WHITE PAPER

TEXAS INSTRUMENTS

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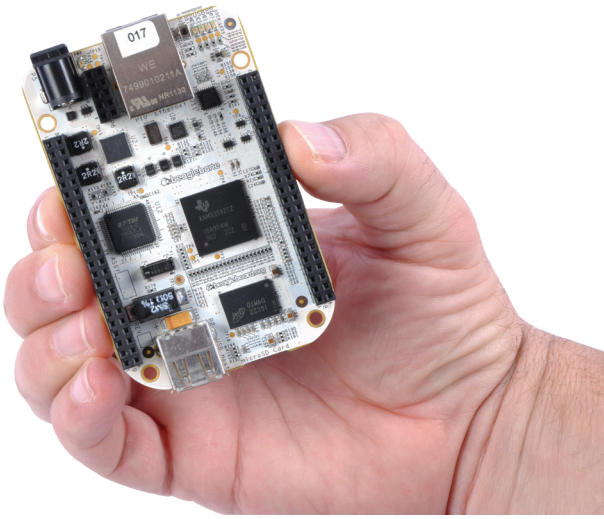
BeagleBone low-cost development board provides a clear path to open-source resources

Introduction

The rapid advancement of open-source software has pointed out the need for open-source hardware. Open-source hardware platforms, such as those offered by BeagleBoard.org, give developers and hobbyists the robust open-source resources they need to deliver new products to the marketplace quickly and, at the same time, reduce their risks. As a flexible and extensible open hardware development platform, BeagleBone from BeagleBoard.org can effectively facilitate a development team's transition into the open-source world. For those who already participate in the open-source community, BeagleBone can function as a stable, readily available development platform fully supported by the diverse universe of open-source resources as well as the reputable support system of BeagleBoard.org.

What is BeagleBone?

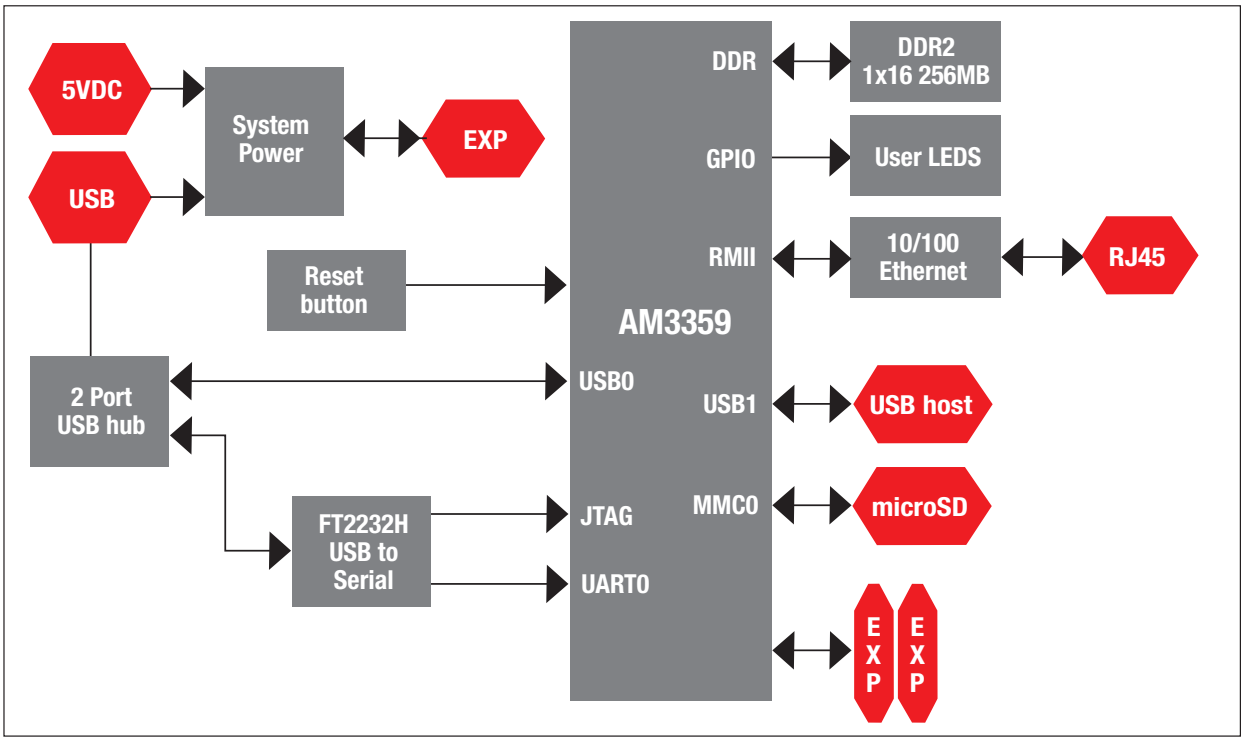
BeagleBone, based on Texas Instruments (TI) Sitara™ AM335x ARM® Cortex™-A8 processor, is a ready-to-use open-source hardware platform for rapid prototyping and firmware and software development. The low-cost BeagleBone follows on the heels of BeagleBoard.org's successful BeagleBoard platform addressing mid-range and upper-end applications such as wirelessly networked autonomous robots, self-teaching electronics education kits, intelligent digital signage, flexible retro-gaming devices, home automation and much more. BeagleBone is a professional grade development platform suitable for professional engineers, designers and developers as well as hobbyists.



BeagleBone is well suited for various mobile systems, robotics applications, web servers, Internet-enabled kiosks, media centers, home automation applications, thin clients, digital signage and many other types of low- and mid-range embedded applications. The ARM Cortex-A8 core runs at 720 MHz and features 3D acceleration with the SGX programmable graphics processing unit.

In addition to the highly optimized processor, BeagleBone also features 256 megabytes (MB) of DDR2 RAM memory, a microSD slot and a four-gigabyte (GB) microSD card with a validation and demonstration image of Linux built using the Angstrom Distribution. In addition to executing the Linux kernel, many complete operating and development environments are supported by community and third-party developers, such as Android™, OpenEmbedded, Windows® Embedded, QNX, Ubuntu, Symbian, Debian, Fedora, Gentoo, FreeBSD and others.

To accommodate a range of sensors, controls, and other types of inputs, it has two 46-pin expansion headers featuring 66 general purpose interrupt generating input/output (GPIO) pins at 3.3V and multiplexed with LCD signals, a parallel memory bus, secondary MMC/SD/SDIO



▲ ***Fig. 1*** *– BeagleBone block diagram*

Features	Benefits
More than 1,400 Dhrystone MIPS using TI's superscalar AM335x ARM Cortex-A8 microprocessors	Runs full Linux operating system with full-featured web servers, native compilers and scripting languages, video analytics libraries and much more
Two 46-pin, two-row, 0.1" spaced female expansion headers	Enables developers easily add off-the-shelf expansion hardware or directly breadboard connections to countless readily available peripherals
Multipurpose USB device connection with on-board hub, USB-to-serial/JTAG conversion device with software reset and reprogrammable high-speed USB device interface	Developers can plug in just one cable to power, debug and interface to their applications and not needing a JTAG emulator saves additional cost
Open GL® ES 2.0 capable 3D graphics accelerator	Achieves photo-realistic, real-time pixel-shaded graphics for gaming and 3D user interface acceleration
USB 2.0 host port that support low, full and high speeds	Can be used for USB peripherals like keyboard, mouse, WiFi, *Bluetooth*®, Web cameras or USB hubs for additional expansion via on-chip USB PHY
microSD connector	Adds multiple gigabytes of storage for your boot image and data and includes a 4GB card.
On-chip 10/100Mbit Ethernet	Network your network and the Internet with minimal software stacks
Four on-board LEDs	Provide user status

▲ ***Table 1*** *– BeagleBone key features*

bus, two I²C buses, five UARTs, an SPI serial port, an I2S/AC97-capable serial port, CAN bus, 6 pulse-width modulators, multiple timers/counters and more digital peripherals in addition to 7 analog-to-digital convertors. One USB cable provides both power and access to the BeagleBone. Through this one USB cable, users are able to access the processor's USB, Serial and JTAG ports. Moreover, BeagleBone can be linked to a BeagleBoard or any Linux computer via USB or Ethernet and act as an expansion module to it.

BeagleBone and open-Source

As BeagleBoard did before it, BeagleBone has shown that the vast resources of the open-source community and the support of a major technology developer are not mutually exclusive. In fact, taken together the two complement each other effectively and benefit developers and hobbyists who are then able to take advantage of the best of both worlds.

An example of a possible BeagleBone user would be a hobbyist, developer or design team that has based their past projects on microcontrollers (MCU) but is now contemplating a microprocessor-based design. Much of the attraction of the open-source world for such developers comes from the extremely rich software ecosystem that the community represents. For designers looking to leverage a richer set of software, migration can be easy and the performance and software availability far exceed any MCU platform, despite being around MCU prices. With open-source resources at its disposal, the design team can quickly deploy a robust set of development tools, ready-to-use functional drivers and other functional modules, including complete USB host and device stacks, rich networking support with firewalling, quota support, throttling and more.

Designers are attracted to an open-source community because of the vast richness and depth of the resources available. Receiving feedback and sharing ideas with other developers increase the quality and breadth of knowledge that could lead to getting their product to market faster. In cases such as that of an MCU design team migrating to a microprocessor platform, the support of TI with its many resources such as software and the BeagleBone and BeagleBoard platforms can be essential to an effective transition.

For example, an MCU-oriented team might decide that its risks would be reduced if it eases into the open-source world by initially adopting development tools contained in the software development kits (SDK) that support microprocessors platforms. These customers will look for a proven hardware platform, as well as one that can leverage open-source and mainstream software offerings. TI has made investments to ensure that its software SDKs are compatible with not only standard TI hardware, but also open-source tools such as BeagleBone. The real value in these software tools is that TI breaks down the most common operations required by customers and documents the process to execute those operations. TI has completed the hard work of understanding the open-source components for you and has seen an increase of community members utilizing these resources.

Even TI's Code Composer Studio™ integrated development environment (IDE) is built upon the Eclipse project, the most popular open-source graphical debugger and development environment, yet TI has customized it to ease your learning curve into open-source. At this stage, the team can begin to explore the many robust options available to it and learn how to collaborate fully with the open-source community in general. Because of the breadth of the open-source community, a designer can reasonably assume that most problems have been solved in some form or fashion by other members of the community who are willing to share their expertise.

What is BeagleBoard.org?

A small group of enthusiastic engineers interested in creating powerful, open and embedded devices pioneered new ground in open hardware and worked together to launch BeagleBoard, BeagleBoard-xM and most recently BeagleBone. The resulting open-source hardware platforms bridge desktop and embedded development, allowing developers to design to their specification and collaborate with the open-source community on creative new applications. The **BeagleBoard.org** community aims to engage passionate developers and fuel their innovations in the open-source development community, whether they are designing projects for work or fun.

Since the introduction of the open-source community in 2008, the support ecosystem, tools and sense of collaborative community surrounding it have grown phenomenally. Currently around 5,000 members, mostly representatives from Fortune 100 companies, industry leaders, hobbyists and academia, play an active role in the **BeagleBoard.org** community.

For example, **BeagleBoard.org** generates around 50,000 visitors every week, making it one of the largest and most collaborative communities in the open-source hardware world. Members are posting 3-5 new projects each week and are getting instant feedback from international and local developers. The open-source community has even extended its reach to diverse areas of the globe such as Brazil, Japan and Turkey, with many more communities on the way. Each community hosts and fosters the sharing of the latest software developments, live forums and online chats for easy collaboration. These communities are available to anyone who wants to join and take advantage of a strong support system where interaction with other developers, learning about new trends and the sharing of ideas happen every day.

Though **BeagleBoard.org** receives ongoing support from TI, it is mostly a self-sustaining community that utilizes distributor pre-orders and previous board sales to fund hardware development. **BeagleBoard.org** is committed to utilizing components available through distribution in low quantities to ensure the open-source hardware design is one that many manufacturers can duplicate and enhance.

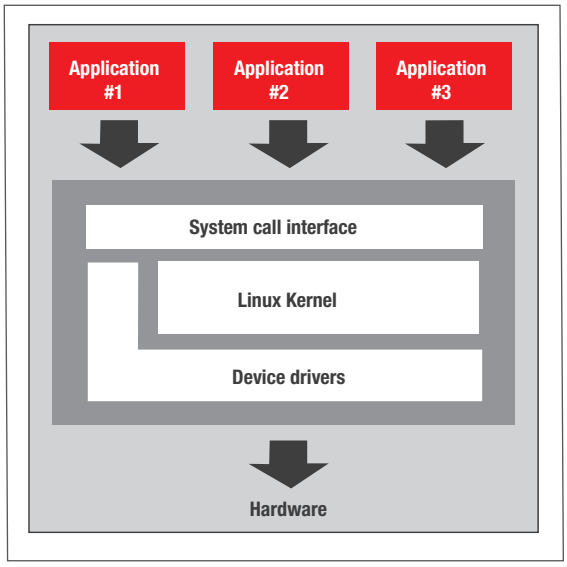
Path to open-source

From professional embedded system design teams to individual hobbyists, **BeagleBoard.org's** versatile and cost-effective BeagleBone provides a powerful development and rapid prototyping platform which functions as a direct path into the open-source world.

The perception among designers and developers of the open-source community has changed radically in recent years as the depth and breadth of development tools, functional modules like driver stacks, middleware frameworks and other resources have rapidly increased. Now, most developers realize that open-source is a force in the industry that must be taken into account. Not doing so runs the risk of being left behind and missing many of the innovations that are emanating from the open-source community.

As an example, many embedded system developers who historically have based their applications on MCU platforms are now discovering that developing their next systems with the Linux OS opens the door to a very rich and diverse set of ready-to-use software modules and plug-ins at no cost. A wide array of interfacing and communications stacks like TCP/IP, USB and many others are readily available. These stacks and drivers have been widely deployed and, as a result, are very robust. By and large, any potential problem has already been identified by other developers who have shared their findings with the rest of the open-source community.

Another advantage of developing under the open-source Linux OS instead of MCU-like direct register-based development is the fact that Linux provides an abstraction layer above the underlying hardware. Unlike direct register-based development, where a shift to a new MCU family or to a new generation MCU would mean re-developing or re-porting much of the previously developed software, a change to a different Linux processor will not require re-development of firmware, system-level or application software. Certainly there will be similarities in the development environment when moving from one MCU to the next generation device, but there typically will be enough differences to require new learning and the re-porting of established code. With Linux, the transition is seamless because the OS interacts with the hardware layers on one side the software layers on the other.



▲ ***Fig. 2*** *– Linux block diagram*

Additional open-source resources

Many of the aspects of the open-source world that attract developers also assist those who decide to make the transition to the open-source community. For example, a number of middleware frameworks make it easier for new and experienced designers to develop functional subsystems like a graphical user interface (GUI) or web server. The type of assistance that the various open-source frameworks have to offer covers a range of capabilities from very specialized tools for specific needs to generalized programming environments. In general, most frameworks feature programming tools, libraries of low- or mid-level functional modules that can be deployed as is or modified to suit a certain system requirement, and other capabilities that facilitate the rapid assembly of functional embedded applications.

An example of such a framework is Qt. Qt is an open-source cross-platform application framework which is widely used to develop GUIs and consoles for applications. In addition to Linux, it can also be used to develop user interfaces and consoles for other operating systems as well, including Windows, Mac OS, Symbian and others. The Qt framework was built in C++ but it makes extensive use of a special code generator. It has been widely adopted by major system providers like Nokia®, Adobe®, Microsoft® (Skype®), Hewlett-Packard, Google™ and others.

Other open-source frameworks (See Table 2) have been as widely deployed as Qt, if not more so. As a result, design teams are able to leverage the capabilities of these frameworks to rapidly develop system or application prototypes. They also relieve designers of the necessity of understanding the minutiae of the underlying hardware as a prerequisite for developing software subsystems to run on it. This allows developers who are more adept at designing an engaging user experience to concentrate on this aspect of the system while engineers more familiar with the requirements of the hardware can focus on the lower levels of the system's architecture.

Frameworks or component providers	Functionality
Qt, OpenGL, X11, GTK, DirectFB	2D and 3D graphics frameworks
Python, Perl, Erlang, Smalltalk	High-level programming languages for rapid application development
Apache, node.js, Ruby on Rails, lighttpd	Web server and network communications development frameworks
OpenBricks	Linux development framework for embedded devices
GStreamer, libav, OpenMAX	Multimedia processing components and frameworks

▲ ***Table 2*** *– Various open-source frameworks (not a complete list)*

BeagleBoard.org is also at the heart of commercial open-source resources, enabling you to quickly leverage existing software and experienced developers to bring your project idea to life. The BeagleBoard-xM is the ARM reference platform for the Yocto Project, a Linux Foundation project that provides templates, tools and methods to help you create custom Linux-based systems for embedded products regardless of the hardware architecture and is supported by many major commercial Linux providers, including Mentor Graphics, Timesys, MontaVista, Wind River and individual consultants.

Mind your licenses

Fundamental to the open-source community is the sense of sharing that pervades its members, who have willingly contributed to the development of many open-source tools and functional modules. This sense of sharing extends to some of the licenses which govern the use of some open-source resources. Generally, some licenses will require that if software that is developed was directly derived from an open-source resource or is partly made up of open-source code then the resulting software is also considered open-source, and it should be shared and made available to the rest of the community.

This is not to say that the open-source community is in conflict with the many commercial companies that want to protect and retain for their use the intellectual property (IP) they develop. To retain control over their IP, such companies should analyze the licenses for the open-source resources they have adopted and carefully control how these resources are used, always keeping in mind the restrictions and requirements embodied in these licenses.

Open-source hardware platforms

BeagleBoard.org's BeagleBone and BeagleBoard hardware platforms capture the vibrant and collaborative spirit of the open-source community. At the same, they bring to bear the vast resources and continued commitment to enable innovation.

For more information

For more information on the BeagleBoard community, go to **www.beagleboard.org**. For more information on the BeagleBone platform, go to **www.beagleboard.org/bone**.

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