g. 2 megapixel sensor. This version starts to support raw sensors. More particularly, we take advantage of the ISP block to process the input raw images, and apply the MediaTek stereoscopic 3A algorithm and control as well. The advantage of supporting raw sensors is for both cost considerations and better 3D image quality. For mass production of the asymmetric dual sensor, Mediatek proposes and develops an IP of a one-shot calibration system in the Module Houses (production plant). To overcome the problem differing color responses from the two distinct sensors, we explored performing photometric correction. Details of these newly developed techniques are illustrated in the later sections.

MT6595/MT6795 N3D supports a two single-camera module, self-learning calibration, different fields of view (FOV), and autofocus. The two single-camera module eliminates the need for stereo camera module, requiring only two separate single-lens modules. This evolution makes the dual camera system more suitable for mass production, with a reduction in costs and manufacturing complexity, and at the same offers higher yield rates. MT6595/MT6795 supports different FOV, that is, the content of main camera can be covered by the auxiliary camera by selecting the wider FOV lens, so that the main camera obtains additional information from the auxiliary camera.

In addition, MT6595/MT6795 supports both autofocus lens and a leading technique of self-learning algorithm for stereo camera calibration in the change of focus positions. Integrated with the autofocus process, the additional depth information achieves a fast autofocus mechanism that overcomes many challenging problems in conventional AF algorithms based on analysis of image contrast.

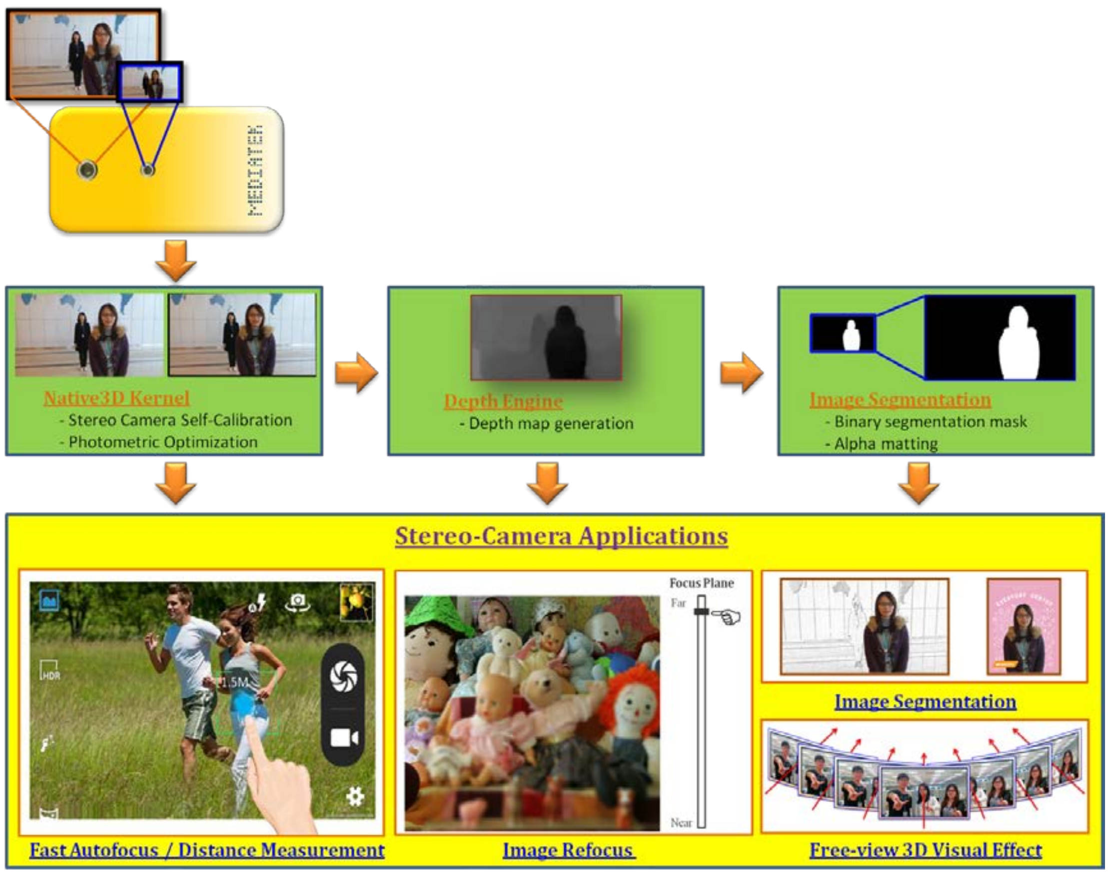



***Figure 2. Stereo Camera Application System Overview***

The stereo camera applications flow diagram is shown above in Figure 2 above. In the top raw, the dual camera takes the stereo image from the asymmetric dual sensors. In the middle raw, the three blocks represent the algorithm cores, which handle the stereo camera calibration, depth estimation, and image segmentation, respectively. The Native 3D kernel performs the stereo image processing, including the self camera calibration and photometric optimization. The Depth Engine subsequently generates the depth map from the calibrated stereo image pair. The Image Segmentation kernel separates the foreground object from the background scene. In the bottom raw, we demonstrate several representative applications based on the stereo camera system, including fast autofocus, distance measurement, image refocus, image segmentation, and free-view 3D visual effect.

# MediaTek's Innovation

Mediatek has developed the dual camera technology based on the foundation of native ISP architecture and heterogeneous computation units on the ICs. Our cost effective dual-camera technology offers both high quality and mass production efficiencies. From the cost effectiveness perspective, adopting asymmetric dual sensors for the stereo camera is an obvious choice. The main camera can adopt the mainstream high-resolution sensor, such as 5, 8, 13 megapixels sensors currently available in the smartphone market. And the required stereo image resolution stays in 1080P (i.e. two 1920 x1080 image frames), so that a 1080P sensor for auxiliary camera is sufficient to satisfy the HD (high-definition) specification in 3D. In this way, the camera feature is fully compatible with the original single camera design, and the added second camera can provide the 3D information.

In addition to cost effectiveness, we achieve the other two design targets-- high quality and mass production capability. For quality consideration, we have to face the essential challenging problems of asymmetric dual sensors. The main challenges of asymmetric dual sensors are synchronization, different color response and geometry.

## Sensor Synchronization

The stereo camera requires the two sensors imaging simultaneously. The two non-identical sensors have unequal frame rate. To solve this fundamental problem, our Native 3D design includes a hardware module to synchronize the two sensors.

## Sensor Characteristics

The two different sensors have different size, lens module, and sensor response which reflect on color response, lens shading, signal-to-noise level, leading to two distinct images. Figure 3 shows an example of a real case of the stereo images from an 8M sensor and a 2M sensor. We can see a totally different sensor response to the two images. The Native 3D solution to this issue comprises two mechanisms, photometric optimization and stereo 3A (i.e. Auto exposure, Auto white balance, and Auto-focus) control. Stereo 3A is an active control mechanism to make the image pair as similar as possible to the sensor response through digital 3A statistics, while photometric optimization compensates the inevitable error in the post-processing step.

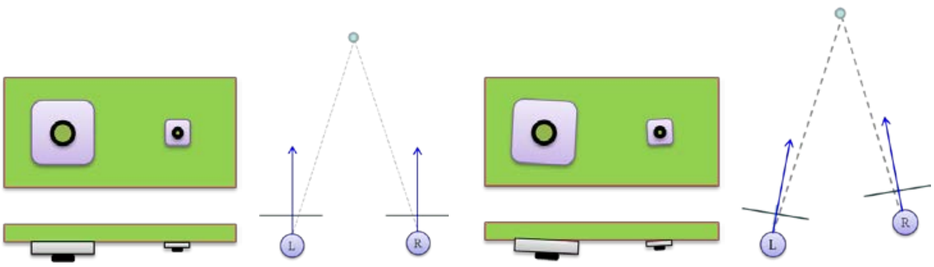

(a) Stereo Image input (b) Image registration between two images

(c) Rectified image pair (d) After color correction

***Figure 3. Problems of Asymmetric Dual Sensors***

## Stereo Geometry

The combination of asymmetric dual sensors results in these two camera modules of different sizes, different lens module, and different module height. Figure 4 shows the ideal and actual case of stereo geometry, and the bias violates the specific geometric relationship in the image space (refer to Figure 3 (b) above as an example). This stereo module assembly error is always inevitable, and the process to correct the error is known as stereo camera calibration.

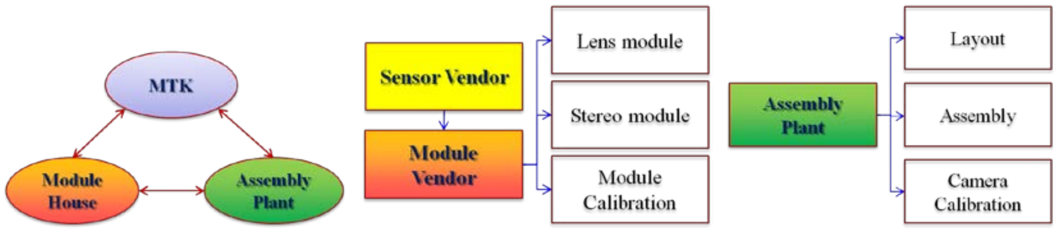



(a) Ideal case (b) Actual Case

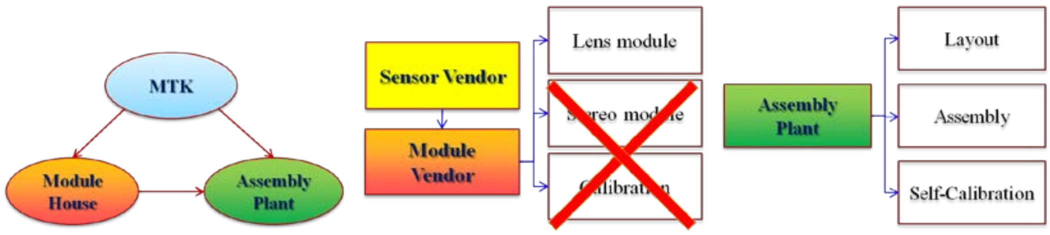
***Figure 4. Stereo Geometry of Asymmetric Dual Sensors***

# Conventional Production Process

The conventional stereo camera calibration process, shown in Figure 5 (a) below, captures the image of a Mediatek designed calibration chart and determines the calibration parameters through the known geometry constraints from the chart. The Module House performs the stereo camera calibration procedures and stores the calibration parameters for later image correction. After camera assembly, the camera device has to run an image warping program according to the calibration parameters to obtain the calibrated stereo images. However, in practice, there exist vendor issues between the three sites, i.e. solution provider (i.e. MediaTek in this case), a Module House, and an Assembly House.  In theory, in this collaboration model the geometry relationship of the stereo module would remain the same before and after assembly. However maintaining the geometry relationship is unrealistic in real production process. In the assembly process an operator has to force the stereo module to fit into the fixture, which violates the geometry consistency. Intuitively, a better way to solve this problem is to perform stereo camera calibration after the assembly process. However, the conventional process not only involves tedious labor effort and longer process, but it also complicates the issues of yield rate between Module House and Assembly plant.




(a) Conventional Production Process




(b) MediaTek Production Process

***Figure 5. Vendor Issues for Mass Production***

# MediaTek's Innovative Production Process

Mediatek's innovative methodology resolves the vendor issues and enhances productivity. As shown in Figure 5 (b), the three-site collaboration turns from double-arrow flow to single-arrow flow, a streamlined unidirectional flow.

This production process differs from the conventional process in three ways. First, the Module Houses take charge of providing two single-camera modules, instead of a stereo module. Second, both the Module House and Assembly plant omit the stereo camera calibration process, which not only results in less labor and time requirements, and offers a higher yield rate. Last and most important, the key assumption of the geometry consistency process before and after assembly can be resolved. Importantly, we develop a self-calibration algorithm embedded with the ISP block, based on cutting-edge vision and learning techniques. In addition to improvement in mass production, the solution possesses advantage of flexibility to resource of computing units on the platform, including ISP, Codec, CPU, and GPU. In addition, the self-calibration is robust enough to changed stereo geometry due to an accidental drop or other external force.

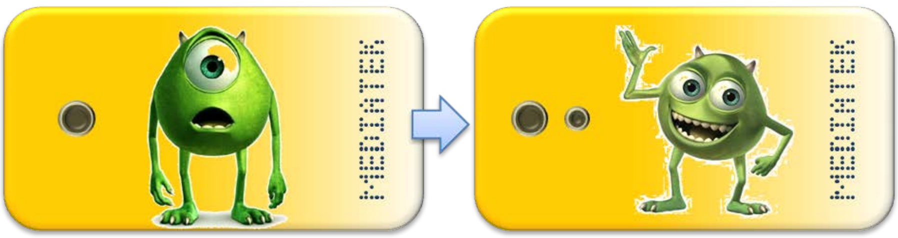



***Figure 6. Monoscopic Vision Evolves to Stereoscopic Vision***

# Conclusion

Beyond the fundamental building blocks of the dual camera technology, MediaTek provides excellent service to business partners and potential customers. Our reference design includes

- Layout design
- Sensor interface ( MIPI / Parallel / I2C )
- Camera sensor specification and combination
- Camera lens specification
- API ( Application Programming Interface ) to embedded core algorithms
- 3D media data processing, storage, transmission
- 2D/3D display support
- Stereo camera calibration and verification tools

Dual camera technology builds the foundations of stereo vision on the Mediatek SoC with competitive cost, high quality, and ease of mass production. The evolution from single camera (i.e. monoscopic vision ) to dual camera (i.e. stereoscopic vision) not only pursues the nature of stereo vision to explore, recognize, and interact with the real world, but opens up many potential opportunities to create valuable stereo/3D applications