Ultracapacitors Help Revolutionize Common Plumbing Tools And Procedures

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Superior Tool Company, manufacturers of professional plumbing equipment for over 50 years, wanted to design an automatic pipe-cutting tool to replace the old-style, manual tubing cutter that had been in use for decades. To adequately replace the old-style cutter and gain product acceptance from plumbers, the company knew it needed to find a battery-like solution that would provide sudden bursts of high power and offer a longer life than what conventional battery systems could offer. Ideally, because plumbers can make up to 100 cuts in one working day, the power cutter would need to store power and recharge quickly, with lifetime capable of performing at least a hundred cuttings before the need to recharge. To provide mobility, the solution would need to be cordless, but with greater power performance than battery only cordless power tools on the market.

Ultracapacitors were then evaluated for implementing in parallel with batteries as a means of supplying the initial peak loads rather than the battery. Trials with this methodology enabled a significant improvement in battery life with all chemistries tested and enabled the ability to design the product with alkaline batteries. After several tests with a variety of power options, Superior chose to design with San Diego-based Maxwell Technologies' BOOSTCAP® ultracapacitors together with a battery. Trials with this methodology enabled a significant improvement in battery life with all chemistries tested and enabled the ability to design the product with alkaline batteries. The solution was developed in conjunction with Maxwell Technologies, and their marketing and distribution partner, Tecate Industries, a division of the Tecate Group headquarters in Poway, California.

Plans were made to produce tools capable of using either primary alkaline cells or rechargeable NiMH cells. The initial target specification for the cutting tool necessitated a ½" copper pipe to be cut in less than 10 seconds with the ability to make at least 100 cuts utilizing either primary alkaline cells or rechargeable NiMH cells as the energy source. Lab testing determined the work required to cut a piece of ½" copper tubing in ten seconds to be on the order of 50 watt-sec. Initial calculations determined four series connected alkaline AA cells could provide the

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necessary energy. A typical alkaline AA is rated at 2500 mAH. Assuming 33% efficiency, four cells can produce roughly 54,000 watt-sec yielding 360 cuts. What was not considered in the initial calculations was the internal impedance of the alkaline cells and the high initial current load demanded by the cutting tool. With the typical internal impedance of a AA alkaline at 200 mOhms and a peak load current draw between 4 and 5 amps, it was quickly determined the initial voltage drop rendered the tool inoperable. It was determined as a rule of thumb that peak currents higher than 0.5 A were too demanding and caused undesirable affects on the battery sizes required for this application.

All battery chemistries were then investigated and/or tested. In primary cells, life and capacity are equivalent. At four amps however, it was determined AA alkaline cells produce a small fraction of their rating. In rechargeable NiMH cells both capacities per charge and life cycles decline as current increases. Lithium cells tend to be internally protected against high power demands to avoid excess cell heating. Conventional lithium ion rechargeable cells (for example the cells used in laptop computers are rated below two amps.) are also limited in power. Recently, some of the major professional power tool manufacturers have come out with new technology lithium cells. These are adequate in environments where power and energy storage are needed but not economical in a tool that is only actually cutting five minutes per day.

Testing with NiMH versions quickly necessitated a six cell battery configuration. After testing the device it was determined a ten second cut was too long from a user perception stand point. The cut time specification was reduced to under 5 seconds. The idea of ultracapacitors was introduced to the team based on their use in vehicle applications as a solution for limitations of batteries supplying and absorbing energy quickly due to their relatively high impedance. Maxwell Technologies was contacted to determine the viability of this approach for the present application.

Ultracapacitor/battery parallel arrangements were tested with the new requirements of less than 5 second cut time. Initially, alkaline cells tested alone produced under 10 cuts at much longer times than 5 seconds. Applying ultracapacitors in parallel enabled the alkaline approach to provide the design goal 100 cuts with 3-5 second cut times. This was a phenomenal change in performance brought about by allowing the ultracapacitors to shield the high currents from the battery. Less dramatic although impressive improvements occurred with the NiMH battery. The number of cuts between recharges was increased by over 30%. It is anticipated that the life would be more than doubled due to the reduced peak current demanded by the battery. With these results it is clear the addition of ultracapacitors to the design enable the application specifications to be met.

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The final design (patent pending) includes three 10F, 2.5V ultracapacitors in series. A schematic is provided in figure 1. This allows 6 alkaline cells and the three ultracapacitors rated up to 7.5 V to be placed in parallel. Load balancing resistors (R1-R3) are placed in parallel with each ultracapacitor. This is provided to ensure equal voltage distribution across the ultracapacitors. The value of the resistor is chosen to ensure that any variations in internal leakage current of the ultracapacitors will be overwhelmed by the balancing resistor. The battery life extension is due to the fact the ultracapacitors buffer the high current from the batteries. A DPDT on/off switch (S1) disconnects the ultracapacitors from the battery and from the load. This extends the life of the ultracapacitors and eliminates the possibility of the tool being started inadvertently since the run switch is designed for easy access. Decoupling the ultracapacitor from the battery allows the ultracapacitors to slowly discharge and prevents the batteries from feeding the continual current draw that would result due to the balancing resistors. The implementation of this design has allowed the use of smaller capacity battery cells enabling reduced cost, size and weight of the tool and charger (or elimination in the case of alkaline), It has also allowed a class of high power/energy cordless tools to be realized that was not previously economical for consideration. The final product is illustrated in figure 2.

Customer Profile

Superior Tool Company is a manufacturer of professional quality plumbing tools. For over 50 years, the have offered customers worldwide professional quality, innovative products. The company focuses exclusively on plumbing tools and problem solving plumbing products.

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Figure 1: Battery/ultracapacitor schematic for cutting tool application

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Figure 2: UltraCut™ cordless tubing cutter

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