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INTEGRATED POWER MANAGEMENT FOR MICROSYSTEMS

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Integrated Power Management for Microsystems

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There is a need for a universal power module for microsystems. This module should provide power conditioning, energy storage, and load matching for a variety of energy sources and loads such as microelectromechanical systems (MEMS) and wireless sensors and micro-robots. There are a variety of potential ambient and human powered energy sources, which can supply some of the power needs of the military. The challenge is to capture these available sources of electrical energy and condition them to meet the voltage, current, and overall power demands of field-deployable microelectronics and MEMS-based devices such as wireless sensors and micro-robots. Most natural and man-made energy sources found in the environment have a low specific power and are not generally available on a continuous basis. Likewise, human-based energy sources must be optimally managed to meet the power needs in the field. Therefore, a power supply must have the ability to capture the available energy and store it in such a manner to be useful to meet the mission requirements of the device that is connected to the source. It must continuously monitor the status of energy stored and determine the expected demands of the device. A microelectronics-based power management chip can be developed to meet these objectives.

The major challenge in realizing this concept will be the design of an intelligent power-conditioning chip that consumes a minimum of power to perform the functions of power conditioning, storage, load matching, and status monitoring.

For a versatile chip design that can use a variety of energy sources, it is important to not constrain the energy source characteristics unduly. One suggested approach assumes only that the source is capable of delivering charge to a small capacitive load. This would be true for photovoltaic, piezoelectric, rotary or linear electric generators, thermoelectric and many other sources. As shown in Fig. 1, the resulting source voltages are monitored, and when a sufficient value is present, the power converter will multiply the voltage up to the storage supply voltage and transfer it to storage. The storage element may be an ultracapacitor or rechargeable battery. Power would be delivered to the load through another switched capacitor circuit. This would allow metering of the power delivered to the load and, if needed, a voltage transformation. The metering function could also be used to help keep track of the amount of energy remaining in the storage element. A reserve energy storage element would be used to maintain power for the intelligent power controller, which is responsible for administering power transfers and for monitoring the demand signal from the load. It is anticipated that the load may require some very low level of power continuously (for a wake-up circuit, for preventing loss of memory, etc.), so an unswitched low-power output is provided. When the demand signal from the load signals a request for significant power, the intelligent power controller replies using the power status signal. If sufficient power is available in the storage element, then the power status signal is true and power is transferred to the load until the demand ceases. Another function of the intelligent power controller is to recharge the reserve energy storage element periodically.

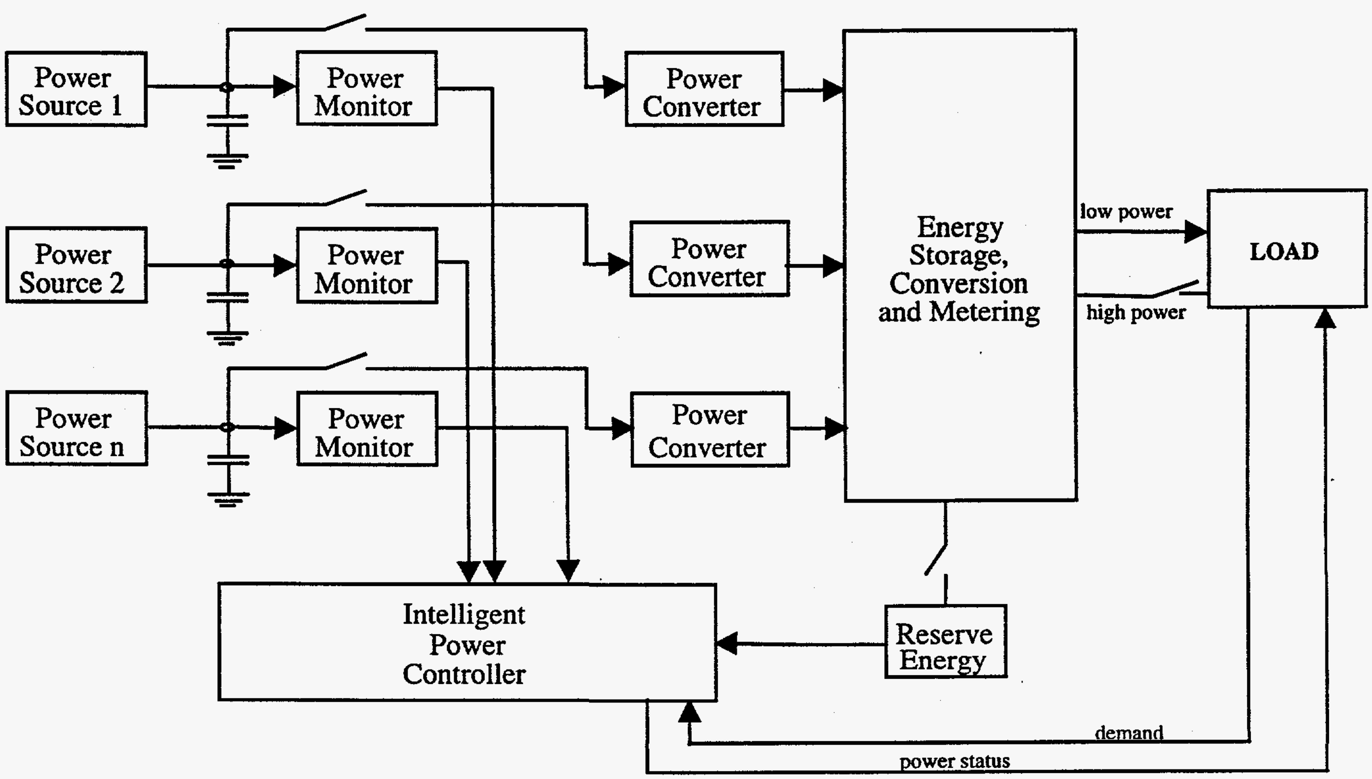

Fig. 1. Concept of power conditioning chip

The power conditioning integrated circuit (IC) would be implemented using CMOS technology. Integrated circuits fabricated using standard CMOS processes offer a number of features well suited to this application: digital circuits that require essentially no static power, low-power analog circuits, and good switches that are necessary for switched capacitor circuits. It should be possible to implement the entire circuit using a single IC with a very limited number of external components (such as capacitors too large to implement on the IC, i.e., those greater than a few tens of pF.) A prototype device would be made using a 1.2 or 0.8 micron process that would allow 5-V operation. This choice should not be restrictive as the same circuit could be converted to other CMOS processes. Processes of 0.5 micron or smaller would allow a greater density of logic for a given die size, but would be limited to 3.3-V operation. To deliver greater voltages to the load, a 3-micron process could be used which would allow approximately 20-V operation, or external components could be added to implement a boost dc-dc converter.

The prototype power conditioning IC would be capable of delivering a peak power of 100 mW at 5 V. The nominal operating condition would be a very low duty cycle for a relatively high power load, and a low-power source available for long periods of time, or a moderate-power source available intermittently. An example would be a wireless sensor and transmitter requiring 100 mW for 10 ms every 10 minutes and a source delivering perhaps five microwatts continuously. However, the device should also be capable of delivering approximately 100 mW continuously if sufficient power is available from the sources. Scaling for higher power outputs would be addressed by including features that would allow using multiple devices in parallel, or by resizing power sections of the IC to allow greater power input and output levels.

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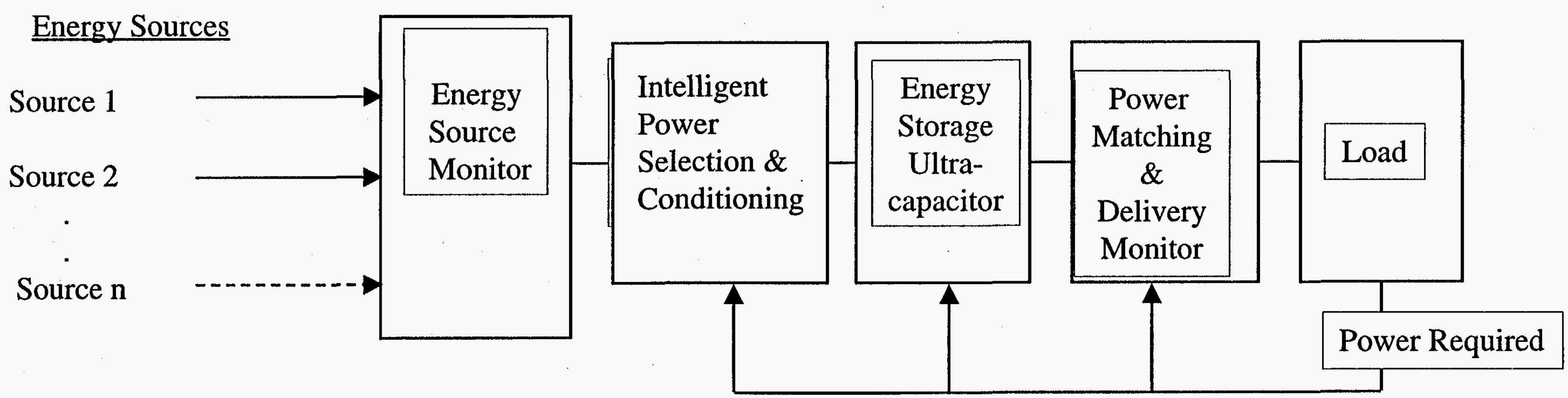
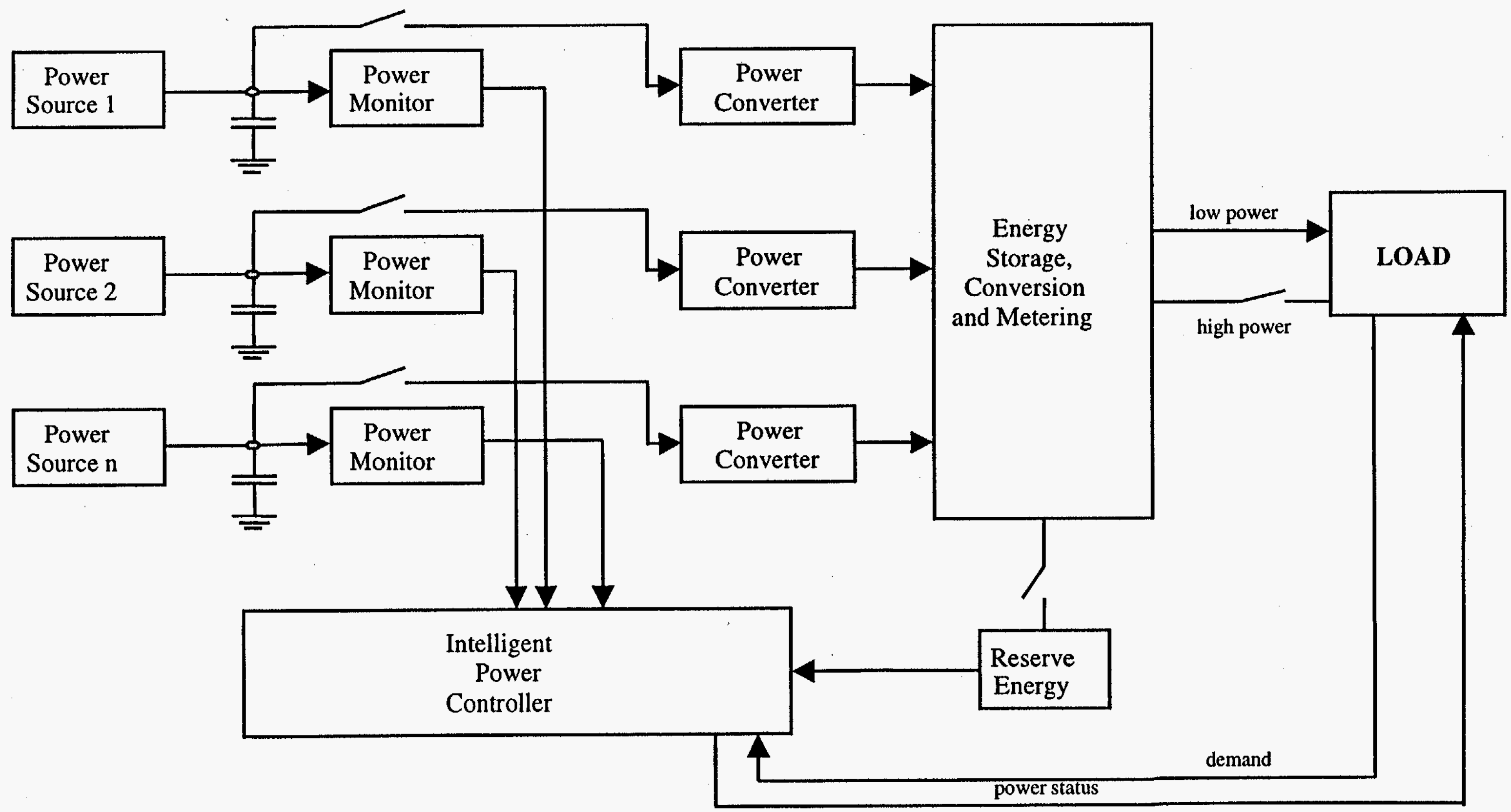
Universal Power Module Will Condition a Variety of Energy Sources and Match to a Variety of Loads

- Most energy sources do not naturally produce suitable power for the load, i.e.. proper voltage level
- Most human powered energy sources are intermittent and have a low specific power
- A number of loads such as wireless sensors and transmitters require power on an intermittent basis
- Intelligent power module will capture energy, store, condition the energy to proper voltage, and deliver to load on demand

Concept of An Integrated Intelligent Micropower Supply



Concept of Power Conditioning Chip



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The Universal Module Performs Several Functions

- Power monitor determines status of charge collected from energy source
- Power converter converts charge to voltage for storage
- Storage medium also matches to load requirements and keeps track of available stored energy
- Intelligent controller administers power transfer to load and monitors demand signal from load
- Reserve energy supplies power to intelligent controller

The Power Module Could be Implemented on a Chip Using CMOS Technology

- CMOS digital logic circuit requires essentially no static power
- Capability of low-power analog circuits
- Provides good switches
- Five volt operation possible with 1.2 or 0.8 micron process
- Twenty volts with 5 micron process
- Peak power delivery approximately 100mW at 5 V
- The concept should be scaleable depending on load power requirements

Our First Fully Integrated Wireless Data-Acquisition Chip

- Two Thermometers
- Two Uncommitted Inputs
- 10-bit ADC
- Control Logic
- Spread-spectrum Radio-frequency Transmitter