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WHITE PAPER

Migrating Low-Power And Cost-Sensitive X86-Based Designs To Next Gen Technology

The AMD G-T16R Accelerated Processing Unit (APU) represents the latest APU configuration of the AMD G-Series family. With its excellent performance, low average power, compatibility with legacy I/O, and low price, the AMD G-T16R APU provides an ideal migration path for power- and cost-sensitive x86 based designs.

1. Introduction

The AMD Geode™ LX family of processors, announced in 2005, has been delivering x86 processing and versatility to applications for industrial control, medical, transportation, infotainment, point-of-sale, and thin client applications for more than six years and are planned to be available through 2015. AMD Geode LX processors provide a combination of low-power x86 processing and graphics capabilities needed for designing innovative and creative products. With an average power of 2.45W[i], the AMD Geode LX800 offers designers a complete set of features that deliver full desktop functionality to embedded and portable devices.

The AMD Embedded G-Series platform debuted in early 2011 as the world's first integrated circuit to combine a low-power central processing unit (CPU) and a discrete-level graphics processing unit (GPU) into a single embedded Accelerated Processing Unit (APU). The unprecedented level of graphics integration offered by the APU builds a new foundation for high performance multi-media content delivery in a small form factor and power efficient platform for a broad range of embedded designs. Based on the power-optimized core codenamed "Bobcat" paired with AMD Radeon™ HD 6000 Series graphics, the AMD Embedded G-Series platform combines power and performance in a compact Ball Grid Array (BGA) package that is ideal for low-power and small form factor embedded applications such as digital signage, x86 set-top-boxes (xSTB), IP-TV, thin clients, information kiosks, point-of-sale, casino gaming, media servers, and industrial control systems.

The first AMD G-Series APUs announced in 2011 delivered exceptional performance, with thermal design power (TDP) between 5.5 Watts (W) and 18 W. But the AMD G-Series' wattage was higher than the 3.9W TDP of the AMD Geode LX 800 processor – a factor that helped make the AMD Geode very successful in a variety of embedded applications.

AMD addressed the wattage issue with the newest model in the AMD G-Series family of APUs announced in June 2012: the AMD G-T16R APU. With a TDP of just 4.5W and an average power of 2.3 Watts[i], the AMD G-T16R delivers lower average power than the 2.45W[i] of the AMD Geode LX800. Additionally, the AMD G-T16R delivers as much as three times the performance[ii] of the AMD Geode LX800 processor. With its competitive price and support for DDR3 memory, which can save up to 28% on the cost[iii] of memory while providing twice the capacity and more than three times the speed, the AMD G-T16R offers a comparable system cost to AMD Geode LX processor-based designs.

To help enable designers making a transition from an AMD Geode LX processor, or other x86, based-board design to an AMD G-T16R APU based board, support for the use of legacy I/O cards is achieved through a full 32-bit PCI interface and ISA bus solution[iv] with DMA support. For designers engineering a new board design, it is a two-chip solution with an integrated CPU and GPU paired with an I/O companion, such as the AMD Geode LX, but in a 58% smaller footprint[v] package.

2. Why Migrate to an AMD G-Series Solution?

A key advantage of long-life embedded motherboards is their ability to be designed into and continue to be manufactured as part of a system for many years without changes. This helps avoid the recurring engineering costs associated with frequent redesigns associated with commercial motherboards. A challenge of embedded motherboards is that as they mature, the availability of components used on the board declines making them more expensive to manufacture. Along with the decline in availability of components on the board, the availability of peripheral components they were designed to connect to also declines making them more expensive, or requiring workarounds to connect to readily available peripherals.

To help OEMs make the transition from outdated motherboards and peripheral components, the AMD G-T16R APU offers support for legacy I/O and simultaneously offers a transition path to the latest peripheral interfaces and technology. The AMD G-Series platform continues to support many critical legacy I/O such as a full 32-bit PCI interface, an ISA bus solution with DMA support, and the LPC interface for support of Super I/O functionality. To enable the transition to the latest components and peripheral interfaces it supports the latest in high speed and serial I/O standards, display interfaces, and state of the art DDR3 memory technology. When paired with the AMD A50M controller hub it delivers support for advanced interfaces such as 6Gb/s SATA, Generation 2 PCI Express®, and HD Audio. For full-featured platforms, the AMD A55E controller hub is an alternative paring choice with the added features of Gigabit Ethernet MAC, RAID (0/1/5/10) support with FIS-based switching, and a full 32-bit PCI bus. Companies looking to upgrade their existing AMD Geode LX-based or other legacy x86 processor based designs should consider the following advantages of an AMD Embedded G-Series-based design:

The AMD G-Series platform delivers an upgrade path for legacy applications

The AMD G-Series platform delivers a solution that can be designed to be compatible with existing system peripherals while at the same time offering an upgrade path to next generation I/O through;

- Support for legacy I/O and displays that simplify the design into legacy applications while offering a migration path to the latest generation of I/O and display technologies.
- Support for a variety of embedded and real time operating systems to help ease software migration.
- A broad range of available standard form factor motherboards that enable embedded OEMs to quickly migrate their system solutions to these new boards.

The AMD G-Series platform offers a good combination of value and low power

Its combination of small footprint and very low power help it fit into the mechanicals and cost structure of existing designs through;

- Operating with an average power of only 2.3 Watts[i] for the AMD G-T16R APU compared to 2.45 Watts for AMD Geode LX800[i], enables very small form factor, fan-less and portable applications.
- With a similar power profile to the AMD Geode LX800, the reuse of cooling solutions and chassis designs from existing designs may be possible.
- Providing a highly integrated two chip platform, the APU and its companion Controller Hub, with a combined footprint of only 890mm^2, to help ease its design into small form factor boards.

The AMD G-Series platform helps to reduce product and life cycle costs

By offering a migration path to the latest in I/O and peripheral technology and easy avenue to higher performance the AMD G-Series platform enables power and cost optimized solutions that OEMs can leverage to reduce product and life cycle costs through;

- Exceptional value for an extremely power efficient combination of x86 compatible processing and graphics.
- Offering several footprint-compatible AMD G-Series platform options to enable a common scalable platform design to serve multiple product configurations. Helping to reduce development costs, simplify the supply chain, and reduce operational complexity and associated costs, to drive better platform economics.
- Support for the latest DDR3 memory to help reduce memory costs for legacy applications, while delivering higher performance and capacities. The average price for 1GB of 1333MHz DDR3 memory is $5.60. 28% less than the average price of $7.84 for 512MB of 400MHz DDR memory[iii].

3. Four considerations for design migration of long-life products

When hardware designs become obsolete, OEMs have little choice but to redesign their systems. When doing this, there are also four main considerations that force OEMs to examine their plans for migrating their products to next generation solutions: price, power, performance and features.

3.1 Price

Pricing pressure for long-life products comes from multiple directions. As systems mature, the boards and peripherals from which they are built tend to become more expensive to manufacture. At the same time, though, competition and customer expectations drive down the price at which an OEM can sell the product. For every long-life embedded product, there is an ideal time in the product life cycle that makes them optimally profitable. This varies by application and market, but is generally defined as the time between when all of the engineering costs have been amortized and during which all of the components and technology to build the product are still readily available at a reasonable cost. Exceeding that time window not only begins to drive down the revenue on products due to customer pricing concessions, but also tends to drive down margins due to increased component costs and engineering expenses required to mitigate component and peripheral obsolescence.

The AMD G-T16R APU addresses the major component and peripheral availability issues through support of the latest I/O technology. The following table compares the AMD G-T16R APU to the AMD Geode LX processor for some of the key system-level components.

	AMD Geode LX 800 + CS5536	AMD G-T16R APU + A50M/ A55E	Design Implications
Memory	DDR1 400	DDR3 1066	1GB of DDR3 provides three times the speed and twice the capacity of 512MB of DDR at 28% lower cost[iii].
Hard Drive	PATA	SATA	SATA drives are now more common, higher bandwidth, and lower cost
Ethernet	PCI Based	Integrated or PCIe® based	Readily available, high performance and low cost components
USB	Up to 4 devices	Up to 16 devices	Many USB ports available to support common and inexpensive peripherals. No hub required for designs that require support more than 4 USB devices

Table 1: Price advantage of current I/O technology

3.2 Power

Staying within the defined power constraints is often a challenge when considering options for platform migration. Solutions based on the latest technology often focus on delivering more performance rather than driving down power consumption. Hardware designers are challenged with the task of finding a new solution that supports the latest I/O and peripheral technology, delivers as-good or better performance to meet customer expectations and a software development group's tendency for feature creep, and needs to fit into the same or smaller enclosure.

The AMD Embedded G-Series platform, based on the low-power x86 "Bobcat" core whose internal advanced multi-core micro architecture is power-optimized from the ground up, delivers power optimized execution, clock gating, power gating, and system power states. It delivers excellent performance in a very low-power solution. Combining the "Bobcat" core with low-power discrete-class graphics, all on one die, delivers a new, low-power and cost effective platform for embedded solutions. The AMD G-T16R APU delivers lower average power and better performance per watt than the AMD Geode LX800 processor, which was one of the key benefits of the AMD Geode LX solution for many embedded designs.

The following charts illustrate the power consumed by the AMD G-T16R APU and the AMD Geode LX800 processor while running the WinBench® 99 Business Graphics benchmark.

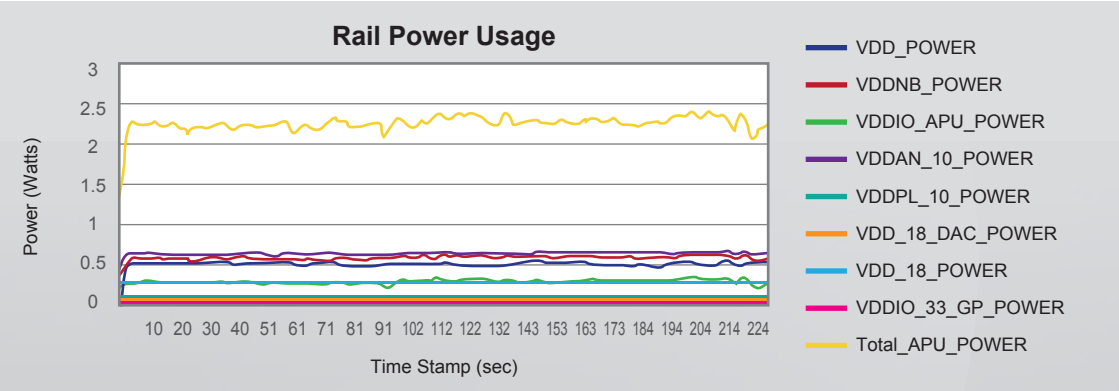

Figure 1: Power consumption of the AMD G-T16R APU running WinBench 99 Business Graphics[vi]

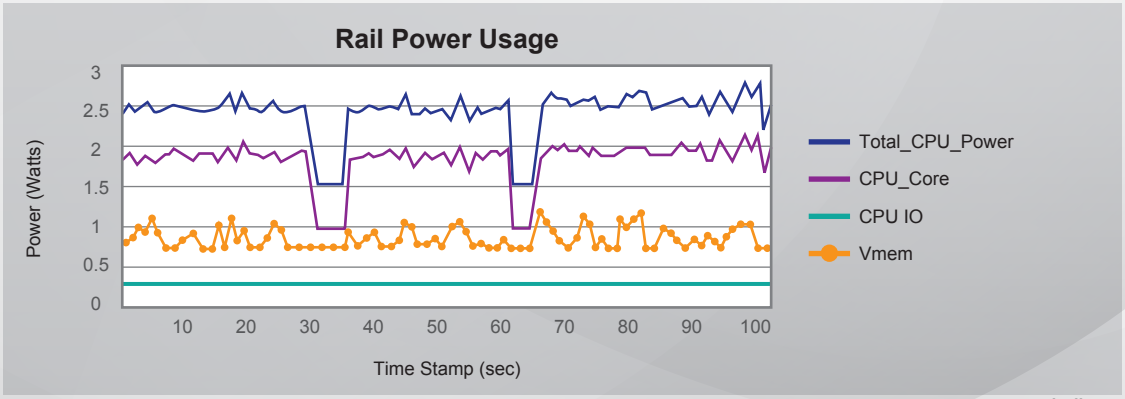

Figure 2: Power consumption of the AMD Geode LX800 processor running WinBench 99 Business Graphics[vi, vii]

3.3 Performance

While performance is often not a major selection criteria for low-power and cost-sensitive applications, being able to deliver good performance in a solution that meets the power and cost limits of a design enables system and software architects to differentiate their products from their competition. The goal of the AMD G-T16R APU was to deliver a solution that operated within a similar power envelope and offered comparable system-level costs as an AMD Geode LX800 processor-based solution, but delivered substantial additional performance to enable OEMs to innovate and differentiate their products. The following charts demonstrate the performance advantages that the "Bobcat" core and APU architecture deliver for these applications.

Stream is a measure of raw system memory bandwidth.

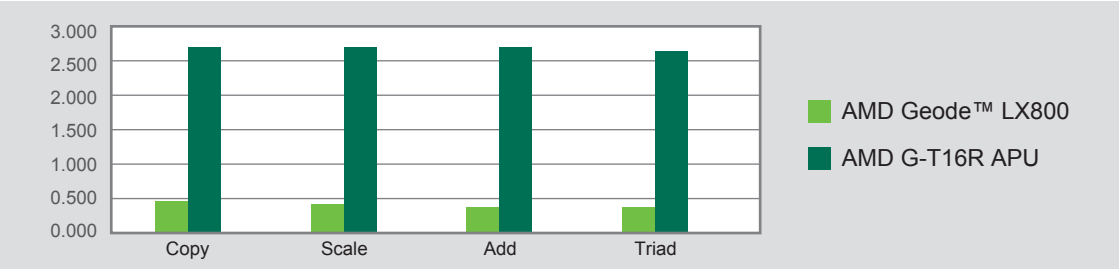

Figure 3: Stream in Ubuntu[ix]

EEMBC CoreMark measures the capability of an embedded processor associated with a specific compiler.

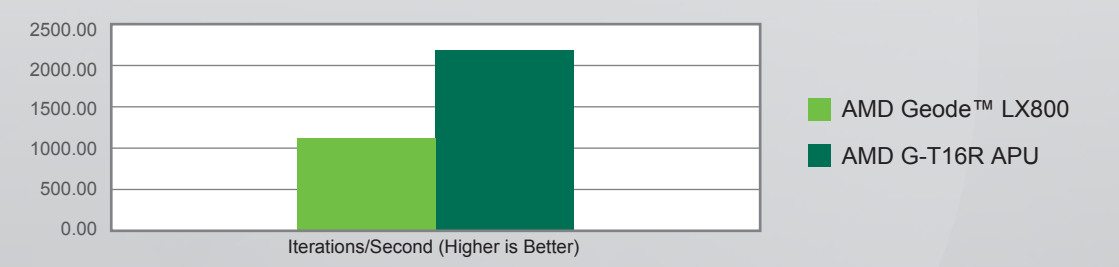

Figure 4: EEMBC CoreMark[ix]

SciMark 2.0 is a Java benchmark for scientific and numerical computing.

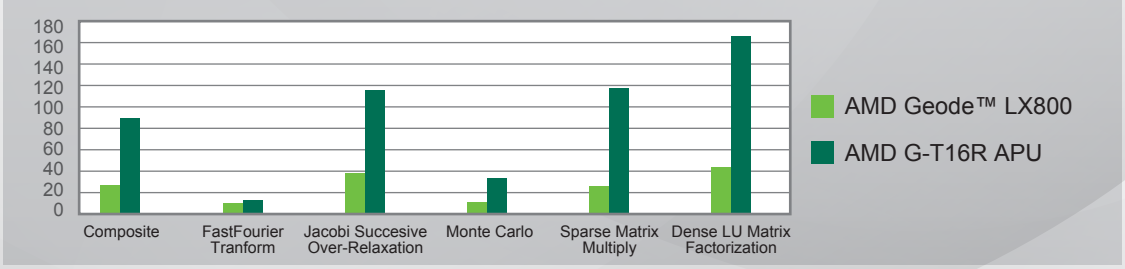

Figure 5: SciMark 2.0 in Ubuntu[ix]

3.4 Features

Feature support can be particularly important when migrating a system from legacy I/O to the latest generation of I/O technology. The ability to support legacy peripherals in existing systems while enabling those systems to be upgraded to the latest technology is often a consideration when selecting a migration path in long-life embedded designs. In many cases, there are certain features that simply must be supported to meet the requirements of the solution. The AMD Embedded G-Series platform offers a broad range of features enabling support for the unique requirements in a wide variety of embedded applications.

The table below compares some of the key features of the AMD Geode LX processor and the AMD Embedded G-Series platform and summarizes some of the migration considerations related to each feature.

	AMD Geode LX 800 + CS5536	AMD G-T16R APU + A50M/A55E	Migration Considerations
Display	VGA, TFT	VGA, LVDS, DVI, HDMI™, DP, eDP	The AMD G-T16R APU allows systems to support both legacy display interfaces and the latest in display technology
Hard Drive	PATA	SATA	SATA drives are now more common, higher bandwidth, and lower cost. For applications that require continued support for PATA drives, adapters are available
Audio	AC'97	HD Audio	Seamless migration to higher fidelity, 7.1 surround-sound support provides sufficient audio capabilities for most general embedded applications
USB	Up to 4 devices	Up to 16 devices	Many common and inexpensive peripherals can now be supported through USB
Hardware Video Acceleration	External device required	Internal Unified Video Decoder	Enables hardware decode support for the latest video while minimizing CPU overhead and power consumption
Legacy I/O	ITE8888 PCI to ISA	ITE8888 PCI to ISA (A55E)	Full ISA support, including full DMA
PCIe	No	Dual 1x4(or 4x1)	With software compatibility with PCI and wide peripheral card availability, eases migration from PCI based cards

Table 2: Feature comparison for the AMD Geode LX processor and AMD Embedded G-Series platform

4. Upgrading Your AMD Geode LX-Based System

There are a number of standard form-factor motherboards available based on the AMD Embedded G-Series platform. Some board vendors that have specifically created designs to support the AMD G-T16R APU include:

Company	Model	Form Factor	Board Image
Advantech	PCM-3356	PC/104	
Aewin	PM-6101	PC/104 Plus	
Arbor Technology	EmETX-a55E0	ETX Module	
aValue	ECM-A50M	3.5” Motherboard	
MEN Mikro Elektronic	SC24	Module	

There are more than 75 standard form factor embedded motherboards and system-level solutions designed around the AMD Embedded G-Series platform published in the AMD-based Embedded Product Catalog. Since the AMD Embedded G-Series family is footprint compatible, the AMD G-T16R APU is easily supported on these platforms. Please contact your AMD Embedded Group sales representative to identify which vendors are supporting the AMD G-T16R APU in their designs. In addition to non-standard form factors and system-level designs, boards are available in the following standard form factors with support for the AMD Embedded G-Series platform:

- Qseven
- Mini-ITX, Nano-ITX and Pico-ITX
- 5.25”
- 3.5”
- COM Express Basic / Compact
- ETX, XTX
- PC/104, EPIC, PC/104 Plus

5. Migrating a Board Level Design

AMD provides a variety of reference designs for the AMD Embedded G-Series platform in a variety of form factors with different I/O configurations and memory topologies (including DIMMs and DRAM down) on the AMD Embedded Developers Web site. While the list is continuously expanding, the reference designs currently available target the following standard form factors:

- Mini-ITX
- COM Express: 1.0 Type 2, 2.0 Type 6, and 2.0 Type 10
- Micro-ATX
- PCI-104 Express
- EPIC Express

A separate set of option schematics is available that showcases the various AMD G-Series APU display options including 18-bit single-channel LVDS, 18/24-bit dual-channel LVDS, VGA, DVI and HDMI, DisplayPort, and Embedded DisplayPort.

The table below compares the key features of the AMD G-T16R APU to the AMD Geode LX800.

	AMD Geode LX800+CS5536	AMD G-T16R APU+A55E
Architecture	x86 32-bit Scalar	x86 64-bit Superscalar w/ full OOO
x86 CPU Cores	1	1
Clock Speed	500Mhz	615Mhz
Memory	DDR1 64-bit @ 400MT/s	DDR3 @ 1066MT/s
L1 Cache	64KB/64KB	32KB/32KB
L2 Cache	128KB Unified	512KB L2
FPU	MMX™, 3DNow!	SSE1,2,3, SSSE3 ISA, SSE4A, MMX™
Virtualization	No	AMD-V™
Graphics	DirectX® 9 (2D)	DirectX 11 3D
I/O	VIP / VOP	1 x4 PCIe gen 2 (configurable)
Video Acceleration	External	Internal: UVD 2.0
Video Processing	Supports video scaling, mixing and VOP, Hardware video up/down scalar, Graphics/video alpha blending and color key multiplexing	HD HQV and SD HQV support: noise removal, detail enhancement, color enhancement, cadence detection, sharpness, and advanced de-interlacing, super up-conversion for SD to HD resolutions
Video Output	Single: CRT, TFT	Dual Independent: DisplayPort, eDP, HDMI, DVI, LVDS, VGA
Max Display Resolution	1920x1440x32-bpp @ 85Hz	1920x1200 @ 60Hz
Southbridge / Companion Device Connection	PCI 33/66Mhz	"UMI": 1 x4 PCIe
Security	128-bit AES (CBC/ECB), True Random Number Generator	None
Debug	JTAG – FS2 (Inactive)	JTAG – Sage (Active)
Power Consumption [1,2]	TDP= 3.9w Average= 2.45w	TDP= 4.5w Average= 2.3w
Technology	130nm	40nm
Package	481-terminal BGA cavity up	413-terminal BGA ("FT1")
Solution footprint	40 x 40mm + 23 x 23mm = 2129mm^2	19 x 19mm + 23 x 23mm = 890mm^2
Ethernet	External PCI device	Internal (A55E) or through PCIe (A50M)
Boot ROM	LPC	SPI

Table 3: AMD Geode LX800 compared to the AMD G-T16R APU

The AMD G-T16R APU is supported by two I/O controller hubs: the A50M and the A55E; both connect to the APU via a high bandwidth x4 PCIe channel rather than a standard PCI bus. The table below shows a feature comparison between the CS5536, the A50M, and the A55E.

	CS5536	A50M	A55E
Processor Connection	PCI 66Mhz	PCIe - x4 gen 1	PCIe - x4 gen 2
Clock Generation	N	Y	Y
Ethernet MAC, EEE	N	N	Gigabit MAC, Y
Hard Drive	ATA 66	SATA – 6 x 6Gb/s	SATA – 6 x 6Gb/s
Flash	NAND Flash and/or NOR Flash	N	N
RAID, FIS-Based Switching	N	N	0,1,5,10,Y
Audio	AC '97 DMA Audio	HD Audio – up to 4 channels	HD Audio – up to 4 channels
PCIe	N	4 x 1 gen 1	4 x 1 gen 2
PCI	PCI 66	N	32-bit, 33Mhz up to 4 slots
I/O	LPC, SMBus, UART, up to 16 GPIO	SPI, LPC, SMBus, up to 102 GPIO	SPI, LPC, SMBus, up to 102 GPIO
USB 2.0 + 1.1 ports	3 Host Ports, 1 Host / Client	14 + 2	14 + 2
APU Fan Control	N	Y	Y
Consumer IR	Y	Y	Y
RTC	Y	Y	Y
MCTP	N	Y	Y
Boot	LPC	SPI	SPI
Power Consumption	TDP = 0.65w Average = 0.425w	TDP = 5.9w Average = 0.965w	TDP = 5.9w Average = 0.965w
Package	208-pin PBGA 23mm x 23mm	605-pin FCBGA 23mm x 23mm	605-pin FCBGA 23mm x 23mm

Table 4: I/O Controller Feature Comparison

For detailed information on migrating a board design from the AMD Geode LX800 to the AMD G-T16R APU, please see the Migrating an AMD Geode LX-based design to the AMD G-T16R APU white paper posted on the AMD Embedded Developers Web site.

6. Summary

Embedded systems based on the popular AMD Geode LX platform have been deployed across a wide range of industrial control, medical, transportation, infotainment, point-of-sale, and thin client applications. While the AMD Geode LX platform is planned to be offered through 2015, its associated product roadmap does not include future advanced configurations necessary to support the latest technology required by some of these applications. The AMD Embedded G-Series platform provides an ideal migration path for AMD Geode LX platforms that need to be upgraded now and in the near future by delivering a solution that supports long-term availability and can be designed to be compatible with existing systems while also offering an upgrade path to next generation I/O and display technologies. The AMD G-Series platform provides the benefits of higher performance/watt, smaller footprint, additional graphics and video capabilities, new interface standards, and improved economies of scale all while maintaining compatibility with a variety of real-time embedded operating systems and support for critical legacy interfaces.

When comparing the AMD G-T16R APU to other solutions in its class, the AMD Embedded G-T16R APU offers a smaller footprint than the Intel Atom solutions[x] and can deliver more than twice the graphics performance[xi] and up to 5X the floating point performance[xii] of the Intel Atom D2700 at a fraction of the power[xiii] and cost[xiv].

For more information on the AMD G-T16R APU please visit http://www.amd.com/G-Series.

7. Additional Help and Information

AMD provides extensive collateral and technical support for customers throughout all phases of their development cycle including:

- Product specifications, design guides, and application notes.
- Software and hardware development tools including reference designs, software/BIOS development kits, layout examples including Gerber files, IBIS models, and design verification tools.
- Schematic and layout reviews and other design services.

For further assistance or to gain access to downloadable collateral, customers should contact their AMD Embedded Solutions sales representative or visit the AMD Embedded Developers Web site at http://wwwd.amd.com/dev.

About AMD

AMD is a semiconductor design innovator leading the next era of vivid digital experiences with its groundbreaking AMD Accelerated Processing Units (APUs) that power a wide range of computing devices. AMD Embedded Solutions give designers ample flexibility to design scalable, x86-based, low-cost and feature-rich products, and drive energy conservation into their systems without compromising application performance or compatibility, graphics performance, or features. For more information, visit http://www.amd.com/embedded.

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i While running a Winbench 99 business graphics benchmark the AMD G-T16R APU consumed an average of 2.284W. I/O Controller Hub power is estimated based on the measured average power drawn by the I/OCH of .965W during a run of 3DMark 06. System Configuration: AMD G-T16R APU (DVT) at 30°C, "Inagua" Development Board, 4GB 1.35V DDR3, Windows 7 Ultimate. The AMD Geode LX800 consumed an average of 2.450W. The average power consumed by the CS5536 was 424.9 Milliwatts. System Configuration: AMD Geode LX 800 (Rev C0 500 MHz), "Norwich" Development Board, 256MB DDR-400, Windows XP Pro SP1. EMB-27

ii Performance comparison based on the geometric mean of the SciMark2 Composite, FFT, Jacobi Successive Over-Relaxation, Montecarlo, Sparse Matrix Multiply and Dense LU Matrix Factorization benchmark tests for a 22.05 for the AMD Geode LX 800 and 65.55 for the AMD G-T16R APU. System configurations: AMD G-T16R APU, IBASE MI958, 4GB DDR3, Ubuntu 11.04, AMD Geode LX 800, AMD Geode™ LX DB800 Development Board, 1GB DDR1 SO-DIMM, Ubuntu 11.04. EMB-28

iii The Session Average DRAM Spot Price listed on http://www.dramexchange.com/ on May 30th at 18:00 (GMT+8) was $0.70 for DDR3 1Gb 128Mx8 1333MHz and $0.98 for DDR 512Mb 64Mx8 400MHz. EMB-35

iv See the AMD Embedded G-Series Platform Support of Legacy ISA Bus application note on the AMD Embedded Developers Web site for more information.

v The footprint of the AMD G-Series APU+A55E is 890mm^2 and the footprint of the AMD Geode LX + CS5536 is 2129mm^2.

vi System Configuration: AMD G-T16R APU (DVT) at 30°C, "Inagua" Development Board, 4GB 1.35V DDR3, Windows 7 Ultimate.

vii System Configuration: AMD Geode LX 800 (Rev C0 500 MHz), "Norwich" Development Board, 256MB DDR-400, Windows XP Pro SP1.

viii Since Vmem also provides power to the external DDR SDRAM implementation, only 32.5% of Vmem PWR is used in AMD Geode LX total_CPU_power calculations.

ix System configurations: AMD G-T16R APU, IBASE MI958, 4GB DDR3, Ubuntu 11.04, AMD Geode LX 800, AMD Geode™ LX DB800 Development Board, 1GB DDR1 SO-DIMM, Ubuntu 11.04.

x The footprint of the AMD G-Series APU+A55E is 890mm^2 and the footprint of the Intel Atom E6XX+EG20T is 1013mm^2. See http://ark.intel.com/products/52491/Intel-Atom-Processor-E620-%28512K-Cache-600-MHz%29 and http://ark.intel.com/products/52501/Intel-EG20T-PCH. EMB-29

xi Internal testing of AMD G-Series processor-based embedded systems as of May 25, 2012 showed 3DMark™06 scores of 1067 for the G-T16R. The 3DMark06 score for the Intel Atom D2700 was 501. System configurations: AMD G-T16R APU, IBASE MI958 Motherboard, 4 GB RAM, Windows 7 Ultimate, Intel Atom D2700 Processor, Jetway NC9KDL-2700 Motherboard, 4 GB RAM, Windows 7 Ultimate. EMB-30

xii The calculated single precision GFLOPs for the AMD G-T16R is 46. The calculated single precision GFLOPs for the Intel Atom D2700 is 8.52. Calculated SP GFLOPs = (# of x86 cores x (# of FP bits per core / 32 bit (SP Operation)) * CPU Frequency) + (# of OpenCL enabled GPU cores * (# of FP bits per GPU core / 32 bit (SP Operation) * GPU Frequency). EMB-31

xiii Power comparison based on TDPs for the AMD G-T16R APU of 4.5W, vs. the Intel Atom D2700 of 10W. EMB-34

xiv Intel Atom D2700 price, $52, based on http://www.intc.com/pricelist.cfm as of May 13, 2012. AMD G-T16R APU estimated price of <$25 is based on low volume MSRP, purchased through distribution as of June, 2012. EMB-32