AMD

AMD PowerNow!™ Technology

Dynamically Manages Power and Performance

Informational White Paper

Trademarks

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Informational White Paper

AMD PowerNow!™ Technology Dynamically Manages Power and Performance

Overview

The AMD-K6™-2E+ and AMD-K6™-IIIE+ embedded processors are targeted at tethered applications. Because these applications use non-exhaustible sources of power, system designers are primarily concerned with cooling the embedded processor efficiently with a fan-less or passive heat sink. As a result, it is critical for such an application to fall below the power threshold for a passive thermal solution and still function reliably without the need for a fan.

AMD's new power-management feature, called AMD PowerNow!™ technology, enables a low-power AMD-K6-2E+ or AMD-K6-IIIE+ processor to actively function while dissipating less than 3 W of power. With its multiple modes of operation and dynamically supported frequencies and voltages, AMD PowerNow! technology empowers a developer to optimize power and performance to best meet the requirements for a passive thermal solution without compromising performance.

What is AMD PowerNow!™ Technology?

AMD PowerNow! technology is an advanced, second-generation power-management feature that reduces the overall power consumed by the processor through control of voltage and frequency. This power-saving technology is designed to be dynamic and flexible by enabling instant, on-the-fly, and independent control of both the voltage and frequency. Currently, AMD PowerNow! technology is available on all AMD-K6-2E+ and AMD-K6-IIIE+ low-power embedded processors.

The AMD-K6-2E+ and AMD-K6-IIIE+ embedded processors extend the performance range of Socket-7 compatible x86 embedded processors to unparalleled levels. AMD PowerNow! technology enables reduced power consumption with performance on demand for power-sensitive embedded applications.

Dynamic Control of Voltage and Frequency

Unlike many other currently available power management features, AMD PowerNow! technology is designed to provide very fine and dynamic control of voltage and frequency.

■ AMD PowerNow! technology is able to support up to 32 different core voltage settings ranging from 0.925 to 2.00 V[1] with voltage steps as small as 25 or 50 mV.

■ The technology also supports the complete frequency operating range of the processor in use and is independently controlled, allowing steps of 33 or 50 MHz[2] from an absolute low of 133 or 200 MHz.

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1. *Absolute electrical ratings, provided in each processor data sheet, must be adhered to for each specific processor model.*
2. *Depending upon a bus speed of 66 or 100 MHz.*

Operating Modes

Along with the finest granularity of control in the industry, AMD PowerNow! technology supports different modes of operation.

■ In *High-Performance mode*, the processor runs at the maximum rated voltage and speed providing the maximum performance possible.

■ Changing to *Power-Saver mode* configures the processor to run at the lowest voltage and frequency supported for the most efficient power profile.

■ In *Automatic mode*, the speed and voltage are dynamically and automatically determined by actual performance demands of the application. *In Automatic mode, the needs of the application environment dictate the amount of performance required and power used*. This mode of operation ensures that only the required amount of power is dissipated to meet the performance demands of the application.

These features are possible through the modifications made in the AMD-K6 processor core. They include an integrated CPU clock speed control and additional pins to control an off-the-shelf programmable voltage regulator. None of these features requires changing any external bus frequencies, thereby maintaining overall integrity of the system and reducing the possibility of complications.

Key Features

■ Supported on all AMD-K6-2E+ and AMD-K6-IIIE+ low-power processors.

■ Up to 32 allowable core voltages driven by Voltage Identification (VID) pins.

■ 25 and 50 mV core voltage steps for the finest control.

■ Scalable frequency control from a low of 133 or 200 MHz with steps of 33 or 50 MHz.

■ Voltage and frequency are independently configurable.

■ Automatic mode support for precise and errorless power and performance scaling.

Implementing AMD PowerNow!™ Technology

AMD PowerNow! technology is available on all low-power AMD-K6-2E+ and AMD-K6-IIIE+ processors. AMD's newly-released second-generation power-saving technology is easily accessed and controlled through the Enhanced Power Management (EPM) 16-byte I/O block.

■   The *Enhanced Power Management Register (EPMR)* is a model-specific register (MSR). It is used to map and enable access to the *EPM 16-byte I/O block*.[1]

■   By modifying the EPM block, the operating system (OS) can change the voltage and bus frequency multiplier settings[2].

As shown in Figure 1, the external VID[4:0] pins can be routed to an external programmable voltage regulator to modify the V_{CC2} core voltage.
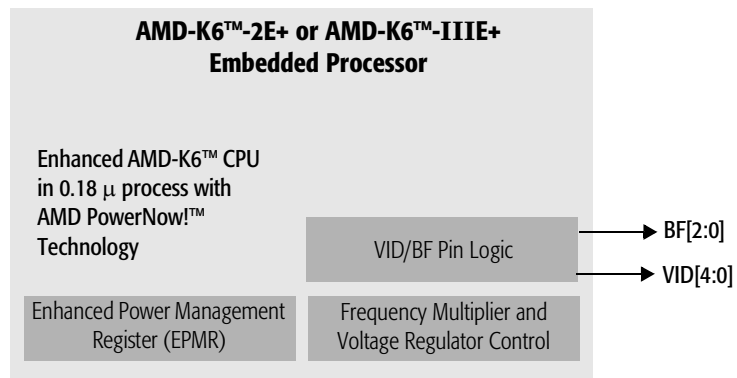
Figure 1.   AMD-K6™-2E+ or AMD-K6™-IIIE+ Processor with AMD PowerNow!™ Technology Signals

1. *See the* Embedded AMD-K6™ Processors BIOS Design Guide Application Note, *order# 23913, and the* AMD PowerNow!™ Technology Platform Design Guide for Embedded Processors Application Note, *order# 24267, for more information about the EPMR and the EPM I/O block.*

2. *Bus frequency pins need not be modified. The internal processor frequency is updated by altering the internal processor clock and not the external bus frequency.*

Processor frequency is modified by writing to a 4-byte field in the EPM I/O block that controls the bus frequency multiplier. This is done internally to the processor and does not affect any external signals or clocks. The external Bus Frequency (BF) pins should be used for power-on self test (POST) and RESET strapping only; the pin states are not modified when invoking AMD PowerNow! technology.

For the AMD-K6-2E+ and AMD-K6-IIIE+ low-power processors, operation can be maintained down to a core voltage of 1.4 V at a processor clock frequency of 200 MHz. With a multitude of intermediate steps between the rated maximum and minimum of the processor, a system designer can pinpoint and implement the optimal performance and power profile for any application at any time.

Ease of Implementation

- Built-in bus frequency (BF) multiplier and VID control.
- Dynamic VID pins for controlling V_{CC2} regulator.
- Programmable bus frequency (BF) with on-chip registers.
- Default VID state for "safe" power-up.
- Clock multiplier and regulator voltage is controlled by software.
- CPU uses BF pins.

Software Control

For embedded applications, software to support AMD PowerNow! technology can be implemented in one of two ways.

■ For real-time operating systems (RTOS), like embedded Linux, AMD PowerNow! technology is supported in the operating system or BIOS.

■ For Microsoft® operating systems, AMD PowerNow! technology is supported through a publicly available driver.

It is the driver, OS, or BIOS that places the processor in the EPM Stop Grant State and invokes desired changes.

Software control allows AMD PowerNow! technology to be easily implemented, even for short design cycles. The only unique software required from the system designer is software that:

■ Implements Automatic mode

■ Determines what factors should drive a frequency or voltage transition

In some cases, this may be as simple as tracking CPU activity to step frequency and voltage up and down in accordance with demand. In this case, the designer would need to incorporate the CPU monitoring into the application environment so that AMD PowerNow! technology state transitions are only invoked under desired conditions.

The modifications for actually altering voltage and frequency take place in EPM Stop Grant State and are handled transparently.

Real-Time Operating System Environments

In the RTOS environment, AMD PowerNow! technology is supported through the operating system (OS) and/or BIOS. The RTOS or BIOS carries the burden of invoking the EPM Stop Grant State and reading and writing to the EPMR and the EPM 16-Byte I/O block. Additionally, locking the processor from external interruption, writes, or snoops during the AMD PowerNow! technology transition is handled automatically.

Microsoft® Operating Systems

In Microsoft operating systems, AMD PowerNow! technology state changes are invoked by a System Management Mode (SMM) handler. SMM is the control vehicle for safely accessing the EPMR and EPM 16-byte I/O block to control the processor's operating voltage and frequency.

The key benefit of using SMM while changing the state of the processors' operation is that, in a Microsoft operating system, SMM provides full access to the processor, while locking out external accesses that could interrupt a successful transition. This is easily done in SMM by setting the Advanced Configuration and Power Management Interface (ACPI) defined ARB-DIS bit to prevent PCI/AGP bus master access while modifying model-specific register (MSR) bits.

Designing a System Enabled with AMD PowerNow!™ Technology is Easy

- RTOS control and support are provided.
- Driver for Microsoft operating system support is provided.
- AMD PowerNow! technology state changes are handled directly through software control.
- AMD PowerNow! technology driver for Microsoft® operating system invokes SMM handler for state transitions through the SMI command port.
- Internal bit values reflect voltage and bus multiplier values invoked in EPM Stop Grant State.
- EPM Stop Grant State timer ensures stable supply voltage and Phase Locked Loop (PLL) frequency. (Maximum duration for stable operation is 200 μs.)
- Processor automatically returns to normal operation upon exiting EPM Stop Grant State.

Power Dissipation

AMD PowerNow! technology can cut power dissipation by almost 75%[1], as shown in Figure 2.
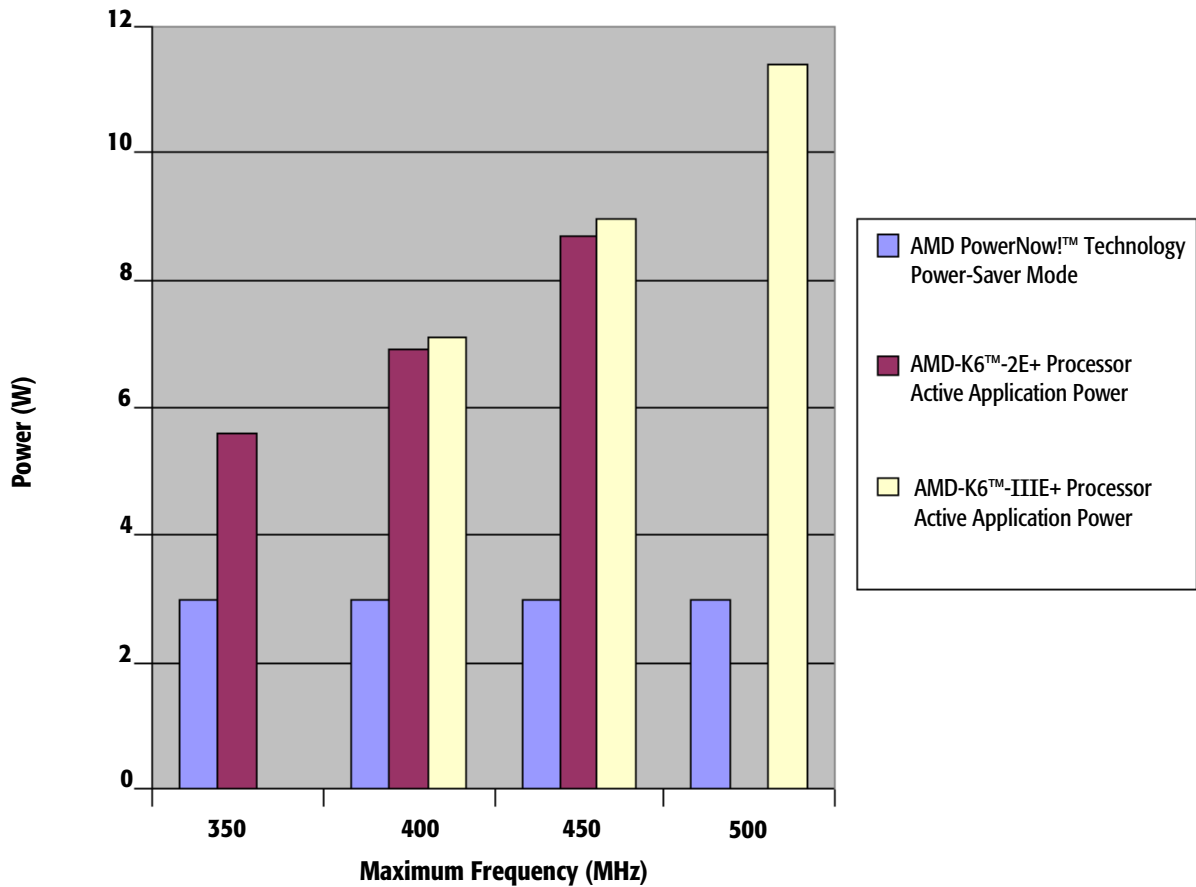

Figure 2.   Power Comparison (High-Performance Mode versus AMD PowerNow!™ Technology Power-Saver Mode)

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1. *Comparison of active application power dissipation of an AMD-K6-IIIE+500ANZ processor at a maximum frequency of 500 MHz and AMD PowerNow! technology Power-Saver mode of 200 MHz at 1.4-V VCC2.*

Competitive Advantages

AMD PowerNow! technology offers numerous advantages over the competition's solution. These advantages include:

■ Customization

■ Three modes of operation (Automatic, High-Performance, and Power-Saver)

■ Increased power savings

■ 3 W versus 7 W

■ Higher degree of flexibility for both voltage and frequency

■ Independent and dynamic control

■ Multiple voltage and frequency settings supported

■ Available on *all* AMD-K6-2E+ and AMD-K6-IIIE+ low-power processors

Feature Comparison

Table 1 compares the features of AMD PowerNow! technology with Intel's SpeedStep.

Table 1.   Feature Comparison of AMD PowerNow!™ Technology and Intel's SpeedStep

Feature	AMD PowerNow!™ Technology	Intel SpeedStep
Customer Customization	Yes	No
Low-Power Mode	Estimated 3 W[1]	Estimated 7 W[1]
Operating States	Up to 32 (more flexibility for developers)	2
Automatic Mode[2]	Yes (optimized performance and power usage)	No
Availability	All low-power AMD-K6™-2E+ and AMD-K6™-IIIE+ processors	High-end only (Pentium®III 600+)

Notes:
1. *Power estimates taken by running ZD Winstone® Benchmark with continuous CPU operation.*
2. *Automatic mode–Continuously varies processor operating voltage and frequency based on application demand.*

Supported Frequencies and Voltages

Table 2 and Table 3 list the frequencies and voltages supported by AMD PowerNow! technology for each processor.

Table 2.   Supported Voltages and Operating Frequencies for Low-Power AMD-K6™-2E+ Processors Enabled with AMD PowerNow!™ Technology

Ordering Part Number[1]	Core Voltage	Range of Supported Operating Frequencies[2]	Active Power[3]
AMD-K6-2E+/450APZ	1.7 V	450–200 MHz	8.70–4.90 W
	1.6 V	400–200 MHz	6.90–4.20 W
	1.5 V	350–200 MHz	5.60–3.70 W
	1.4 V	300–200 MHz	4.30–2.95 W
AMD-K6-2E+/400xTZ	1.6 V	400–200 MHz	6.90–4.20 W
	1.5 V	350–200 MHz	5.60–3.70 W
	1.4 V	300–200 MHz	4.30–2.95 W
AMD-K6-2E+/350xUZ	1.5 V	350–200 MHz	5.60–3.70 W
	1.4 V	300–200 MHz	4.30–2.95 W

Notes:

1. *An x in this column represents the package type. See the processor data sheet for a full description of ordering part number notation.*
2. *AMD PowerNow! technology enables the operating frequency to step down in increments corresponding to the available bus frequency multipliers. Note that 250-MHz operation is not supported due to exclusion of 2.5 bus frequency multiplier.*
3. *Active application power dissipation for highest and lowest supported frequency at specified voltage.*

Table 3.   Supported Voltages and Operating Frequencies for Low-Power AMD-K6™-IIIE+ Processors Enabled with AMD PowerNow!™ Technology

Ordering Part Number[1]	Core Voltage	Range of Supported Operating Frequencies[2]	Active Power[3]
AMD-K6-IIIE+500ANZ	1.8 V	500–200 MHz	11.40–5.80 W
	1.7 V	450–200 MHz	8.95–4.90 W
	1.6 V	400–200 MHz	7.10–4.20 W
	1.5 V	350–200 MHz	5.60–3.70 W
	1.4 V	300–200 MHz	4.30–2.95 W
AMD-K6-IIIE+450APZ	1.7 V	450–200 MHz	8.95–4.90 W
	1.6 V	400–200 MHz	7.10–4.20 W
	1.5 V	350–200 MHz	5.60–3.70 W
	1.4 V	300–200 MHz	4.30–2.95 W
AMD-K6-IIIE+400xTZ	1.6 V	400–200 MHz	7.10–4.20 W
	1.5 V	350–200 MHz	5.60–3.70 W
	1.4 V	300–200 MHz	4.30–2.95 W

Notes:

1. *An x in this column represents the package type. See the processor data sheet for a full description of ordering part number notation.*
2. *AMD PowerNow! technology enables the operating frequency to step down in increments corresponding to the available bus frequency multipliers. Note that 250-MHz operation is not supported due to exclusion of 2.5 bus frequency multiplier.*
3. *Active application power dissipation for highest and lowest supported frequency at specified voltage.*

AMD Products Supporting AMD PowerNow!™ Technology

Table 4 lists all the ordering part numbers that support AMD PowerNow! technology.

Table 4.   All AMD-K6™-2E+ and AMD-K6™-IIIE+ Low-Power Processors Support AMD PowerNow!™ Technology

Ordering Part Number (OPN)[1] Enabled with AMD PowerNow!™ Technology	Package	Temperature (°Celsius)	Core Voltage Nominal V_{CC2}	Active Power[2] / AMD PowerNow!™ Technology Power-Saver Mode
AMD-K6-2E+/350xUZ	CPGA, OBGA	0°-85°	1.5 V	5.60 W / 2.95 W
AMD-K6-2E+/400xTZ	CPGA, OBGA	0°-85°	1.6 V	6.90 W / 2.95 W
AMD-K6-2E+/450APZ	CPGA	0°-85°	1.7 V	8.70 W / 2.95 W
AMD-K6-IIIE+400xTZ	CPGA, OBGA	0°-85°	1.6 V	7.10 W / 2.95 W
AMD-K6-IIIE+450APZ	CPGA	0°-85°	1.7 V	8.95 W / 2.95 W
AMD-K6-IIIE+500ANZ	CPGA	0°-85°	1.8 V	11.40 W / 2.95 W

Notes:

1. *An x in this column represents the package type. See the processor data sheet for a full description of ordering part number notation.*
2. *Active application power dissipation for highest supported frequency at specified voltage.*

Questions and Answers

Question: What AMD embedded processors support AMD PowerNow! technology?

Answer: All of the AMD-K6-2E+ and AMD-K6-IIIE+ low-power processors are equipped with support for AMD PowerNow! technology. AMD PowerNow! technology is not limited to any specific speed grade, package type, or core voltage.

Question: Is AMD PowerNow! technology backward-compatible with older AMD x86 based embedded processors?

Answer: No. AMD PowerNow! technology is only available on AMD's latest low-power offerings of the embedded family of AMD-K6 microprocessors, which consist of the AMD-K6-2E+ and AMD-K6-IIIE+ 32-bit processors.

Question: What's the lowest core voltage and frequency supported?

Answer: Currently, processors equipped with AMD PowerNow! technology can support a minimum core voltage at or above 1.4 V and operating frequencies as low as 200 MHz. Frequencies at or above 350 MHz require a core voltage above this minimum. AMD PowerNow! technology software is enabled with VID codes for core voltages as low as 0.925 V.

Question: What is "Automatic mode"?

Answer: Automatic mode is an automated mode under software control that is supported by AMD PowerNow! technology. Automatic mode allows for dynamic and immediate changes to be made to the processor's operating core voltage and frequency based on current application performance or power requirements. The marriage of power and performance is handled automatically through software control and operates free of any user intervention.

Question: How much power is saved by using the AMD PowerNow! technology?

Answer: In embedded application testing and benchmarking, AMD PowerNow! technology can cut power consumption from

11.4 W to 2.95 W for the highest performing AMD-K6-IIIE+ processor. This is an overall power savings of over 70%!

Question: Is the AMD PowerNow! technology easy to implement?

Answer: Yes. AMD PowerNow! technology is enabled and controlled through software in the embedded system's BIOS or OS. In the case of Microsoft operating systems, AMD PowerNow! technology state transitions are implemented through a driver provided by AMD.

Question: To date, what BIOS vendors support AMD PowerNow! technology?

Answer: Currently, Award/Phoenix has support for AMD PowerNow! technology in their mobile-based BIOS. Please refer to AMD's FusionE86[SM] partner list at:

http://www.amd.com/products/epd/desiging/fusionpartners/index.html

for updates to AMD's list of technology, support, and service partners.

Question: What operating systems include support for AMD PowerNow! technology?

Answer: AMD plans for all Linux-based operating systems to include support for AMD PowerNow! technology in the kernel of the OS. Several RTOS vendors will also support AMD PowerNow! technology in their operating systems. Microsoft operating systems like Embedded NT, Windows®98 and WinME can also be enabled with AMD PowerNow! technology through the use of a driver provided by AMD. An AMD CodeKit software package for AMD PowerNow! technology is available in CodeKit 42 at:

http://www.amd.com/products/epd/desiging/codekits/