Evaluation Form – Technical Background Review

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_____ / 30 Technical Content

- Current state-of-the-art and commercial products
- Underlying technology
- Implementation of the technology
- Overall quality of the technical summary

_____ / 30 Use of Technical Reference Sources

- Appropriate number of sources (at least six)
- Sufficient number of source types (at least four)
- Quality of the sources
- Appropriate citations in body of text
- Reference list in proper format

_____ / 40 Effectiveness of Writing, Organization, and Development of Content

- Introductory paragraph
- Clear flow of information
- Organization
- Grammar, spelling, punctuation
- Style, readability, audience appropriateness, conformance to standards

_____ / 100 Total - Technical Review Paper

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Power/Battery Technology for Low-Power Embedded Devices

Introduction

Modern electronics have been seeking higher efficiency in all aspects. One of the most important criteria for increasing the value of the device is the power consumed by the device. As manufacturers move toward environmentally friendly green computing and clean energy concepts, they must design the circuits more power-efficient. When designing a battery-powered device, the low power consumption of embedded systems is an important factor. To design a low-powered embedded device, engineers have to choose a cost-efficient power supply and selecting a suitable microcontroller unit or Raspberry Pi.

Power Supply

A power supply is one of the most important components in embedded system design. In the beginning, the embedded device's power budget or limit needs to be determined. For example, the device should not consume more than 500mA, or it should not operate above 5 V. To estimate the power consumption, a block diagram with all the components and their power consumption should be created. Besides, it is better to keep the overall operating voltage low for the whole board since power consumption is directly proportional to the operating voltage, whether it is a battery input or a DC input from a power supply adaptor. For example, if all the circuitry on the board is powered by 5 V or 3.3 V then using a 6 V power input is better than using a 12/24 V DC input or battery input because power loss will be proportional to voltage difference [1]. Based on the type of power consumption, embedded systems are classified into two types: portable and non-portable. Portable devices have a built-in battery that can be recharged, such as digital cameras, GPS systems, smartphones, etc. Lithium-ion batteries are widely used in portable devices because of its highly robust charge-discharge cycle [2]. In contrast, non-portable devices require continuous connection to a power source, so they usually don't have to worry about power consumption as much as portable devices.

Non-rechargeable Battery

One of the battery options for embedded applications is non-rechargeable batteries. They are the most common batteries on the market, and they are relatively inexpensive for the designer to use. Military in combat, light beacons and remote repeater stations also use these batteries because charging is not practical. Comparing different types of non-rechargeable batteries, AAA cell has the lowest capacity, lowest cost per cell, and lowest energy, but the highest cost per kWh, while D cell has the highest

capacity, highest energy, and highest cost, but the lowest cost per kWh [5]. It can be seen that the energy cost from non-rechargeable batteries is high and increases with smaller battery sizes and systems with high energy densities. The key advantage of the non-rechargeable battery is that it is immediately available [4], very cost-effective in the short-term, and suitable for a broad range of low-power devices that it is essentially the default option for many people.

Lithium Battery

A lithium battery is another candidate for the power supply because it has the greatest electrochemical potential and provides the largest specific energy per weight, it is also the lightest of all metals [3]. In 1994, the cost to manufacture Li-ion in the 18650 cylindrical cell was over $10 and the capacity was 1,100mAh. In 2001, the price dropped to below $3 while the capacity rose to 1,900mAh. Today, high energy-dense 18650 cells deliver over 3,000mAh and the costs are dropping [3]. Cost reduction, specific energy increase, and non-toxic substances are making lithium-ion batteries a universal battery for portable applications, heavy industry, electric powertrains, and satellites.

Solar Energy

In the future, the power supply for electronic devices is likely to be obtained from more environmentally friendly technologies (such as solar energy) [2]. However, solar energy is ecologically sustainable and lacks the same power density as ordinary electricity. In this case, the equipment is expected to work efficiently under any circumstances. Since the heat must be kept to a minimum, power is further lost.

Microcontroller/Raspberry Pi

If the power consumption of the MCU is quite large compared to the overall power consumption of the embedded board, choosing the right low-power MCU is essential. For instance, if the power consumption of the circuit board is 500mA, and an ordinary MCU consumes only 10mA (accounting for 2% of the total current) [1], then spending too much energy on the MCU with the lowest power consumption will not bring any significant impact. Choosing the right peripherals or controlling its power supply through proper hardware and code flow control may bring greater savings. The necessary inference of the switching speed's contribution to MCU power consumption is the number of gates, especially the circuits used in specific applications. All other things being equal, the more gates you switch, the more current the device consumes [6]. This partly explains why 32-bit MCUs generally consume more active power than 8-bit MCUs because there are more gates are switching during active operation

Option 1: Texas Instrument MSP432

The Texas Instrument MSP432P401R Microcontroller includes a 32-bit 48MHz ARM Cortex-M4F, 80uA/MHz active power, and 660nA RTC operation, SAR Precision ADC with 16-bit performance and 40 pin BoosterPack Connector, and support for 20 pin BoosterPacks [7]. The cost of this MCU is $19.99 if ordered directly from Texas Instrument. This MCU has a Real-Time Operating System, high speed of conversion (1 Mega Samples Per Second), multi-threading (allows for concurrent execution of multiple tasks), low power consumption (ULP Bench score of 167.4, best in its range of microcontrollers), flexible clock (total of five different clocks are available), and an address space of 4GB memory [8]. It is designed to optimize performance without compromising power, while only consuming 95uA/MHz in active power and 850nA in standby power [10]. With RTOS, this MCU will be able to perform time-critical tasks before the maximum allowable delay, which is very critical for real-time systems. It uses interrupt handlers and timers instead of busy loops of other microcontrollers.

Option 2: Raspberry Pi Zero W

Raspberry Pi Zero W equip with 1GHz single-core ARMv6 CPU, Video Core IV GPU with 512MB RAM, HAT-compatible 40-pin GPIO header, 2.4GHz 802.11n wireless LAN, and Bluetooth 4.0 [9]. Raspberry Pi Zero W is the smallest and cheapest ($10) Raspberry Pi computer. Even though it is tiny in its size, it can still run the same Raspbian OS (based on Linux) as other Raspberry Pi computers. With built-in wireless LAN, Bluetooth, a mini-HDMI, and a micro USB connector, this small MCU can implement multiple input/output options.

Conclusion

Although non-rechargeable batteries are the most common and inexpensive option for design choice, the lithium battery outweighed non-rechargeable batteries because the energy delivered by lithium battery is much greater than the non-rechargeable battery. The Texas Instrument MSP432P401R Microcontroller has a much lower power consumption than Raspberry Pi Zero W, but it is also more expensive. In the design process, if the designer wants to include IoT features, Raspberry Pi Zero W will have a higher advantage than MSP432 because Pi Zero W already has built-in wireless LAN and Bluetooth. The final component selection will depend on different trade-offs.

Reference

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