Battery Chargers:
Getting Energized About Efficiency

A battery charger system converts mains-voltage ac electricity from a wall outlet into lower voltage dc electricity that is carefully supplied to a rechargeable battery, where it is further converted into chemical energy and stored for later use. Battery charger systems are used in a wide range of products and differ mainly in capacity (the amount of power that is meant to flow through the charger when it is recharging batteries) and battery chemistry. Four battery chemistries currently dominate the market, including: nickel-cadmium (NiCd), nickel-metal hydride (NiMH), lithium-ion (Li-Ion), and lead acid (LA).

In just the last two decades, product convenience has improved by leaps and bounds with the growth of an entirely new family of products that incorporate batteries instead of relying always on the wall plug to supply electricity. Laptops, cordless tools, electric golf carts, forklifts, cordless phones, electric toothbrushes, portable music players, cell phones – all are dependent to some extent on rechargeable batteries. Some estimates suggest there are 15 battery chargers per household in developed countries! These products offer substantial economic and environmental advantages over products powered by throwaway batteries and are more convenient than corded or gasoline-powered products. However, every rechargeable battery-powered product wastes some amount of energy in the process of charging a battery – energy that cannot be used by the product, but which still appears on the user's electric bill and results in increased air pollution from power plants.

A Closer Look at Battery Charger Systems

Battery charger efficiency is evaluated by power use during three distinct modes. The first is charge mode. This is the time when the battery charger is actively charging a connected battery. Efficiency during battery charging is largely determined by the efficiency of its power supply (see 'Ac-Dc Power Supplies' report). There are differences in charge efficiency associated with different battery chemistries, but the chemistry choice is influenced strongly by cost and performance, so it will not be explored in this report. Once the battery is fully charged, the battery charger enters the second mode of operation: battery maintenance mode. Battery chargers usually consume less power in this mode than when they are actually charging, but some inexpensive consumer

appliances continue to draw almost as much power while maintaining charge as when they are actively charging.

In no-battery mode the battery is physically removed from the rest of the product, however the charging components may remain energized. This might occur, for example, if someone leaves their cell phone ac adapter plugged in by their nightstand so that they can charge their cell phone when they go to bed. The ac adapter will continue to draw power from the wall outlet during the day even when disconnected from the cell phone. Estimates suggest that approximately 85% of the total energy used by battery chargers is consumed when *not* charging a battery. Therefore, this report focuses on the technologies that save energy during maintenance and no-battery mode.

Charging Ahead: Technologies to Boost Efficiency

Charge termination is one important innovation developed to address power consumption during maintenance mode. Battery chargers can use a variety of methods – including voltage sensors, charge timers, and temperature sensors – to detect when a battery is fully charged and then reduce the flow of power. With voltage sensing, for example, a comparator detects the spike in voltage that occurs after the battery is finished charging for certain chemistries, signaling the charger to reduce charge current to a minimal trickle thereafter. The trickle is maintained to counteract self-discharge, the charge lost over time when batteries are not actively used.

Some battery chemistries do not tolerate trickle charging (e.g. Li-Ion), so alternate hysteresis charging can be used. A hysteresis charger monitors battery voltage, and supplies the battery with a quick jolt of energy when the

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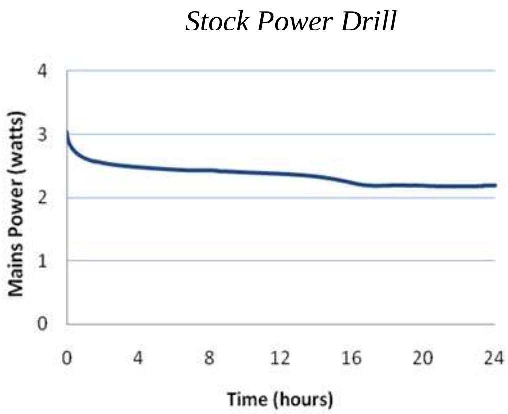
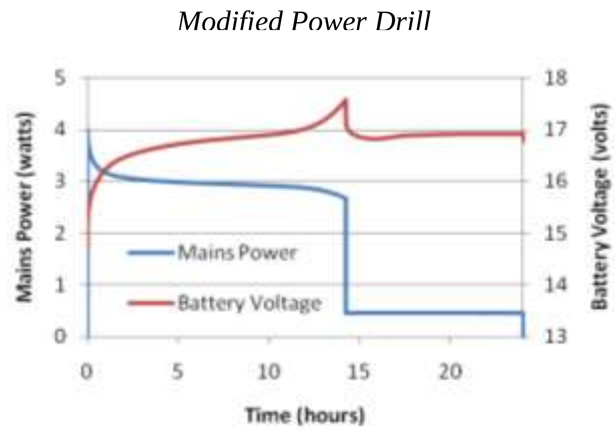
Before And After: Power Tool Efficiency Modifications With Off-The-Shelf Components





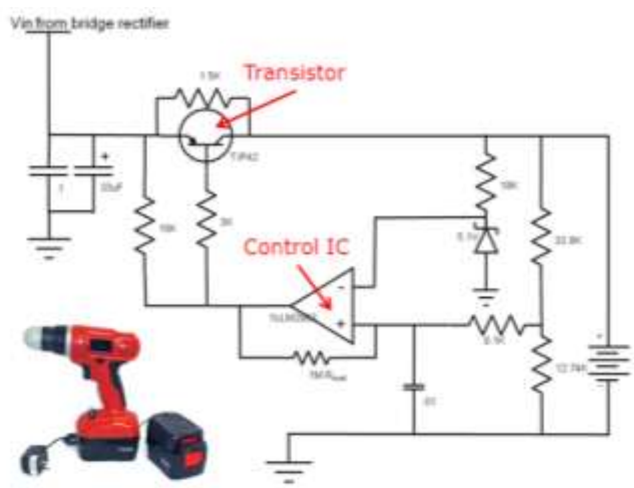
voltage drops below a predetermined value. This can avoid the fixed losses in the power supply if it is completely shut down, but there are greater resistive losses in the battery because of the higher current.

A range of techniques are also available to eliminate power consumption in no-battery mode. A common technique involves placing multiple electrical contacts on the charger so that the entire charge circuit is broken when the battery is removed. Micro-switches or other sensors can be used to detect the absence of a battery as well.

Drilling for Savings: Modification of a Power Tool

Ecos had the opportunity to perform a teardown on a power drill (pictured at right). As shipped, the drill was equipped with inexpensive charge control circuitry, and used roughly the same amount of power over time, even when the battery was fully charged. Ecos modified the charge control circuitry inside the drill, replacing a resistor with a transistor controlled by a voltage comparator.

This relatively simple and inexpensive (AU $1.4 per drill retail) modification reduced maintenance power from 2.2 to 0.46 W. Based on duty cycle estimates, the modified charge control circuitry consumes only 5 kWh per year, a 75% reduction in operational costs compared to the original drill. Such simple modifications are extremely cost-effective, with a simple payback of a year or less. Unfortunately, fierce market competition and market failure – where suppliers compete on price while users pay the electricity bills – means that these simple improvements often fail to make it to market.



Modified power drill circuit diagram

Taking Control of Battery Charging

To date, charge termination strategies like the one above are only present in Li-Ion and rapid battery chargers, mainly to protect batteries from damage, but many commodity products like power tools continue to use less sophisticated chargers and are ripe for highly cost-effective savings. Worldwide, there are approximately 7 billion rechargeable battery operated products in use today, 5 billion of which we estimate could benefit from the types of charge control modifications discussed in this report. Simple and relatively inexpensive design changes could cut energy consumption by 35% for the wide variety of battery charger systems in use. This would result in worldwide electricity savings of 90 TWh per year, the equivalent annual output of 30 typical coal-fired power plants.