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Enabling flexibility in low voltage & battery-powered applications

Source: Microchip

The demand for extremely low power technologies has been an increasing requirement for handheld battery- powered devices. Consumers are demanding a better experience from battery-powered devices with more lifetime and better portability. This in turn, is driving the need for microcontrollers that can operate with lower power and at lower voltages.

Energy sensitive applications, in particular, are now driving demand for unprecedented hours of use from a single battery, measured in years and days rather than hours. Meeting this demand requires integrated devices that have been developed in synergy with the characteristics of lower supply voltages, battery power, and how the application will operate.

Which battery?

Battery selection is crucial to the success of a product. It affects the ergonomics of the product (size and weight) and is crucial to meet the needs of the power drain of the application itself. There are many different types of batteries, each with unique characteristics that define their usage. Here are a few common battery types used in portable applications:

1. CR2032 – Lithium/Manganese dioxide Cell, 3.0V, 3.0g, 225mAH, Low Drain
2. AAA – Alkaline Cell, 1.5V, 11.5g, 1200mAH, High Drain
3. AAA – Lithium Cell, 1.5V, 7.6g, 1200mAH, Highest Drain
4. AAAA – Alkaline Cell, 1.5V, 6.5g, 625mAH, Medium Drain

For the commonly used CR2032 lithium/manganese dioxide cell with a nominal (on load) voltage of 3.0V, the self-discharge current can be as little as 250nA. This type of battery is small, thin and has limited drain capabilities. To achieve maximum battery life, the application must use a microcontroller solution that is capable of operating well under the 1uA range during sleep modes. Many people choose to use the CR2032 in handheld applications as it is small and can power an MCU directly, with its 3.0V nominal voltage dropping down to 2.5V. Unfortunately, this reduces the potential battery life of the device, as it has a capacity of only 225mAH. The CR2032 is not capable of sourcing high drain currents, like those you find in lighting, games and digital audio applications.

Another choice would be to use alkaline batteries: the AA, AAA or the new AAAA. Two of these together (2 x 1.5V) would give the desired 3V MCU supply voltage and a much bigger capacity for increased battery life. Unfortunately, these come at the expense of much larger dimensions and can adversely affect the ergonomics of the product packaging. There is now a need for being able to use a single cell alkaline for the combination of small form factor and high drain capability.

Single alkaline cell vs V_{DD} of less than 1.8V

Some applications require a battery with a high drain capability, like lighting, motor movement and digital audio. This would require the need for a higher drain battery like an AA or AAA alkaline cell. If there are form factor restrictions (meaning only a single cell can be used), there is now a solution to enable the designer to get the best of both worlds – small and high drain. This gives the designer a greater choice of batteries and flexible V_{DD} options.

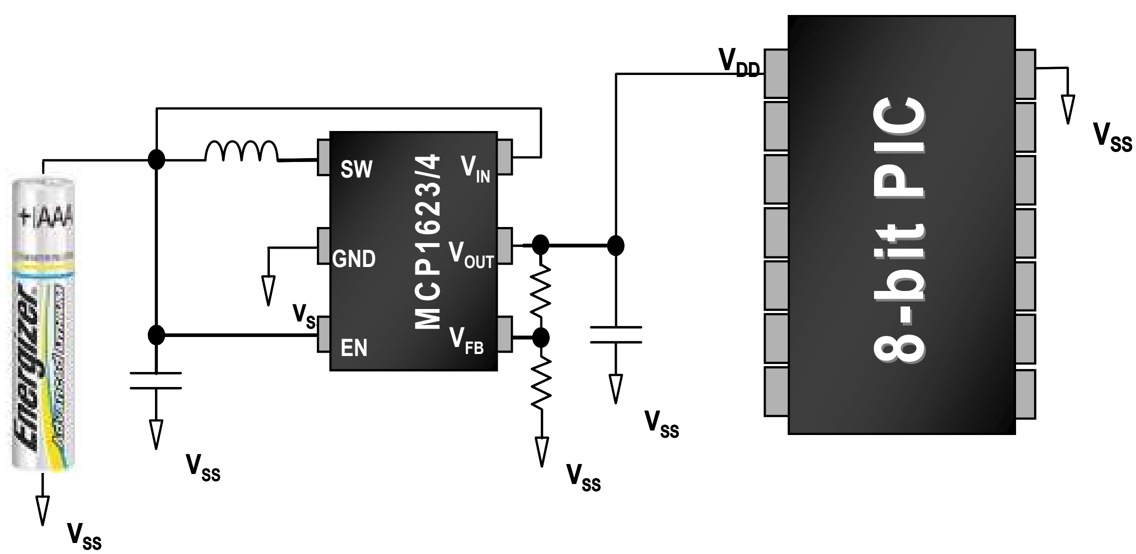
MCU voltage range requirements

The MCP1624 synchronous boost regulator enables any PIC microcontroller to be powered from a voltage of 0.65 to 1.8V. This means that any PIC MCU can be powered from a single Alkaline AA, AAA or AAAA cell. The MCP1624 boosts the lower voltage up to a usable 2.0 to 5.5V MCU supply range. It needs a startup voltage of 0.65V, but can maintain operation down at 0.35V. And it features a shutdown voltage of less than 19uA, helping to reduce battery load when the application is in a sleep or standby mode.

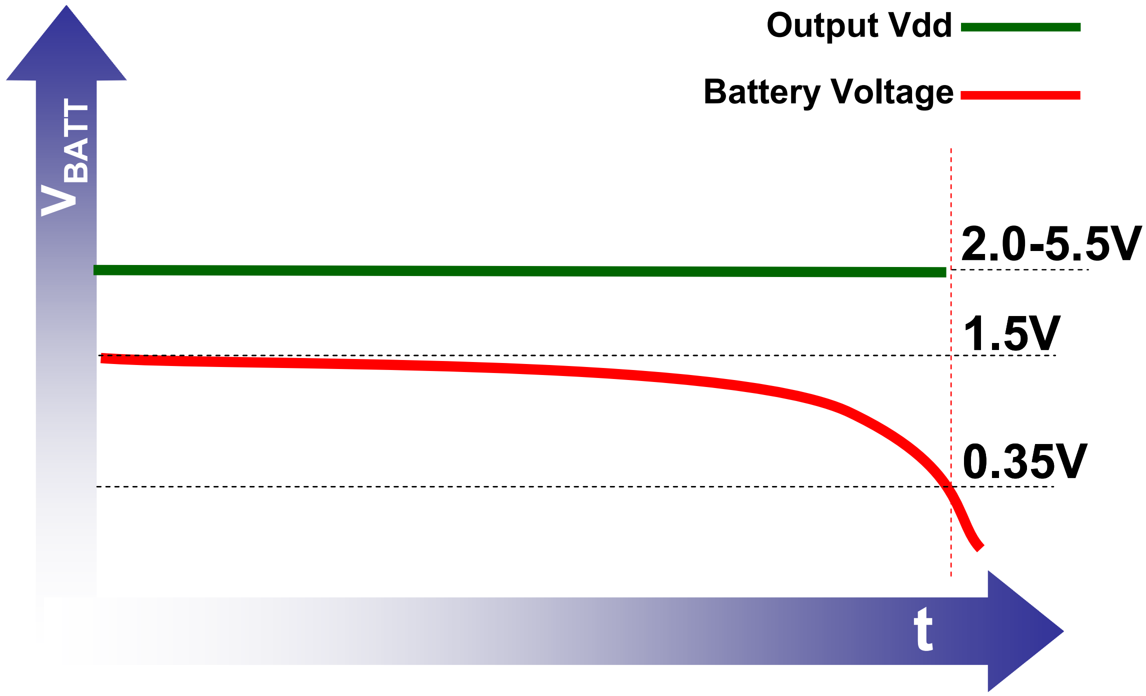
Package size and extra components

The MCP1623/4 Boost Regulators come in a small footprint 6-pin SOT-23 package and only require a small inductor, two capacitors and two resistors externally. Being able to power an application from a single alkaline cell, means there is the ability to have smaller form factor design with a high drain capability. This solution to the low voltage V_{DD} problem also means that the designer has the choice of any PIC MCU. It can also be used to provide a 3V supply for other components in the circuit, like an LCD.

MCP1623/4 Single Cell Reference Implementation



MCP1623/4 Operation Curve of V_{BATT} vs. V_{DD} (Output) over Time



Maximizing Battery Life

Average current drawn over the lifetime of the battery is what determines the battery life. The average MCU current drawn is defined by the average of the sleep or standby current and the run or active current. The time spent in each mode has a large effect on the battery life.

To extend battery life, the following simple design rules need to be followed:

1. Lower Sleep or Standby current
2. Lengthen the time spent in Sleep/Standby mode
3. Lower Run or Active current
4. Shorten time spent in Run/Active mode vs. Sleep/Standby mode

Microcontrollers which feature eXtreme Low Power technology help extend battery life. XLP technology-based microcontrollers have very battery-friendly features:

- Extremely Low sleep/Standby currents
    - Sleep currents of less than 100nA and as low as 20nA
    - This lowers average current especially with longer sleep/standby periods
- Industry leading Run/Active currents
    - Dynamic currents as low as 48uA/MHz
    - Operating in Run/Active mode with currents this low, has the effect of keeping MCU average currents lower than the competition
- Full operation of integrated analog and digital peripherals down to 1.8V
    - Being able to utilize the MCU all the way to the end of the battery life (down to 1.8V) really maximizes the battery life of the application
- Instruction Set Architecture
    - More single cycle instructions mean tasks can complete quicker and there is less time spent in active mode
    - The PIC instruction set is very efficient with between 80-90% single cycle instructions. Many competing MCUs have fewer than 40% of single cycle instructions, lengthening time in active mode
    - This also means the frequency can be lowered to do the same task in the same period of time. This means that the V_{DD} can be lowered, which is a huge contributor in power consumed
- Peripheral control is another method for enabling lower power
    - Unused peripherals (in Sleep or Active modes) can be switched off when not needed.

Battery Example Comparison: CR2032 + PIC MCU vs. AAA + PIC MCU + MCP1624

	CR2032	AAA	Verdict
Size	20 x 3.2mm	10 x 44mm	CR2032 smaller
Weight	3.0g	11.5g	CR2032 lighter
Capacity	225mAH	1200mAH	AAA 5 x Better
High Drain Capable	No	Yes	AAA suited for high drain
Price	$0.20	$0.20	Price Parity in Volume

The example application is a simple low power clock with temperature and battery voltage monitoring, running from a 32 KHz watch crystal. It displays the time, temperature and battery voltage on a small LCD.

Alkaline Cell + PIC MCU + MCP1624 Circuit

The average run current for this circuit including the MCP1624 and LCD is 200uA. If the circuit were active 100% of the time, the battery life of the application would be:

Battery Life (Hours)	**= Capacity/Average current**
- AAAA Battery Life	= 625mAH/200uA = 3,125 = 130 Days
- AAA Battery Life	= 1200mAH/200uA = 6,000 = 250 Days
- AA Battery Life	= 3000mAH/200uA = 15,000 = 625 Days

CR2032 + PIC MCU Circuit

The average run current for this circuit including the LCD is 60uA. If the circuit were active 100% of the time the battery life of the application would be:

Battery Life = Capacity/Average current
Battery Life = 225mAH/60uA = 3,750 = 156 Days

This example shows that the single cell AA or AAA Alkaline + MCP1624 is a viable alternative to CR2032, if the form factor does not need to be the smallest and lightest. The Alkaline capacity overcomes the higher current drain from the boost regulator. The MCP1623/4 products now enable designers to have a much broader choice of battery power in their handheld applications.