SMALL, LIGHT-WEIGHT, BUILT-IN BATTERIES OFFER MORE ENERGY AND IMPROVED COSMESIS
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FINDING SMALL LIGHT-WEIGHT CELLS

One might think that with over a hundred Li-Polymer cells on the market, one could find just the right cell for every application, but this is far from the case. Most cells are made in Asia by companies that only sell in large quantities. Dimensions are driven by the size and shape that is appropriate for 3.6V hand held devices. For these devices thin and flat are paramount, while the linear dimensions are driven by the size of the device and are usually too wide for a prosthesis. Figure 1 shows four cells that have proven usable in prosthetics. Left to right, the first cell is a mere 200 mAh, but is really small. The second, 250 mAh, is the smallest rectangle that will mount crosswise at the end of a child prosthesis. Unfortunately, it has been discontinued by the manufacturer. The third cell, 450 mAh, is slim in two dimensions so it fits well with one cell each on side of a wrist. The 750 mAh cell on the right is good for a full day’s operation of an adult transradial prosthesis.

Cells must be selected for their electrical characteristics as well as for size. For instance, many of lithium ion cells have a high internal resistance limiting the current that can be drawn. Recent changes in the chemistry of some of the lithium polymer cells have opened up new high current applications. To move an elbow or shoulder with weight in the gripping device requires substantial current even when extra cells are added to increase voltage. With battery operation every component must be as efficient as possible and this includes the batteries.

SAFETY WITH LITHIUM BATTERIES

Connecting the Charger Safely

Myoelectric prostheses usually ground the electrodes to the negative side of the battery. This can be a problem if it is possible to connect the battery to a source of high voltage. This might occur in a fault condition if charging while wearing the prosthesis. As long as the prosthesis is turned on, it must be impossible to touch any metal surface that is positive. (An infant once took a nap while skin was touching metal at a positive voltage and received a minor burn.) Isolating...
both the cells and the external connector is the function of the recharge module. Older modules used a double pole double throw switch for this. To save space, newer modules use a switch in the recharge connector to shift the negative side of the battery from the user electronics to the outside of the jack when a plug is inserted. The single pole single throw on-off switch does the same for the positive side, as the switch is moved from on to recharge.

**Electrical Safety for the Cells**

During assembly, two safety features are added to all LTI lithium cell packs. In figure 3, the safety circuit on the left monitors the voltage across both cells of a 750 mAh cell pack. Its most important function is to prevent either cell from being over charged. It also prevents the voltage from dropping too low by disconnecting the cells if the voltage drops below a specified value or if a short occurs. The right cell has a Poly-Fuse™ installed to limit current in a short circuit across just this cell as might occur if the connecting cable were shorted. Also, since a Poly-Fuse™ is a device that changes state with temperature, it may act as a thermal current limiter. The safety devices are mounted close to the center line so that the added thickness can be ignored when the cell is placed along side the concave surface inside a prosthesis.

**Making Cells Fit**

The human forearm is oval just proximal to the wrist and then becomes more or less round toward the elbow. However, it is traditional to make the interface between the terminal device and the forearm round. Thus, there is room for a thin cell on each side of an adult wrist without increasing the overall size. Figures 4 and 5 show that there is plenty of room for the cells supplied in the LTI 450 and 750 mAh batteries. For comparison figure 6 shows how the larger cells that can handle the requirements of the i-Limb™ hand may interfere with cosmesis on a typical installation. The cells almost fit at the wrist, but they are 100 mm long and will cause lumps at the proximal ends.
Safety When Placing the Cells

Lithium polymer cells are covered by a thin membrane which provides little protection from sharp objects. Furthermore, the cells lack resistance to crushing and bending. The shrink wrap added during assembly only helps a little. The technician must use dummy cells when making the definitive outer socket to provide space for cells, cables, and for the recharge modules. If the Recharge Module is located remotely, there will be wire-to-wire connectors that will need a cavity. Careful planning is required so that the final prosthesis can be readily assembled and serviced. One of the most hazardous times for the battery components is during installation when there is a great temptation to push wires and connectors into too small a space.

Figure 7. Recharge connectors and switches have gotten smaller. From the top of the switch the units measure 13, 16.7, 14.7, 11, and 8.3 mm in height. A thin recharge assembly can be placed near the elbow on the forearm.

Robust Recharge/On-Off Modules

Figure 7 shows two older LTI Recharge Modules and three newer ones. All are designed to withstand the rigors of installation in a typical prosthesis while maintaining electrical safety. Sometimes local shops invent their own modules to save space, but the compromises are not acceptable in a device offered for sale. Small switches will not repeatedly switch high currents nor will miniature connectors hold up when one-handed users insert and retract recharge plugs.

Figure 8. The 8.3 mm module top vs. the 11 mm below, both on samples 57 mm OD by 2.6 mm thick.

Figure 9. LTI cell packs come in several styles. The pack made from two AA Li-Ion cells is robust and remains popular. Separate AA cells are often stuffed into fingers of large hands. The newer flat, thin Li-Poly cells can be placed on opposite sides of the wrist or one above the other lengthwise.