Integrated Camera Solution

KAWAGUCHI Hiroshi, TAKAMI Kazuhiko, SUGIYAMA Mikio

Abstract
We have compiled the set of items required for incorporating a camera module in the cellular phone, including the hardware, software, services and know-how, into a “camera integration solution” and are now offering it for the final products manufacturers and device manufacturers in the cellular phone market.

This paper describes the development of the integration solution and introduces the CE130 camera engine for cellular phone use featuring high print quality and a 5M-pixel camera module incorporating the CE130.

Keywords
cellular phone with built-in camera, integration solution, camera engine, camera module, 5M-pixel

1. Introduction
The costs and schedule for development of cellular phone have been increasing rapidly recently due to the complexity of services, diversification of end users’ tastes and the increasing sophistication of products. In addition, the trends of reduction of product lifecycles and strong pressure for price reduction due to severe competition have made a critical issue of how to efficiently develop competitive and highly functional products at the lowest cost and shortest period as possible.

Nevertheless, since it is hard to develop all of the required software and hardware within the company or to manage the information on competitors’ products and software that are being enhanced every day, the demand for solutions that enable development of highly functional products at low cost and in a short period by allowing limited resources to be concentrated in critically competitive areas has become very high among the final product and device manufacturers.

When a cellular phone manufacturer wishes to incorporate a camera function into a cellular terminal, it had previously been necessary for the manufacturer to procure each of the required parts and functions, such as the lens, sensor and LSI, from different vendors. However, it was a high hurdle for a cellular phone manufacture to introduce camera parts that they were not specialized in, and it has been difficult for them to release products that truly matched market needs.

To solve the problems described above, we extracted all of the element technologies required for implementing the camera function and compiled them together with the operation verification service into a product being marketed under the name of “System Technology Platform (STP).”

This paper is intended to introduce our camera engine (CE130) for cellular phone use and the 5M-pixel camera module incorporating the camera engine.

2. Development of Camera Engine (CE130) for Cellular Phone Use Featuring High Print Quality
We developed an image processing camera engine (CE130) with up to 5M-pixel capability for use in cellular phones (Photo 1).

The CE130 camera engine is offered together with all of the technology solutions required for development of a cellular phone with built-in camera, including the software determining the picture quality, technology for combination of sensor

Photo 1  Camera engine for cellular phone (CE130).
and lens, technology for design and manufacturing of the module and the system verification platform as well as consulting service.

The CE130 camera engine and the solution allows cellular phone product manufacturers to shorten the development period of a cellular phone incorporating a high-quality 5M-pixel camera by about 1/3 compared to the previous period and concentrate on development of technologies that may lead to the superiority of their final products, so they can develop strategic final products at lower cost and launch them into the market earlier. Meanwhile, the CE130 also allows cellular phone users to shoot pictures that offer high picture quality comparable to digital still cameras when they are printed, using their cellular phone terminals.

The main features of the CE130 are as follows.

1. **Shooting 5M Pixel Pictures with the Top Class Quality among Cellular Phone Cameras**
   
   This device makes it possible the shooting and storage of pictures up to 5M pixels. This technology allows a small cellular phone terminal to shoot pictures that can be printed with equivalent quality than digital still cameras.

2. **Versatile Functions for Picture Quality Equivalent to Digital Still Cameras**
   
   The CE130 incorporates functions that are indispensable for the shooting of high-quality pictures such as flash control, image stabilization, noise correction, image magnification, image rotation and JPEG compression. This makes a cellular phone terminal capable of quality shooting with an ease-of-use that is similar to digital cameras.

3. **Interfaces Enabling Construction of Various Systems**
   
   In addition to the I2C, the serial peripheral interface (SPI) with high-speed data transfer capability is included to enable downloading and execution of external program software. This facilitates the use of various third-party software as well as maintenance operations in case of software problems, and makes control more flexible compared to a cellular phone based on incorporated software. In addition, a high-speed interface for SRAM connection is also provided. These interface technologies allow cellular phone manufacturers to develop cellular phones incorporating camera systems that are optimum for their required specifications.

4. **Platform Implementation of Application Interfaces and Camera Engine for Facilitating Development of Camera Functions**

The camera engine platform is implemented based on the CE130 camera engine and firmware developed to be used in combination with it. This allows final product manufacturers to develop cellular phone products easily by using the same command interface even when the sensor or lens is changed or a new camera engine is adopted, except for when introducing new functions.

- Establishment of API specification
  
  This abstraction layer offers to the customer an independent set of functions using the LSI specifications.
- Interface abstracting the H/W driver
  
  The driver layer that reduces effects of LSI change in the firmware layer.

**Fig.** shows the outline of CE130 platform and **Table 1** shows its main specifications.

The function blocks and interface layer are separated from the CE130 firmware.

1. Command layer
   
   This layer interprets and controls the commands exchanged with the system software.
2. Function control layer
   
   This layer implements the shooting and communication functions.
3. Optical control/image function
   
   This layer turns the shooting functions into function blocks. Optical Control: Optical quality adjustment; AF/AE/AWB,...
   
   Image Function: Image I/O control, image stabilization, JPEG, etc.
4. Driver
   
   Drivers of the camera engine (LSI), sensor, lens, communication, etc.

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**I2C**: Stands for Inter Integrated Circuit. This is a serial bus proposed by Philips. It uses two signal lines for interfacing of information between devices that are located relatively close to each other.

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**Fig.** Outline of CE130 platform.
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We grouped the hardware required for cellular phone, including the image processor engine (CE130), CMOS sensor, lens, autofocusing mechanism, shutter and flash memory, and the set of software for controlling the hardware into a single module, adjusted them so that they can operated under optimum conditions and developed a camera module product.

As this module allows the cellular phone terminal manufacturers to save the effort of separately procuring individual parts such as lens and sensor, and adjusting the parts into optimum conditions, even a manufacturer without camera experience can easily produce a cellular phone product incorporating a high-function camera with 5M-pixel resolution comparable to digital still cameras.

(1) 5M-Pixel Camera Module with Top-Class Picture Quality among Cellular Phone Cameras
The developed 5M-pixel camera module (Photo 2) achieves top-class resolution among cellular phone cameras.
It employs a 5M-pixel CMOS sensor and a lens unit with autofocusing and shutter mechanisms. It can capture images of quality equivalent to digital still cameras by controlling the CE130 image processor LSI using the firmware stored in the flash memory.

(2) Versatile Functions for Picture Quality Equivalent to Digital Still Cameras
The camera module incorporates functions that are indispensable for the shooting and printing of high-quality pictures such as flash control, noise correction, image magnification, image rotation and JPEG compression as well as image stabilization (optional).
This makes it possible to provide a cellular phone terminal with ease of use equivalent to digital cameras and advanced picture shooting capabilities.

(3) Verification Platform for Verifying the Connection with Phone Terminal
We developed a verification platform for use in verification of the camera module operations, making possible system verification even when the main body of the cellular phone system is not available.
- Verification of hardware level functions and image processor system LSI.
- Verification of camera module functions, development of application interfaces and development of firmware.
- Picture quality tuning.

(4) Means of Evaluation of Picture Quality Equivalent to Digital Still Cameras
We asked professional photographers to evaluate the picture quality of the camera module.
- Collection and characteristic evaluation of basic data including brightness, saturation, hue error, lens and noise.
- Actual shooting in various situations for evaluation of tendencies and properties.

Table 2 shows main specifications of 5M-pixel camera module.

Table 1: Main specifications of CE130.

<table>
<thead>
<tr>
<th>Items</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>10 × 10 × 142mm 277pin BGA</td>
</tr>
<tr>
<td>Sensor</td>
<td>Max. 5M-pixel, 12bit, primary color RGB Bayer sensor</td>
</tr>
<tr>
<td>Optical sync control</td>
<td>Iris, mechanical shutter, flash, LED, AF and optical zooming</td>
</tr>
<tr>
<td>Optical correction circuits</td>
<td>Aberration correction, damage correction, smear reduction</td>
</tr>
<tr>
<td>Image processing circuits</td>
<td>White balance, AE, AF, gamma, black level correction, dark noise correction, sharpening, smoothening, YCC color processing, magnification/reduction data blending, rotation</td>
</tr>
<tr>
<td>Memory I/F</td>
<td>M-SDRAM</td>
</tr>
<tr>
<td>Host I/F</td>
<td>I2C, SPI, SRAM</td>
</tr>
<tr>
<td>YCC Out</td>
<td>YCC(4:2:2 16bit/8bit) / RGB(18bit/16bit)/JPEG</td>
</tr>
<tr>
<td>I/O</td>
<td>GPIO*, 64 lines</td>
</tr>
<tr>
<td>Other</td>
<td>JPEG Enc built in</td>
</tr>
</tbody>
</table>

*GPIO: Stands for General Purpose Input/Output Port.
Using the image processor system LSI (CE130) and the 5M-pixel camera module described above, we will propose camera integration solutions to final product and device manufacturers developing cellular phones. At the same time, we will also develop more advanced image processor system LSIs and system technology platforms by anticipating future market needs.

### 4. Conclusion

#### Authors’ Profiles

KAWAGUCHI Hiroshi  
Project Manager,  
Device SI Division,  
NEC Electronics Corporation

TAKAMI Kazuhiko  
Team Manager,  
Device SI Division,  
NEC Electronics Corporation

SUGIYAMA Mikio  
Team Manager,  
Device SI Division,  
NEC Electronics Corporation

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**Table 2 Specifications of 5M-pixel camera module.**

<table>
<thead>
<tr>
<th>Items</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor</td>
<td>1/2.5 inch, 5M-pixel compatible CMOS sensor</td>
</tr>
<tr>
<td>Max. pixels</td>
<td>5.51 million pixels</td>
</tr>
<tr>
<td>Effective pixels</td>
<td>2,544(H) × 1,908(V)</td>
</tr>
<tr>
<td>Effective area</td>
<td>5.7mm(H) × 4.3mm(V)</td>
</tr>
<tr>
<td>Pixel size</td>
<td>2.2µm(H) × 2.2µm(V)</td>
</tr>
<tr>
<td>Filter layout</td>
<td>RGB primary color, Bayer arrangement</td>
</tr>
<tr>
<td>Frame rate</td>
<td>VGA 30 fps (in monitor mode)</td>
</tr>
<tr>
<td>Host interfaces</td>
<td>I2C: Bus format standard I2C, max. 400kbps</td>
</tr>
<tr>
<td></td>
<td>SPI: Serial I/F, max. 66Mbps in slave mode</td>
</tr>
<tr>
<td>Supply voltage</td>
<td>1.8V, 2.8V, VCC host (I/O), VBAT (for motor drive)</td>
</tr>
<tr>
<td>Optical</td>
<td>Lens configuration: 4 components (plastic &amp; glass)</td>
</tr>
<tr>
<td>specifications</td>
<td>Optical lenses F-number: F2.8 / F5.6</td>
</tr>
<tr>
<td></td>
<td>Focal distance: 6.77mm</td>
</tr>
<tr>
<td></td>
<td>Shutter: Mechanical shutter</td>
</tr>
<tr>
<td></td>
<td>Focusing method: Stepping motor</td>
</tr>
</tbody>
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