



# What You Need to Know About Lithium-Ion

This new generation of batteries will make your current cordless tools seem overweight and underpowered

BY JUSTIN FINK



**E**ver since Makita's first cordless drill hit the market in 1978, nickel-based batteries (NiCd and NiMH) have ruled the world of cordless tools without any major competition. But with Milwaukee's introduction of lithium-ion (Li-ion) power tools in January 2005, nearly three decades of supremacy suddenly was threatened.

In the blizzard of advertising and marketing that followed close on the heels of Milwaukee's debut, Li-ion tools have been introduced by Makita, DeWalt, Metabo, Ridgid, and Bosch. The new batteries sport futuristic names like XLi, V28, LiPower, LXT, and Lithion—and manufacturers have begun calling this the “cordless revolution.”

Print ads and store displays boast that Li-ion offers “twice the cycle life,” “more power,” and “up to twice the run time at a lighter weight.” Milwaukee trumpets its tools as offering “28v power at 18v weight,” while Makita's slogan is “18v power at 12v weight.” The time-tested nickel-based batteries suddenly seem impotent in comparison, and tool buyers are left wondering whether their existing tools are now obsolete. The din is a bit overwhelming, but once you cut through the hype, it's clear that the benefits of Li-ion are real.

These batteries make it possible to produce tools that don't sacrifice weight to gain power, run time, or life span. Li-ion batteries retain their charge over long periods of

# Batteries

# “Li-ion batteries don’t squeeze more work out of

dormancy and aren’t susceptible to memory problems. Maybe best of all, Li-ion could mean that the cordless circular saw will become as common as the cordless drill.

## Higher voltage, longer run time, and deceptive labeling

When it comes to longer run time—the amount of work you get from a battery between charges—the fact is that any increase in voltage also increases run time, regardless of the type of battery. All things being equal, if you compare an 18v NiCd battery with an 18v Li-ion battery, both tools run about the same amount of time before needing to be recharged. Li-ion batteries don’t magically squeeze more work out of the same voltage; they just fit more voltage into a cell to begin with.

A cordless-battery pack is basically a protective case that contains a series of small, cylindrical cells. Each cell holds the same amount of voltage, and they work together as one unit.

Nickel-based battery cells, NiCd and NiMH for instance, each produce about 1.2v of electrical potential. So the 18v battery pack on your drill needs to link together 15 individual 1.2v cells to produce 18v. Yet a Li-ion cell of the same size produces about 3.6v, nearly three times the voltage. This means that depending on the type of Li-ion cell, you can make an 18v battery with as few as five cells (sidebar right).

Technically speaking, though, the potential voltage of each battery cell is different from the actual voltage of the cell once it’s put to work. Imagine voltage as water flowing through a hose. The water leaves the spigot at a high pressure, but by the time it travels to the far end of the hose, it has lost some of its pressure. Batteries work the same way. Although a Li-ion cell truly can hold 4v, battery experts agree that you get roughly 3.6v of usable electricity by the time it’s put to work.

In a market where bigger numbers can mean more sales, Milwaukee and Ridgid labeled their batteries based on this 4v potential rather than on the more realistic 3.6v output. Milwaukee’s seven-cell, 25.2v

batteries are labeled as 28v instead of 25.2, and Ridgid’s six-cell batteries are branded as 24v rather than 21.6. Both companies defend their labeling with claims that their proprietary technology allows for a higher voltage per cell.

## Power struggles and how they affect cycle life

The ability to fit more voltage into a cell of the same size does not necessarily give you more power, although that’s the suggestion in some advertising. Power is actually a combination of voltage and amp hours (amp/hr), which is the number of amps a battery produces over a set period of time. Simply put: If voltage is identical, a 3-amp/hr battery runs twice as long as a 1.5-amp/hr battery, assuming—and this is a big assumption—that the workload and the testing conditions are identical.

The harder the battery works, the shorter its cycle life will be. Cycle life is the total number of charges you can get before needing a new battery.

Just as driving in the city means worse gas mileage than driving on the highway, drilling 3-in.-dia. holes through solid oak gives worse “mileage” than sinking ½-in. screws into clear pine. A long winter’s day of work is also very different from a series of scientific trials conducted in a room-temperature testing facility. Results always depend on workload and conditions. David Selby, chief engineer of Milwaukee’s cordless-tool division, said, “Pick a number between 400 and 2,000 charging cycles, and I can come up with a scenario that will give you that cycle life.”

Until manufacturers agree on an apples-to-apples comparison and make that clear to consumers, cycle-life numbers should not carry much weight when it comes to deciding among different brands.

## Li-ion will stretch the boundaries of cordless tools

When tool buyers began asking for more power, several manufacturers responded by bumping up nickel-based batteries to 24v. But these cordless tools were too heavy to be practical, signaling that nickel-

## Three ways to get the same voltage

The size and shape of most Li-ion battery packs will be similar to the nickel-based packs you are using now, but the cells within are different in size, chemistry, and quantity.



**NiCd and NiMH cells** produce about 1.2v each. To create an 18v battery pack, manufacturers need to link 15 cells together in a series.



**Li-ion cells** come in two basic sizes, and each can produce 3.6v per cell, three times the voltage of a single nickel-based cell. When combined, Li-ion cells create a battery pack that is up to 45% lighter than a comparable nickel-based pack.

Milwaukee, Ridgid, and DeWalt are using big cells with high amp/hr ratings (center photo), while Makita, Bosch, and Metabo are using twice as many of the smaller, low-amp/hr cells to achieve roughly the same run time (bottom photo).



The performance of both types will be about the same, but using smaller cells does allow for design flexibility when building oddly shaped or slim-profile battery packs to fit specialty tools, perhaps something we will see more of in the future.

# the same voltage; they just fit more voltage into a cell."

based cordless technology had peaked. Now Li-ion allows tools to operate at 36v and weigh nearly the same as an 18v NiCd, a big leap forward.

By packing up to three times the voltage into a battery cell, Li-ion technology allows developers to stretch the useful boundaries of cordless tools at both high and low voltages. "Tools large and small, which were previously impossible with NiCd, are now a reality," says Bosch Li-ion product manager Edwin Bender—and the result has been tools of all different shapes and sizes (pp. 58-59).

Some manufacturers—DeWalt, Milwaukee, and Bosch, for instance—see Li-ion as an opportunity to cut the cord on power-hungry tools like rotary hammers and impact wrenches.

Makita and Ridgid are in the middle of the voltage spectrum with 18v and 24v, respectively. Metabo is releasing its Li-ion tools in the nickel-based range of voltages: 18v, 14.4v, and 12v.

Although Bosch has a line of 36v Li-ion tools, it is the only manufacturer that has released low-voltage tools as well. So far, Bosch has a couple of new ultracompact 10.8v drill/drivers and plans to release more tools in this series in the future.

Which voltage will gain the best share of the market? Steve Steadings, Ridgid's director of product development, is sure the competition will be interesting. "We've all picked our horses," he says. "It's up to the buyers to decide who wins."

## Prices are high because the battery's heat needs to stay low

On average, a Li-ion tool kit costs about 40% more than its nickel-based counterpart, a jagged pill to swallow. Part of this price increase is because the raw materials needed for Li-ion cells are more expensive, but the introduction of charge-, discharge-, and heat-monitoring technology is where the bulk of the money is going.

Any time an energy transfer occurs, there is heat, and heat is a battery's worst enemy. Because Li-ion tools are being put to use with high voltages and difficult workloads, reducing or dissipating the resulting heat has become critical. Damage to even one or two cells permanently weakens the overall power of the battery pack.

Manufacturers have included electronic cell protection in their Li-ion products; that actively adjusts Li-ion cells to make sure they work within safe tolerances. If they do not, the electronics can go as far as shutting down the battery until it cools enough for work to begin again. Bosch, Metabo, and Makita also have incorporated vents into their batteries and fans into their charging stations to keep batteries cool during recharge.

Milwaukee, DeWalt, and Ridgid stand by their Li-ion technology, saying heat is not a major issue with their tools. "Other companies are integrating fans into their chargers only to compensate for a technological deficiency," says Milwaukee's David Selby.

It's difficult to know whom to believe, but according to independent battery expert Isidor Buchmann ([www.batteryuniversity.com](http://www.batteryuniversity.com)), Li-ion cells are more fragile and more likely to be damaged by heat than nickel-based cells. If a NiCd or NiMH battery were to short-circuit, the pack simply would heat up and smolder. Without cell-monitoring electronics, a Li-ion battery could catch fire. This phenomenon, called *thermal runaway*, happens when an increase in heat triggers even more heat to be released, and a destructive chain reaction ensues. How Milwaukee, DeWalt, and Ridgid have found a way around this problem is difficult to know, and they aren't revealing their secrets.

It's true that any battery is potentially dangerous, but Li-ion is no more dangerous than the nickel-based batteries that are used today. Each battery pack typically receives the same UL stamp of approval that you find on a lightbulb or telephone, which verifies that the product is safe for consumers. In fact, Li-ion cells are nontoxic to the environment, but it's still recommended that they be recycled (contact [www.rbrc.org](http://www.rbrc.org).)

## New batteries for old tools?

Supply and demand most likely will drive down the prices of Li-ion tools over the next few years, especially as more manufacturers get onboard with the technology. If you can't wait that long, though, a few manufacturers have designed Li-ion battery packs that are compatible with their existing tools, a gesture that aims to help buyers ease into this new technology.

Currently sold by Metabo and to be released by Milwaukee in the summer, these retrofit batteries have all the necessary cell-monitoring electronics integrated into the battery pack and are sold along with the required Li-ion charger.

The retrofits will save you money—especially if you already own Milwaukee or Metabo tools—but it's too early to tell whether using Li-ion batteries in a tool designed for nickel-based batteries will be cost-effective in the long run.

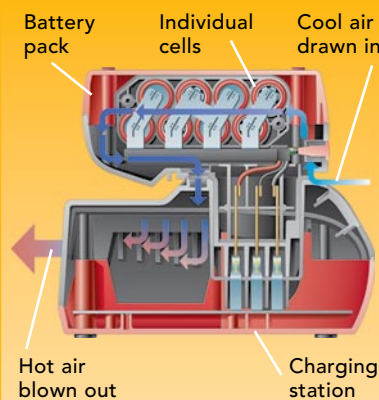
Bosch believes that by placing the necessary cell-monitoring electronics inside the battery pack, manufacturers are creating more heat in a place where high temperatures can be dangerous. These companies are mixing the variables of the Li-ion equation by teaming new technol-

ogy with old tools. If the combination is problematic, Li-ion batteries may get a bad reputation whether or not they are truly to blame.

## Li-ion batteries can be treated much the same as their nickel-based predecessors

Li-ion batteries need protection from extreme heat and freezing temperatures, just like nickel-based batteries. Also, it's not good to drain them intentionally past the point where the battery needs a recharge. The claim that Li-ion has no negative memory effect is absolutely

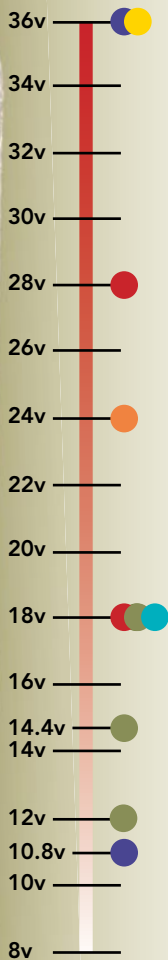
"Heat-monitoring technology is where the bulk of the money is going"



Heat is a by-product of every energy transfer, and the higher voltages common to Li-ion batteries mean the possibility of higher heat. To combat this problem, Metabo has incorporated a fan into its charging station to pull air through the battery (shown above) and across the cells while they recharge. Bosch also has designed its battery to dissipate heat toward the outside of the pack to help keep the internal workings cool.



## Different brands, different approaches



Nickel-based batteries (NiCd and NiMH) have been used in 7.2v to 24v tools, but their sweet spot is between 12v and 18v. Much higher than 18v, and the larger battery size literally begins to outweigh the benefits. Lower than 12v, and the battery simply doesn't last long between charges.

Because Li-ion cells squeeze more voltage into the same-size package, manufacturers are claiming that the 12v to 18v comfort zone is expanding to include professional-grade tools anywhere from 10.8v to 36v. This range is certainly impressive, but after a few years on the market, expect the wide spectrum of Li-ion voltages to narrow considerably.



### Milwaukee V18 and V28

The first to hit the market, the Milwaukee V28 made a big splash among users who relied on high-draw tools tethered to an extension cord. The V28 line now includes a 6½-in. circular saw, a drill/driver, an impact wrench, a reciprocating saw, a rotary hammer, and a portable bandsaw, all aimed at the heavy-duty user. A new line of V18 Li-ion batteries (available in the summer) will be compatible with existing nickel-based cordless tools, and is meant to entice a wider crowd into trying the new technology. [www.v28power.com](http://www.v28power.com)



### Makita LXT

Makita is playing up the lightweight benefit of Li-ion technology by targeting 18v-tool users and offering them the same power at the weight of a 12v tool. The motor technology has been enhanced, and the tools also have been redesigned with ergonomics in mind. Right now, the line includes a 6½-in. circular saw, a hammer drill, an impact driver, and a reciprocating saw. [www.makita.com](http://www.makita.com)

### Metabo LiPower

Aiming to reduce the weight of its existing line of tools, Metabo applied Li-ion to its 12v, 14.4v, and 18v platforms. So far, Metabo is the only manufacturer to offer Li-ion tools in so many different voltages. New LiPower tools include a 6½-in. circular saw, a rotary hammer, and a reciprocating saw operating on the 18v Li-ion platform, as well as the option of 12v, 14.4v, or 18v drill/drivers. LiPower batteries also are compatible with the existing Air-Cooled line of Metabo tools. [www.metabo.com](http://www.metabo.com)



**"We've all picked our horses, and it's up to the buyers to decide who wins."**

—Steve Steadings, Ridgid



## DeWalt 36v

Focusing all its attention at the highest voltage, DeWalt is building on its nickel-based line with the addition of 36v Li-ion power tools. DeWalt is the first manufacturer to create a cordless circular saw with a 7¼-in. blade and the only manufacturer to offer a jigsaw. Other tools to be released include a hammer-drill, a reciprocating saw, a rotary hammer, and an impact wrench. [www.dewalt.com](http://www.dewalt.com)



## Bosch Litheon

Although Bosch has developed a Li-ion-powered rotary hammer that operates at 36v, the company wants to send the message that Li-ion technology also can enhance the performance of low-voltage tools. Bosch's two ultra-compact 10.8v drill/drivers (one pistol grip, one stick grip) are small enough to fit in your pocket, yet can sink 100 3-in. screws before needing a recharge. [www.boschtools.com](http://www.boschtools.com)

## Ridgid XLi

Ridgid plans to launch its 24v XLi series in the summer, still targeting the 18v cordless-tool buyer but offering a longer run time. Tools in this line include a hammer drill, a 6½-in. circular saw, and a reciprocating saw. The company also plans to expand its impressive lifetime service guarantee to include its new Li-ion batteries, a warranty far beyond any offered by the competition. [www.ridgid.com](http://www.ridgid.com)



true, but it was also true of nickel-based batteries. *Memory effect* is the process by which a battery habitually is recharged before being drained completely, resulting in a battery that becomes conditioned, or “forgets,” that it can discharge completely. Manufacturers fixed this problem a long time ago, so unless you are using an early version of a cordless tool, memory effect is a myth.

One characteristic that is real, however, is Li-ion's ability to hold a charge over a long period of time, something manufacturers refer to as shelf life. According to Metabo, nickel-based batteries lose about 25% of their stored charge every month that they sit dormant, but a Li-ion battery loses only about 2% of its stored charge over the same time period. This will be a nice benefit for tools that are used only occasionally, but won't matter much for tools that are used every day.

Li-ion batteries also offer a consistent amount of power throughout use. No more dramatic dips in performance as the battery gets close to being discharged, so you can work longer before needing a recharge. This consistent power makes it impossible to judge how much juice is left, so many manufacturers added an LED gauge on the battery to show how much power remains. Makita and DeWalt are the only manufacturers (so far) to omit this gauge on their Li-ion batteries.

## Where is the future of cordless tools headed?

New technology often brings an undercurrent of mild panic that the old technology soon will disappear. But manufacturers all are saying that they have no immediate plans to eliminate nickel-based tools because nickel-based batteries are still very much a viable solution and because lots of people are invested in them heavily.

In three to five years, though, expect to see a major shift as the cost of Li-ion technology drops. As the pricing gap between nickel and Li-ion platforms closes, manufacturers believe that Li-ion tools will take over the majority of the cordless market.

Li-ion tools also are still in their infancy and are expected to grow and change during upcoming years. Look forward to seeing better results from the batteries as manufacturers continue to play with the configuration of individual cells. For the short term, don't expect to see current Li-ion tools reach voltages much higher than 36v without sacrificing weight and ergonomics.

Manufacturers are also busy researching the technology that will be available 8 to 10 years from now, which may take tools to even higher voltages, smaller sizes, and lighter weights. It took a while for Li-ion batteries to make the leap from consumer electronics to power tools, but manufacturers still consider the consumer-electronics market to be a great bellwether for up-and-coming technology that later may be applied to tool use.

According to Buchmann, battery innovations have been only moderate over the past 150 years when compared with other technological advances. “People want an inexhaustible pool of energy in a small package that is cheap, safe, and clean, and it is anyone's guess whether a superior electrochemical battery, an improved fuel cell, a futuristic atomic-fusion battery, or some other groundbreaking energy-storage device will fulfill this dream.”

Don't toss your corded tools yet, though, because cordless technology always will have one limitation: Eventually, you have to recharge the battery. □

Justin Fink is an assistant editor at *Fine Homebuilding*. Photos by Krysta S. Doerfler, except where noted.