ECEN 425 Assignment 1 Hand-in

Going Beyond Datasheets

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Rechargeable Battery Selection

In order to make an appropriate selection of battery for a given project/product a variety of aspects should be considered that may not be readily available from a given manufacturer but are more operational and technology-based characteristics. When it comes to rechargeable batteries, whether they are to be used as the primary power source or just a secondary cell, both performance specification as well as condition and maintenance criteria must be considered.

Specification Criteria

This section outlines and defines technical performance specifications valuable in selecting the correct battery for an application.
Voltage - A battery (cell) will have to maintain operation voltages; its *nominal voltage*, at which a given battery is reported to operate in normal conditions. This differs from pack cell count and chemistry. The second is its *discharge cut-off voltage*, this is the minimum allowable voltage at which a battery maintains its performance spec or is safe to use.
These define the operational voltage range of the given battery to be considered as either a direct source or input to PSU.
Energy Density - A battery can be characterised by its *Energy Density* both volumetric (Wh/L) and gravimetric (Wh/kg). These are characteristic of battery chemistry and packaging.
These will be the primary considerations if the application is either space and/or mass constrained.
Max Output Current - Defined both as the maximum current at which a battery can be continuously discharged and the maximum current that can be pulse or burst drawn from the battery. These limits are defined by the safe operation of the battery to prevent damage and maintain rated capacity.
Nominal Capacity and Energy - Nominally given in Amp-hrs and Watt-hrs respectively available at a constant discharge C-rate (A measure of the rate at which a battery is discharged relative to its maximum capacity) from 100% to the batteries discharge cut-off voltage. The higher the C-rate the lower available capacity and delivered energy.
High Power vs High Energy - Is the battery rated to a high current source for a short period or a more long term continuous discharge source.
Cost - Related to density, the cost can be defined in terms of Wh per dollar (average) but also by a variety of measures. Such as cost per charge/discharge cycle, form factor, environmental rating.

Maintenance Consideration

Safe Discharge - To prolong a battery's life, the level and interval of discharge is a large factor in determining the usable charge cycle count of a battery. This is quantified by the Depth of Discharge (% of capacity) between specific State of Charges (% of capacity). I.e Lead-Acid at a DoD% or 50% will last longer if it goes from 100% SoC to 50% than from 70% to 20%.

Recharge Cycle Count - Charge/discharge cycles the battery can experience before it fails to meet performance criteria. Cycle life is estimated for specific charge and discharge conditions. The actual operating life of the battery is affected by the rate and depth of cycles and by other conditions such as temperature and humidity. The higher the DoD%, the lower the cycle life.
Self-Discharge Rate - Percentage of a battery's capacity that it loses over a given unit of time. Usually an average % over a month. This is not everything though, as technologies can have a varied self-discharge rate over time, ie high discharge initially.
Charging Requirements - Different battery chemistries will have different requirements, levels of complexity, and hazards associated with the required recharging procedure.
Charging cut-off (overcharge) voltage to which a battery can be safely charged to in normal charging mode.
Different batteries will require different charging procedures before reaching the floating (self-discharge compensating) voltage. The result of violating this procedure can differ from just degrading lifetime to catastrophic and dangerous failure.
Charge/Discharge Maintenance - Some batteries can be required to be discharged or recharged regularly to maintain their lifetime.
Operation Conditions - The batteries also require different levels of safety requirements, in terms of operating conditions (charge and discharge) and as well as levels of protection circuitry.

Technology Comparison

Lead Acid - One of the older rechargeable technologies still in use. It remains in use (car starter motors, electric wheelchairs, deep cycle marine applications) in comparison to newer technologies due to its very **low cost** (per unit), its ruggedness requiring no protection other than **thermal stability** to prevent runaway **(-20-50 degrees)**.
These batteries have a low energy density on both measures, so are heavy and bulky so use in physically unconstrained systems is required. They however can deliver very peak current pulses **(300+ Amp)** but require charging recovery time.

Self-discharge	Low internal resistance, 5% / month
Cell voltage	2V, but common 12V packages
Cut-off voltage	Charging: 2.4V, Discharge: 1.7V
Cycling	200 at 80%DoD, but for the longest life stay above 50% SoC with max DoD of 50%

They are tolerant to overcharge, only losing lifetime without catastrophic failure.

Nickel-Cadmium and Nickel-Metal-Hydride
NiCd is older but used where temperature tolerance **(-20-70 degrees)** and high current is required **(20C).**

In terms of protection, they only require overcurrent fuse protection in addition to thermal stability. NiCd however has a memory effect and requires a periodic full discharge to maintain the full SoC% range.
NiMh is the more modern chemistry that is more energy-dense and replaces the prior in a lot of applications, except in specialised and tested industry (ie aviation etc)

	NiCd	NiMh
Self-discharge	20%/month	30%/month
Cell voltage	1.2V, low requires higher cell count	
Cut-off voltage	Discharge: 1.7V, Charging detection via signature	
Cycling (worst case 80% DoD)	1000	500

Overcharge will result in capacity loss, heat generations and possible pressure venting from the package.

Lithium-(ion, Li-Po, LiFePO)
Lithium-based battery chemistry is the focus of modern battery development. They now dominate the commercial market due to high energy density, higher cell voltage, very high cycle count and **low self-discharge** leading to possible lower cost per cycle for low term use. With the BMS circuits, they don't require special discharge maintenance.
They are however expensive, and due to safety requirements, implementations need continuous protection circuitry to balance cells (charge/discharge), over-discharge, overvoltage, current limit, thermal monitoring etc.
These lithium-based batteries fail catastrophically, with significant fire risk and electrolytic leakage if not properly constructed or protected.

- *Li-ion* is the most widely manufactured and the cheapest/most energy-dense.
- *Li-Po* can be more physically robust, less chance of electrolytic leakage. With a higher peak current draw than Li-ion
- *LiFePO* fails in a much safer, less prone to thermal runaway and more stable, also with higher peak current draw than Li-ion.

	Li-ion	Li-Po	Li-FePO
Self-discharge	3% / month, but mandatory protection can consume up to 3%		
Cell voltage	3.6V	3.7V	3.3V
Cut-off voltage	Charging: 4.2V, Discharge: 2.5-3V		Charging: 3.6V, Discharge: 2.5V
Cycling (worst case 80% DoD)	500-1000		1000-2000

Mechanical Lubrication Selection

The use of correct lubrication is vital to the ongoing success of a mechanical design. They will ensure continuous operation, reduce wear and breakdown and where necessary can seal and prevent corrosion.

Specification and Ratings.

Lubricant can be quantised based on a few performance properties.

Viscocity - Both static and dynamic. Ie how the lubrication will flow with time. It should be considered because it represents a mechanical resistance in the design, so if a part is small and fast-moving, a high viscosity lubricant can impede that performance
The *SAE* viscosity weight grade of a particular lubricant can be used to quantise this performance at a given operating temperature.

Temperature - A lubricants properties can differ with temperature. Both the lowest temperature where a liquid/semi-liquid can still flow/be applied and volatility/flashpoints; ie will it evaporate and/or ignite.

Pressure - Operation in low pressure required good adhesion, minimal off-gassing, and lack of built up.

Types and Usecases

Wet

Wet lubricants are oil-based, either synthetic, mineral or vegetable derived and include low viscosity oils and higher viscosity greases. They are can be useful in where ease of application and coverage is a factor, can provide seals and are able to provide some thermal capacity.

Oil - Good coverage, moving parts

These are thin liquids that provide good coverage, low resistance and are able to wick into small spaces. They can be pumped through or be distributed by the mechanical system.
There can be issues with oxidation that either additive or use of synthetic bases can solve, though note that synthetics are more expensive.

They should not be used in situations where there is significant **particulate exposure** as they will gum up. They themselves will contaminate surrounding components if not sealed and have a **limited lifetime** due to **low adhesion** and possible water exposure.

Grease - Great adhesion, low maintenance, sealing

Oil-based with thickening additives and sometimes lubricating solids. They provide significantly **more mechanical resistance** than other lubes so are not usable in lower power moving parts. What they excel in however is adhesion, once applied they will **stick for a long time**.
They are particularly useful in providing a seal, say from moisture or air at a gasket interface.

Lithium thickeners are petroleum-based so unsuitable with polymers, non-corrosive, high temperature resistant and are general purpose high load lubricants.
Silicon-based greases can be used on a variety of surface, have low temperate resistance and can be formulated to have good thermal conductivity and low off-gassing, so suitable for cryogenic/vacuum use.

Dry - non-gumming, clean application, environmentally stable

As a counter to wet, dry lubes are comprised of fine friction-reducing particulates such as graphite (electrically conductive), silicon, and PTFE (polymer). There can be applied in a variety of manners, from direct powder, evaporating solvent spray etc.
They offer **zero off-gassing**, extreme temperate and pressure resistance (that would oxidise or break down oils) and do not gum up or lose performance with particulate intrusion.

They however are susceptible to solvent wash away, and generally wear away faster and need more maintenance/reapplication than a wet lube. They are appropriate for vacuum etc.
Generally more expensive for lower performance.