WHITE PAPER

Paul Brohlin
IC Design Engineer,
Motor Lab,
Texas Instruments

Dave Freeman
Chief Technologist,
Power Supply Solutions,
Texas Instruments

Baher Haroun
Chief Technologist,
Wireless Business Unit,
Texas Instruments

TEXAS INSTRUMENTS

Driving innovation in energy efficiency and low power

Introduction

Technology innovation is pervasive and constant. It has revolutionized the world, through the era of personal computers, the explosion of the Internet, and today's mobility and connectivity in our homes, cars and literally everywhere. Vanishing are the days when access to a wall outlet is the only way to charge a device. Consumers demand the latest and greatest in mobility and functionality. We expect devices to run the most complex functions using the least amount of battery (or energy) possible. Innovations in energy efficiency and low power are enabling these demands today and are critical to sustain future advancements in emerging applications in areas like cloud computing, healthcare, security, transportation and more.

Many consumers probably don't even realize the actual energy cost for mobile devices. In 2006, it was estimated that the average customer of mobile operator NTT DoCoMo, one of the largest wireless providers in Japan, used about 70 watt hours (Wh) per day per mobile phone,[1] which is much more consumption than the four to five Wh the phone battery could provide.

Figure 1 demonstrates the expected data traffic growth through 2020 for the U.S.[2] Traffic is generated by phone call, text messaging, Internet data and so on. All these exchanges add up to trillions of bits (terabits) being moved. It takes large amounts of energy to move this data. Sending a terabit/s is estimated to require a quarter to half of a mega-watt hour. While we want the ability to send and receive more data, corporations and consumers are becoming more environmentally conscious. Building more electricity generation plants is not the answer. Rather, in order to support this growth in data traffic, more efficient use of energy must be developed.

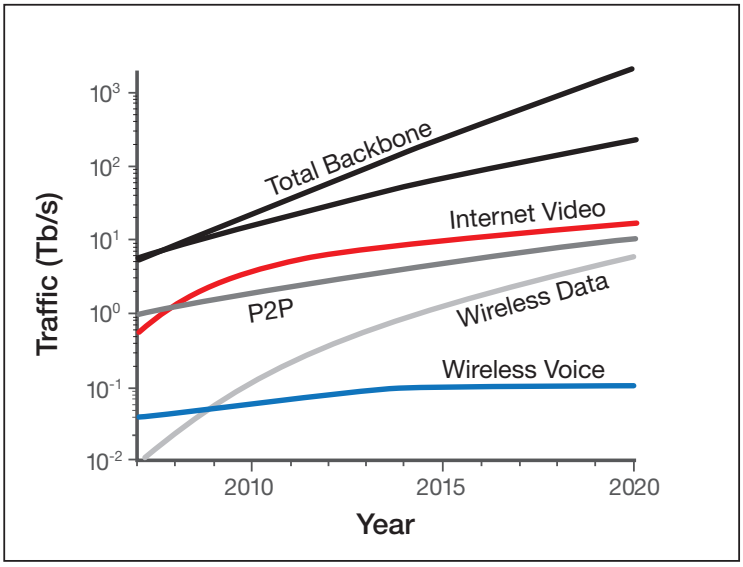

Figure 1. Aggregate network backbone traffic for North America.

Current and future directions

A combination of energy harvesting devices, more efficient power conversion and devices that consume less energy will help meet the innovation challenges described above for emerging applications such as wireless sensing, cloud computing and transportation.

Energy harvesting uses the available energy around us, including light, motion, vibration, radio frequency and even body heat to power sensor systems. A number of offerings available today are converting low-level ambient light into power for a variety of applications, such as light-powered wireless sensor networks that eliminate costly battery replacement. In the near future, energy harvesting solutions may also enable wireless patient monitoring by converting energy from body heat. Other applications, such as structural monitoring of bridges, can be enabled by the combination of harvesting energy from vibrations and very low power wireless sensors.

Beyond the mobility of devices, the growing role of cloud computing for all global transactions is driving a needed focus on energy efficiency and low power. If the Cloud represented a nation or country in and of itself, as seen in Figure 2, in 2007 it would have ranked number five in total energy consumption[3]. If we continue business as usual, the Cloud is projected to move up in energy consumption rank within the next decade.

And what that means, of course, is that we need to sustain the Cloud growth without growing its energy consumption. These energy efficiency improvements can come from many directions. Examples include improving the power conversion efficiency, improving the processor and memory efficiency, reducing the power loss in data transfer and developing more efficient software.

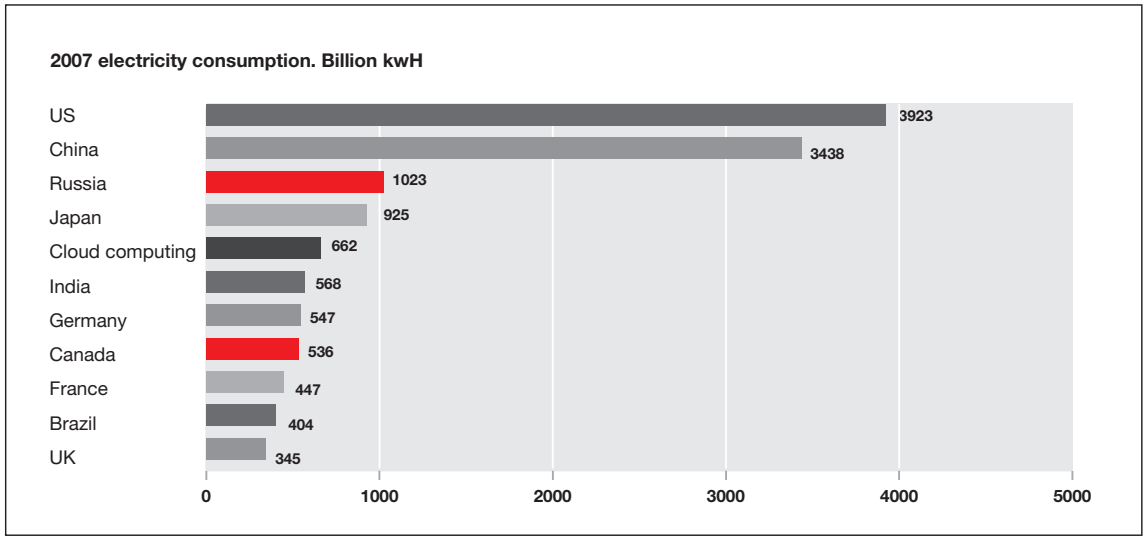

Figure 2. The energy consumption rate of Cloud computing (if it were a country) was ranked number 5 in 2007 and is growing today, underscoring the need for technology innovation to drive consumption down.

Power conversion efficiency for the Cloud encompasses many aspects. High efficiency Point-of-Load (POL) power supplies can regulate the voltage required by the processor needs. POL supplies improve efficiency by two means. First, power can be distributed at a higher voltage to reduce board transmission losses. Second, when processing requirement is low, the processor supply voltage can be reduced by the POL supply allowing the processor to run more efficiently.

Processor and memory efficiency can be attained in many ways. One way is to build the processors and memory in an advanced semiconductor process using lower voltages and smaller capacitances. However, the largest power impact is usually achieved by using specialized processors architectures which are very efficient at specific tasks, such as specialized video data compression and decompression cores.

Another area of power saving is to carefully change the supply voltage and speed of digital circuits to match the task at hand and then completely shut down once the task is finished. This careful use of computation resources reduces power consumed in standby due to leakage or unnecessary switching of logic gates.

Reducing power loss in data transfer is achieved by carefully choosing the methods for which bits are encoded, signaling level and type of connections used and the physics of the transmission medium (copper wire/transmission line, optical cable, or even a wireless link.)

More efficient software can reduce computation, storage and the amount of bits transmitted, improving the system's efficiency.

Energy efficiency – part of TI's foundation

Texas Instruments has a long history of innovation in low power and energy efficiency, starting with a solar powered calculator in the early 1980s, and a solution for a hearing aid customer that required a low power digital signal processor (DSP) in the mid 1980s. The need to maximize operational time while proving greater functionality and extended battery life has continued since that time.

Work in these areas was extended as TI began developing power-efficient solutions to serve the needs of cell phone manufacturers. Today, TI is the leading provider of power management chips. To meet our customers' needs and continually innovate to the next level of low power and energy efficiency, we take a systems approach throughout the entire signal chain. This is required to best optimize low power and energy-efficient applications.

Examples of innovative approaches to energy efficiency abound in TI's analog, embedded processing and wireless products. The need for that innovation – the requirement that efficiency always be a top priority of every product design and every product idea – is driven home across every area of the company, from product development and design and the process technologies that serve as their foundation, to packaging and manufacturing and software development (Figure 3). TI is also pioneering research in our labs, and through collaboration with industry consortia, university research and development partners.

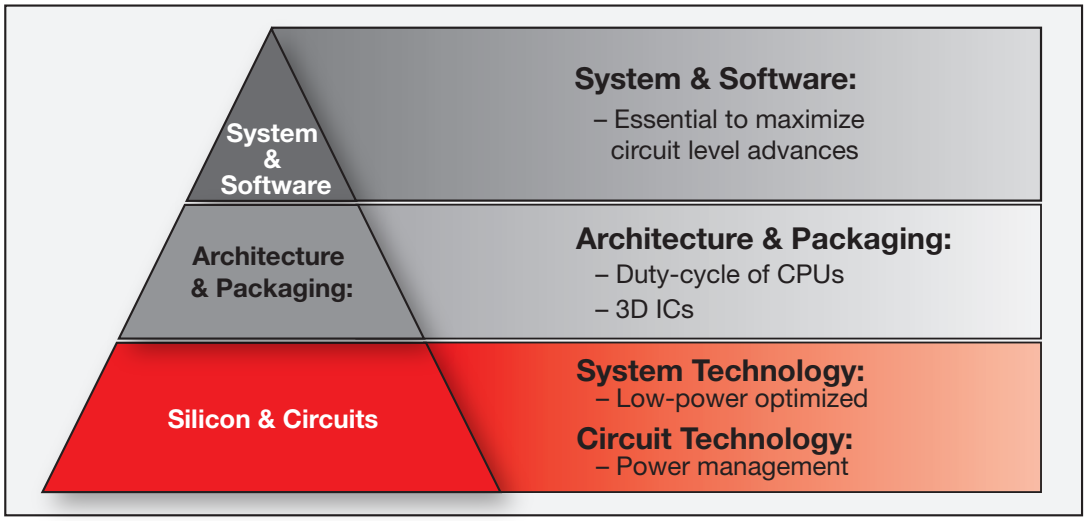

Figure 3. From circuit technology to systems and software, TI considers energy efficiency when developing semiconductor solutions across its entire portfolio.

How it works

There are many ways to measure energy efficiency: power in versus power out, calculating the energy necessary to quickly move one bit of information from one place to another, or determining the energy to convert analog signals to digital information. TI engineers and designers continually evaluate product performance versus energy consumed to optimize product efficiency.

Energy conversion is an important component of any solution. The ability to provide efficient energy conversion solutions at various power levels is key. For example, converting energy from micro-power sources requires nana-powered solutions so the harvested energy is not totally consumed by the conversion. In other cases, efficient energy solutions are needed across a broad load range for applications that only need full power during short periods of operation and can go from light load to full load in a short amount of time. Lastly, many systems derive their electrical energy from high voltage sources like the AC line, so the energy conversion needs to be able operate from high voltage while maintaining high efficiency.

The efficiency metric of determining the energy needed to move a single bit from one place to another is important – whether the product is a sensor, a cell phone, or a server or the Cloud. This data path may be wired or wireless. As you can imagine, the energy per bit is quite different depending on the transfer medium. Parameters for this metric include the distance and bits per second. An increase in either of these parameters will increase the energy requirements. The optimized solution will meet the goals of distance, bit-rate and energy constraints while maintaining optimal error rate.

Another component in total system efficiency is digital computation efficiency. As the expectation of processing and presenting greater amounts data evolve, the energy demands change. The goal is not to do less but do more with less. Computations are required every time data are touched, from complex signal-processing functions, to data searches, to image analysis or image compression. This is yet another area in which TI products are prominent players.

Summary

Application-driven roadmaps will continue to define what we do at TI, as we move into greater mobility, connectivity, and the immersive environment. Innovation in energy management and doing more with less is critical for the success of our customers. TI's strengths will help transform the next generation of products to deliver the right balance of performance and energy use required to meet future needs.

For more on TI innovation in energy efficiency and low power:

- Visit TI's innovation web page: www.ti.com/energy-wp-lp
- Register for the myTI newsletter to get updates on TI technology innovations based on your preferences: www.ti.com/energy-wp-myti
- Check out TI's energy web page: www.ti.com/energy-wp-lp2
- Share knowledge and ask questions in TI's E2E™ community: www.ti.com/energy-wp-e2e
- Read up on energy efficiency trends in TI's PowerHouse blog: www.ti.com/energy-wp-phblog

References:

1. Minoru Etoh, Tomoyuki Ohya, and Yuji Nakayama "Energy Consumption Issues on Mobile Network Systems"
2. Bishop, David; Hartman Adrian; Kilper, Daniel; Korotky, Steven; Suvakovic, Dusan. "Energy Efficient Networking: Avoiding a Future Energy Crunch"
3. Cook, Gary; Van Hor, Jodie. "How Dirty is Your Data? A Look at the Energy Choices That Power Cloud Computing." Greenpeace.org. Retrieved from http://www.greenpeace.org/international/Global/international/publications/climate/2011/Cool%20IT/dirty-data-report-greenpeace.pdf

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Mobile Processors	www.ti.com/omap		
Wireless Connectivity	www.ti.com/wirelessconnectivity		
	TI E2E Community Home Page		e2e.ti.com

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265