X2000's Three CPUs

1. Overview

Released by Ingenic, the X2000 is an SoC that unveils the CPU core XBurst2. Among the core's features are its heterogeneous tri-core architecture, built-in Gigabit Ethernet interface which is compliant with IEEE1588-2002, capacity to connect 3 cameras simultaneously, low power consumption, and etc.

The X2000 can be configured to work in 3 cores mode : 2 logical cores based in XBurst2 and one Burst0 core. Such a heterogeneous architecture provides a solid technological basis for multi-app applications. This article illustrates the structure of the heterogenous tri-core, as well as demonstrates the strength of the three CPUs in an application scenario.

2. X2000's Three Cores

In addition to a VPU (Video Processing Unit) and two ISPs (Image Signal Processor) inside, the X2000 incorporates an XBurst2, configured as 2 logical cores, and an XBurst0 core.

The main CPU core – SMT based dual cores

As of 2021, XBurst2 is the newest member of Ingenic's CPU core family. Its features include:

- An operating frequency at 1.2GHz
- An architecture based on 32-bit MIPS32 ISA R5 and MSA128 which is a MIPS SIMD instruction set extension
- An Ingenic ISA extension of 128bit SIMD: MXA128
- SMT (Simultaneous Multi-Threading) based logical dual cores, ensuring better cooperation between them and thus a better power-efficiency
- L1 32KB Instruction Cache and 32KB Data Cache
- A Floating Point Unit and Programmable Memory Management Unit
- L2 512KB Cache
- Advanced power management mechanism which features in shutting down the clock supply to idle blocks

A secondary core -- XBurst0

The secondary core XBurst0 features:

- A working frequency at 240MHz
- A TCSM (Tightly Coupled Sharing Memory) of 32KB, which can be accessed by the main CPU core, DMA as well as the secondary CPU core.

The relationship of the three CPUs and the resources

Multiple resources are incorporated in an X2000 SoC. Their relations with the CPUs cores, which are shown in figure 1, are the hardware basis for X2000's multi-app applications.

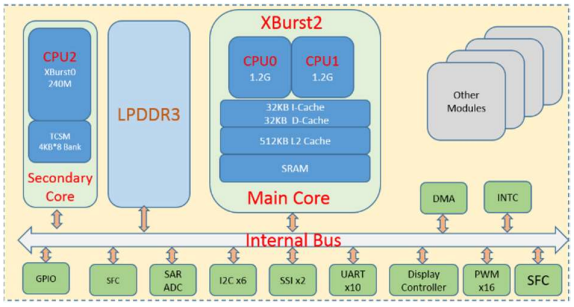

Figure 1: The Relations among CPUs and Other Resources

3. Scenarios to take advantage of X2000's cores

Given the 3 built-in cores and the related resources, as depicted in figure 1, the X2000 can assist in solving three kinds of multi-app applications.

【Scenario 1: the secondary core assists in computing】

With the use of the mechanisms DMA and interrupt, the main cores can allocate tasks to the secondary core, as shown in the following procedure:

① The main cores transfer the information about the LPDDR space containing the executable codes and related data as well as the information about the address space to the secondary core.

② The secondary core undertakes the task accordingly.

③ The secondary core hands in the result to the main cores.

For the assisting role to be undertook competitively, the task in question should have such characteristics:

- ✓ No floating point calculation is involved, since the secondary core has no FPU.
- ✓ The instructions and/or the data to be processed are randomly located in LPDDR, which means that the caches of the main cores have no advantages.

As an example, the image binarization of the puppy in figure 2 involves data that is not stored in a successive memory space and thus is an ideal task to be assisted by the secondary core.

Figure 2: Object Image Binarization. If in the format of NV12, the image data are not successively stored.

【Scenario 2: the secondary core and some peripheral interfaces work together to produce a specific port】

In some applications, additional interfaces can be produced by the secondary core together with the general purpose I/O. For instance, an additional I2C can be defined. This type of flexibility can prove useful in specific application scenarios.

【Scenario 3: the secondary core acts as a real-time control agent】

In some applications, certain external events demand real-time, or say predictable responses, which is a challenge for the main cores running Linux or other OS. In such cases, the secondary core can act as a real-time control agent, receiving data from and sending control commands to external devices in a predictable way.

The Cloud Thermal Printer is an application built by an Ingenic's customer with an X2000. The situation involves the Scenario 2 and Scenario 3 simultaneously which will be explained more thoroughly in the following section.

4. A typical multi-app application of X2000 – the Cloud Thermal Printer

The Cloud Thermal Printer is a typical case for the multi-app application of X2000.

Specifications of the Cloud Thermal Printer

- The control of the thermal printing head: the control of motor, the control of heating, the overheat detection and prevention, the paper and paper jam monitoring; a printing speed up to 123mm/s
- Operating System and software: open source Linux4.4, SDK for multi-app applications and other driver software
- Connectivity: Wi-Fi, Bluetooth, Ethernet, USB, UART; Configuration over Wi-Fi; upgrading over the air
- Input: keypad, touch screen, camera
- Output: LCD, voice
- Standards supported: Internet Printing Protocol, Common UNIX Printing System
- QR code reading(optional): QR code reading & producing which can be included to build QR reading and thermal printing in one device
- Decoding: PDF and JPG, thus less demanding for network capacity

The hardware solution of the Cloud Thermal Printer

The hardware solution of the Cloud Thermal Printer is illustrated in Figure 3. Thanks to the highly integrated architecture of X2000, the solution is concise.

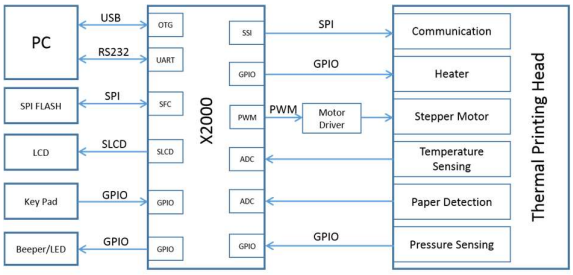

Figure 3: The Hardware Solution of the Cloud Printer

The software solution of the Cloud Thermal Printer

The software solution of the Cloud Thermal Printer is illustrated in Figure 4.

The software solution consists of the Operating System, SDK package, service software package for application development and specific printer modules. The Cross Cores and DMA in the SDK package facilitate the coordination between the main and secondary cores while the OpenAMP module provides the API to develop applications.

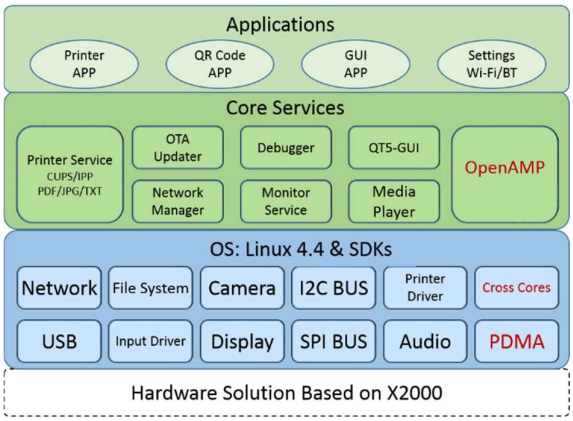

Figure 4: The Software Solution of the Cloud Thermal Printer

Tasks preformed by main and secondary cores

Tasks of the main cores

- Managing all the resources in the SoC
- Running the Linux
- Receiving the printing and QR reading tasks
- Data Processing and computing
- Allocating printing tasks to the secondary core through DMA

Tasks of the secondary core

- Monitoring the status of the printing head
- Coordinating the printing and data preparing tasks
- Communicating with the printing head and feeding the data to it

5. Conclusions

The heterogeneous multi-core architecture of an X2000 is a solid base for building multi-app applications incorporating computing and real-time control, thus many more AIoT application can be covered.

With built-in multi cores, a LPDDR up to 256Mbyte, dual Gigabit Ethernet ports, three camera ports and types of connectivity, X2000 is a sound choice to build AIoT applications upon.