Batteries and Charging Systems for QRP

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Introduction

QRPers have a wide variety of battery types to choose from today. The widespread growth of personal electronic devices has resulted in new types of batteries becoming available, significant improvements to traditional battery technology, and widespread availability of inexpensive small batteries. I first prepared a talk similar to this for the 2001 Iowa QRP forum. Since then, the battery front has changed significantly; Ni-Cd has largely been supplanted by Ni-MH for new use in the AA size and rechargeable lithium batteries are becoming more widespread and a bit less expensive.

I discuss the various types of batteries available to the QRPer and the relative advantages and disadvantages of each. Schematic diagrams for simple battery chargers are presented, although high-performance commercial battery chargers, at least for AA batteries, are getting so inexpensive that building your own is not as advantageous as it once was.

Solar power is attractive for field operation. Many QRP contests, including Field Day, offer special multipliers for using renewable energy sources. A solar panel is essentially a constant current source, so charging a battery with one is easy. I discuss charging batteries with a solar panel and present a couple of simple charging regulators.

Portions of this paper and accompanying viewgraph presentation are based on a presentation I gave at the Iowa QRP forum in 2001, and a slightly revised version of that same presentation that I gave at the Duke City Hamfest in 2003. I have based some of my sections on my QRP-L posts, so they may sound familiar to long time readers of that reflector.

As an aside, the underused QRP-L reflector searchable archive,
http://www.kkn.net/archives/html/QRP-L/
is a wealth of information, not only on batteries, but on nearly all topics of interest to the QRPer. QRPers, both novice and experienced alike, are wise to start their search for information there. Over the 12 years that QRP-L has existed, there is hardly a topic of interest to hams that has not been discussed there. The archive has all but a few posts spanning this time. Use it.

Abbreviation Used in this Paper

A – Ampere, a measure of current
AH - Ampere hour, used to specify the capacity of a battery
C- Capacity of battery, generally specified in Amp Hours (AH) or milliamphours (mAH)
FYBO- Freeze Your Bu** Off, a winter contest sponsored by the Az SQRPions
mA - milliampere
mAH – milliamperehour, used to specify the capacity of a small battery

Ni-Cd- Nickel cadmium, a rechargeable battery chemistry type
Ni-MH – Nickel Metal Hydride a rechargeable battery chemistry
SLA- Sealed Lead-Acid, a rechargeable battery type
V- Volt

Types of Batteries

Batteries fall into two general categories, primary and secondary. Primary batteries are designed to be used once; secondary batteries are designed to be recharged and used multiple times. The common alkaline battery is a primary battery; the Nickel Cadmium (Ni-Cd) battery is secondary battery. Table I lists common battery types.

Table I – Types of batteries commonly used for QRP

Primary	**Secondary**
Carbon - Zinc	Lead-Acid (Gel Cells)
Alkaline	Nickel Cadmium (Ni-Cd)
Lithium	Nickel Metal Hydride(Ni-MH)
	Lithium

Primary Batteries (one time use)

Carbon Zinc

Carbon-Zinc batteries are useless for QRP use. The capacity is small and gets worse as more current is drawn. They can leak and corrode battery holders or worse yet, your favorite QRP rig. They have a short life. Tom, WB5QYT, told me that he tried carbon-zinc batteries in his FT-817 once. He got just 20 minutes of battery life out of that set with no transmitting! Fortunately, Carbon-Zinc batteries are becoming harder and harder to find. When they are available, they are cheap. They are often packaged with inexpensive toys, tools, and flashlights. You may find them sold side by side with alkaline cells at discount drug stores and flea markets, often marked as “heavy duty”, but do not make the mistake of purchasing them instead of the preferred alkaline cells. Alkaline batteries are marked as such; if in doubt, look for the word “alkaline” on the package somewhere. You can use carbon-zinc batteries in an emergency if nothing else is available, but you will be disappointed and frustrated at their performance.

Alkaline

Alkaline cells are the workhorse of the primary battery world. They are widely available, consistent in quality and provide reliable power over a long time. They are widely available in sizes other than the ubiquitous AA. They have a relatively large capacity, and are inexpensive. They have a long shelf life, usually in excess of 5 years. If you don’t do a lot of work that requires batteries, they are a good choice for the occasionally trip to the field. They have two to three times the capacity of rechargeable Ni-Cd cells.

They do have their downside. The power output is not constant, but varies over the useful life from 1.55 V per cell to about 0.9 V per cell. This has a couple of drawbacks. In order to extract all of the useful power available in the battery, your rig should be able to operate over this entire range, which means 12 V down to 7.2 V for a nominally 12 V powered rig. Few rigs can do this. Those that can will show a steady power reduction over the range. Not a bad thing in and of itself, as some prefer a gentle degradation to a sudden one, but you should be aware of it.

The alkaline battery has a reduced output at 32 F; about 0.5X that at room temperature. It gets worse below that. You might want to use another battery technology for FYBO, or stuff that battery inside your jacket to keep it warm.

If you buy alkaline batteries in bulk, the price for AA alkaline batteries is reasonable, $0.20 to $0.30 each. Large buying club stores such as Costco or Sam's Club often have the best prices.

Lithium

Lithium cells are very lightweight for the power they provide and hence provide high capacity for their size. They typically supply twice the amp-hour capacity of alkaline cells, but are much lighter. They have extremely long shelf lives; 10 years or more is commonly specified. They have two down sides; they are very expensive and they provide 3 V rather than the 1.5 V we are accustomed to for primary cells. A lithium cell is nearly fully discharged when it approaches 2.5 V per cell. In order to extract all of the energy in a 12 V lithium battery pack, a QRP rig should operate down to 10 V. Lithium cells provide excellent cold temperature operation, hence they are a good choice for FYBO.

Overall, the detractions of lithium cells overwhelm the attractions, particularly the cost, and limit their utility for QRP. Recently AA lithium cells with nominal 1.5 V have become available, but they are still quite expensive. I have not evaluated them.

Secondary Batteries (rechargeable)

Sealed Lead Acid (Gel-Cells)

Sealed lead acid batteries, a type of lead acid battery that often goes by the name gel-cell, are widely available, but not in smaller than C size. A "D" sized cell is also available, as are larger single cells, but most QRPers use a 12 V or a pair of 6 V batteries in a single package. These are specified by their capacity; 2.5 AH, 4.5 AH, and 7 AH are all commonly available and are useful sizes to QRPers. Larger sizes are available, but these are more useful to the home station or extended portable operation than they are to the QRPer for portable operation. They have less capacity than Ni-Cd or Ni-MH batteries and much less capacity at high discharge rates. The voltage drops as the cell is discharged, so a 12 V rig must operate at 10.5 V in order to get the most out of a SLA when it is nearly fully depleted.

Sealed acid cells have a low self discharge rate, typically 1% to 5% per month. They keep 80 % of their capacity at 32 F, but decrease rapidly below that as anyone who has tried to start a car in a South Dakota winter can testify.

Sealed lead acid cells are easy to charge and easy to keep charged by "floating" them at a constant voltage. They can be charged with constant voltage, constant current, or a mix of the two methods. Manufacturers often print the charging recommendations on the side of the battery.

Trickle charging at a constant voltage is about a foolproof method of charging SLA batteries as there is. Unless the battery manufacturer supplies different values, apply a constant voltage of 13.2 V to 13.8 V at an available a current of c/4 or less. The current will generally decrease to zero as the battery becomes fully charged. As the battery self discharges the charger will supply additional current and keep it fully

charged. There are two downsides to this method. It takes a long time to fully charge the battery. As the battery approaches the charger voltage it draws less and less current and charges slower and slower. It is not possible to charge the battery to full capacity using this technique, but typically it is possible to charge it to 85% of rated capacity.
The SLA can also be charged with a constant current. Using this technique, the battery is charged at c/10 to c/4 (or whatever value the manufacturer specifies), until a terminal voltage of 14.4 V is reached. The battery is nearly fully charged at this point and may be float charged to maintain charge.

Constant voltage and constant charging may be mixed and this is the technique that is often used in commercial chargers. Using this multi-mode technique, the battery is charged at a constant current until 14.4 volts is reached. The battery is then held at this voltage until the current drops to 10% or so of the charge value. Then the charger switches to the float voltage, usually 13.6 V or so. This technique results in a fully charged battery. There is a commercial IC available that does this, the TI (formerly Unitrode) UC3906. I have provided the data sheet and application note on the CD.

The SLA is capable of giving good life. Expect 500 to 1000 full discharge/charge cycles. The fewer deep discharges the SLA sees, the greater number of charge/discharge cycles you will get out of the battery. Charge the battery immediately after use to prolong life. Store the battery fully charged and top it off every 6 months or so to account for self discharge.

The SLA is a good choice for a battery to run a home QRP station or to operate a station that is used in portable operations where transportation is done by car. They are a bit heavy for backpacking. SLA batteries are widely available new in a variety of sizes. They are relatively inexpensive. SLA batteries are widely used in alarm systems, uninterruptible power supplies, and emergency lighting systems. Batteries in these systems are usually pulled for preventative maintenance every year or two and the pulls are often available surplus or as giveaways. These batteries have usually been well maintained and have lots of life available after they are pulled. Alarm companies are a good place to check for these pulls.

Nickel Cadmium (Ni-Cd)

Ni-Cd cells are a good choice for QRP use, although in the AA size, they have been largely supplanted by Ni-MH batteries. Ni-Cd cells have fairly high capacity for their weight, certainly better than SLA batteries. This makes them a good choice for portable use. Ni-Cds have a flat discharge curve, holding constant at nearly 1.2 V until fully discharged. They are pretty much fully discharged at 1 V. Therefore, equipment running on a 12 V Ni-Cd pack should operate at voltages down to 10 V to extract the most energy from a Ni-Cd battery.

Ni-Cd cells have good capacity at 32 F and decrease somewhat below that, but are better than alkaline cells or SLA batteries for cold weather operation. They have a relatively high self-discharge rate, 10% or so a month, so if they are not used and charged often, they should be topped off every month or so.

Ni-Cd cells can be charged indefinitely with a constant current charger at c/10. Charging at this rate for 14 hours will result in a full charge. The battery can be left connected to the charger, but it is wise to reduce the current to 0.02 C or less if the charger is to be left connected. A better way to charge these batteries is to monitor the voltage with respect to time as the battery is charged with a constant current charger. When the voltage ceases to rise and begins to decrease, the battery is fully charged. This effect is shown in Figure 1. The temperature also rises when full charge is approached. Commercial chargers use this technique or a combination of these techniques. I have included the data sheets from the Maxim MAX 712/713 ICs on the CD, both which use this method. A simple versatile charger can be built from this chip. Commercial chargers are commonly available inexpensively and are a good way to charge cells. Unlike the SLA, the endpoint voltage cannot be used to determine when a Ni-Cd battery has reached full charge, as the endpoint voltage depends on how the battery was discharged previously.

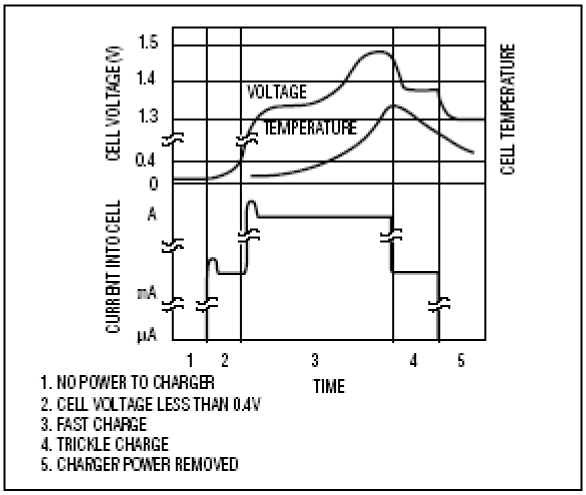

Figure 1 – Voltage and Temperature of a Ni-Cd cell being charged with constant current. The voltage peaks when the cell is fully charged and the temperature rises. Full charge can be determined by detecting when dV/dt goes to zero or negative, or when the temperature rises. Commercial chargers use these methods to determine full charge. (From MAX712/713 data sheet)

The Ni-Cd battery is capable of giving good life. Expect 500 or more discharge/charge cycles. The fewer deep discharges the Ni-Cd sees, the greater number of charge/discharge cycles you will get out of the battery. Charge the battery immediately after use to prolong life. Store the battery fully charged and top it off every month to account for self discharge.

Although Ni-Cd cells have been largely supplanted by Ni-MH in the AA size, if you want larger capacity, Ni-Cd is still the choice. C cell and D cell sizes are available and Radio Shack stocks both. One of the best values in rechargeable batteries is the 2/3 C or “sub C” size. These are widely used in rechargeable power tools and rechargeable household appliances such as portable vacuum cleaners. Due to their wide use, they are often available in surplus cheaper than either C cells or AA cells, often with solder tabs. It is easy to make up a 12 V battery pack using 10 of these cells and heat shrink tubing. One should beware of Ni-Cd C and D cells that are the correct size physically, but contain a smaller AA, 2/3 C, or C cell. Several manufacturers, including several major battery manufacturers, do this to save money. These cells have limited capacity.

Be sure to check the capacity when you purchase a Ni-Cd or Ni-MH C or D cell. Table II lists capacity of the various sized cells to help guide your choice.

Nickel Metal Hydride (Ni-MH)

Due to the proliferation of digital cameras, Ni-MH cells are widely available in AA size in large capacities. AA Ni-Cd cells, once widely available at discount stores are now hard to find. The Ni-MH chemistry has significantly improved in the past 5 years and the discharge rate, 15% to 20% per month, is significantly lower than when first introduced.

Ni-MH cells share many of the same characteristics with Ni-Cd cells. They have a flat discharge curve and good capacity at 32 F. At 15% to 20% self discharge per month, Ni-MHs have a much more rapid self discharge rate than do Ni-Cds or SLA batteries. If not used and charged regularly, they should be topped off every two weeks or so.

Unlike Ni-Cds, Ni-MH cells are intolerant of overcharging. Some have reported success at charging these at 0.05C with no damage, but it will take 28 hours to fully charge a discharged battery at this rate. It is better to monitor the voltage when charging and cease charging when the voltage stops to increase, dV/dt = 0. This behavior is shown in Figure 2. The peak is quite shallow, so waiting for the derivative to go negative, like can be done for Ni-Cd cells, will lead to overcharging of Ni-MH cells and their quick demise. The temperature also rises when the cell becomes fully charged. Both of these techniques are used in commercial chargers. An IC, the Maxim MAX712 can be used to build an effective Ni-MH charger. I have included the data sheet on the CD.

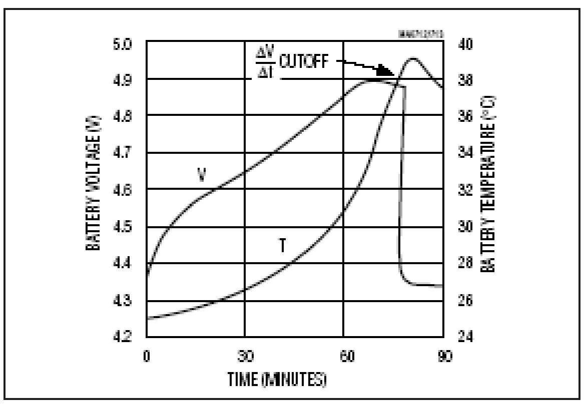

Figure 2 – The voltage and temperature response of a Ni-MH battery being charged at constant current. The voltage maximum, indicating full charge is much shallower than it is with a Ni-Cd cell. (From MAX712/713 data sheet)

Ni-MH batteries are most widely available in AA size. Other sizes are harder to find. Panasonic makes them in AAA, sub C, and D cells. Digi-Key stocks these cells. Beware of large cells being sold with AA cells in them. Check the capacity.

The Ni-MH battery is capable of giving modest life. Expect 300 to 500 full discharge/charge cycles. This is significantly less than either the Ni-Cd or SLA. The fewer deep discharges the Ni-MH sees, the greater number of charge/discharge cycles you will get out of the battery. Charge the battery immediately after use to prolong life.

Store the battery fully charged and top it off every 2 weeks to account for self discharge.

If you need an AA battery pack for QRP use, particularly for backpacking applications, Ni-MH batteries are a good choice. Care should be exercised with their charging.

Lithium

Lithium cells are now becoming widely available due in large part to the widespread use of cell phones. They have very high power density, but as anyone who has replaced a cell phone battery knows, they are expensive. Rechargeable lithium cells share many of the properties of the primary lithium cells; they have long shelf life, are lightweight and are very usable in cold weather. The rechargeable lithium cells are usually in nonconventional proprietary physical packages, so incorporating them into existing battery packs can be difficult.

Lithium batteries are usually available in 3.6 V or 7.2 V sizes. A 12 V rig operating on lithium cells would need to operate from either a 10.8 V or 14.4 V rechargeable battery pack. Neither Voltage is ideal for the rig, 10.8 V is too low and 14.4 V is a bit high when fully charged.

Lithium batteries are usually charged with constant voltage until the battery is fully charged. Charging must be terminated as soon as full charge is reached, or the battery heats rapidly and can destroy itself. Commercial chargers are the best way to charge these. I am unaware of anyone using a homebuilt charger with lithium cells. Lithium batteries are being widely used by radio-control hobbyists, as they are quite concerned with weight considerations.

Calculating the Battery Capacity Needed

A common question on QRP-L is how much battery do I need for such and such an operation? It is straight forward to calculate the battery capacity you need.

First you need to determine how much average current the battery needs to supply to the rig when receiving, Irec and how much it draws during transmit, Itran. My K1 draws about 80 mA at comfortable listening level. At 5 Watts output power, it draws about 0.8 A. CW is a 40% duty cycle mode. This information should be in the instruction manual, or you can measure it yourself with an ammeter. Manufacturer's numbers tend to be on the low side.

If we spend half our time transmitting and half our time receiving, typical of a contest situation, then the average current, Iav, drawn by the transceiver is:

Iav = 1/2 (Irec) + 1/2(Itran) = 1/2(0.08A) + 1/2 (Itran)

For casual operating, you might want to change the fraction spent transmitting and receiving. A ratio of ¾ listening – 1/4 transmitting is probably more typical of non-contest operating.

Recalling that CW is a 40% duty cycle mode,

Itran = 0.4(0.8A) + (0.6)(0.08A) = .32 +.042A =.362A

The 0.6 is the fraction of time the rig spends in receive during a typical transmission. The average current the K-1 will draw is then:

Iav = 1/2(0.08A) + 1/2(.362A) = 0.04A + 0.181 A = 0.220A

Now determine how long you wish to operate. If you want to operate for 12 hours, then the current capacity the battery needs to supply is:

C = 0.22A(12 hours) = 2.64 Ampere Hours

You will need a SLA battery that has a larger capacity than this for several reasons.

1. Most battery capacities are stated for a 20 H discharge rate. If Sealed Lead Acid batteries are discharged at a faster rater, they will have less capacity. At the 10 hour discharge rate, the capacity is about 0.8 to 0.9 times the 20 hour rate.

2. You do not want to fully discharge the battery, as that can cause permanent damage. You should leave at least 10% charge remaining.

3. It is difficult to fully charge SLA batteries, particularly with a simple charger. A battery that is trickle charged will be able to supply only 85% of its rated capacity.

With all these caveats, you should over specify the battery capacity, unless you don't have a hard and fast requirement for time duration. Using the worse case from the above 3, we need to multiply the C by:

1/0.8*0.9*0.85 = 1/0.61 = 1.6

So we need to look for a battery that has a capacity of:

1.6*2.64 = 4.2 AH or greater.

SLA cells are available in a 4.5 AH capacity. If you power accessories such as a keyer, tuner, or lamp, you should add in that current draw. With the exception of the lamp, the power required by these devices is usually negligible compared to even the receive current drawn.

You can do a similar calculation for Ni-Cd or Ni-MH batteries. Ni-Cds can deliver nearly their full rated capacity at almost any reasonable discharge rate unless the current draw is very high. It is easy to fully charge Ni-Cds with a constant current charger as long as the charge is stopped at the proper time. You don't want to fully discharge the Ni-Cds though. So, only factor 2, restraining from fully discharging the battery applies from above; and we need to adjust our capacity only by 1/0.9 or 1.11 so we need to have 2.9 AH capacity. C cell Ni-Cds and Ni-MH AA cells have a capacity of about 2.5 AH, but that would be a bit light. Ni-Cd D cells have a capacity of about 4.5AH, but they are pricey. It is difficult, but not impossible to find Ni-MH batteries in sizes other than AA. Table II lists the various size cells available in the various chemistries.

These calculations are approximate and depend greatly on personal operating habits. It is best to leave some headroom until you are familiar with the power consumption of you rig and your operating habits.

Table II- Size and Capacity of Cells Available for Various Battery Types

Cell size	Alkaline (mAH)	Lead-Acid	Ni-Cd (mAH)	Ni-MH (mAH)
AAA	1100	NA	250	700
AA	2450	NA	1000	2300
2/3 C (sub C)	NA	NA	1500	3000
C	7100	2500	2400	NA
D	14000	4500	4400	6500
Lantern Battery	20,000 (6 V)	NA	NA	NA

SLA batteries are usually specified by capacity, C, or the AH rating, rather than a physical size, so it is easy to determine the capacity required. Ni-Cd, Ni-MH, and alkaline batteries are specified by physical size and the capacity is not always obvious.

Battery Chargers

Several techniques are commonly used to charge batteries: constant current, constant voltage, and a mixture of the two techniques. Homemade versions of all three are possible, and are described below. Commercial versions of chargers are so inexpensive and perform so well, that many do not think that building a charger is worthwhile. Since charging Ni-MH and lithium batteries requires care, it may be best to purchase a commercial charger for these batteries. Determining when a battery is fully charged is the trick in successfully charging a battery, and time, voltage, current, and temperature are all used. This is generally the most difficult part of building a homemade charger. The easiest chargers to build are those for non-critical battery charging situations, trickle charging SLA batteries at constant voltage, and Ni-Cds at constant (and low) current.

The Simplest Charger

ST Microelectronics makes an IC in a TO-220 package, the PB137, that is a complete constant voltage battery charger with reverse polarity protection, over voltage protection, over temperature protection (for the charger), and short circuit protection. It requires 3 parts, the chip and two capacitors. Figure 3 shows the diagram.

The IC is available from Mouser for $0.50, so a good trickle charger for SLA batteries can be built for less than $1.00, exclusive of the Vin supply. The PB137 should have a hefty heat sink; the power dissipated will be (Vin-13.7)Icharge.

The PB137 is based on the L200, an adjustable voltage regulator that provides adjustable current limiting, variable voltage, over voltage protection, over temperature protection and short circuit protection, It is quite popular in England, but until recently was not widely available over here. It is quite superior to the LM317 we use for the same applications and deserves to be more widely used. It is now available from Digi-Key.

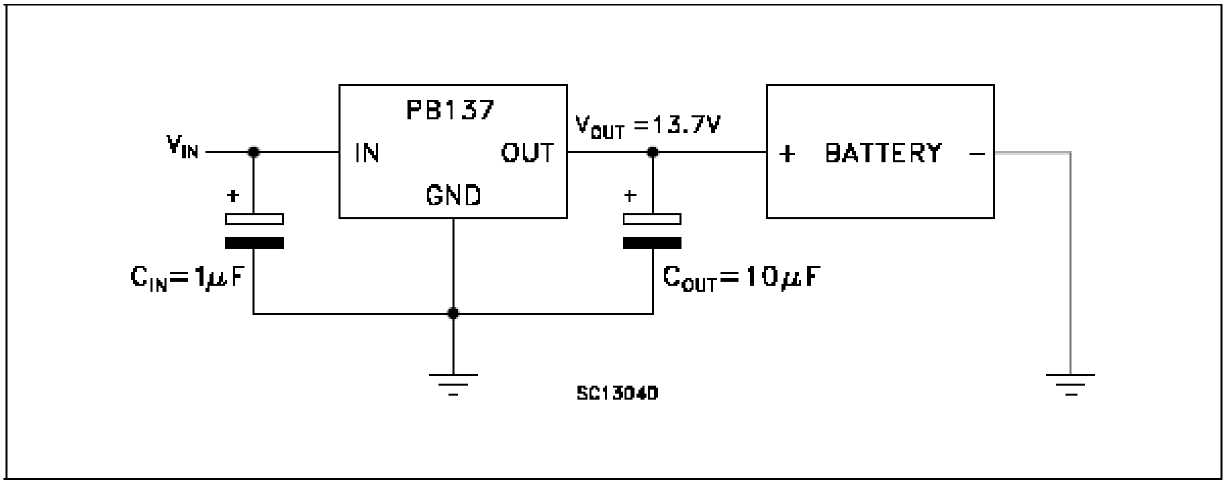

Figure 3 – A trickle charger for SLA batteries based on the STMicroelectronics PB137 IC. Vin should be 16 V or greater. Tantalum capacitors are preferred for Cin and Cout but any electrolytic will do. The input capacitor is there to prevent oscillations when the chip is far removed from the supply and the output capacitor reduces transients. Wall warts may require additional filtering if used for Vin. The IC can supply up to 1.5 Amperes, depending on the input supply. The PB137 has built in current limiting and short circuit protection to prevent damage to itself. The PB137 is in a TO-220 package, which needs to be adequately heat sunk. (From the PB137 data sheet)

Constant Voltage Chargers

A constant voltage charger can be made from three terminal voltage regulators. Low drop out regulators such as the LT-1086 are preferred, but the good old LM-317 is commonly available and more likely to be in your junk box. It is one of the few parts that Radio Shack still carries, so you can find the parts for this project easily. Figure 4 shows a constant voltage charger schematic from the LM-317 data sheet.

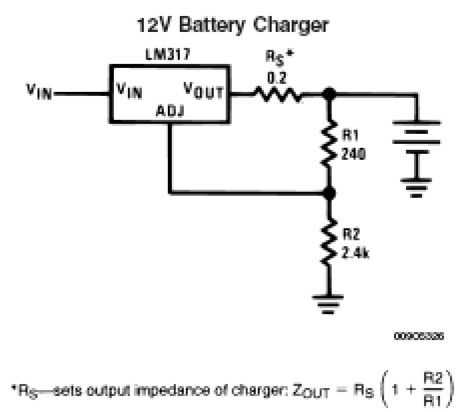

Figure 4 – A battery charger built from an LM317 variable voltage regulator. It is advisable to place a diode between the regulator and the battery to prevent discharge of the battery if a short circuit occurs in the charger. If the charger is located far from the supply, a 0.1 uF tantalum bypass capacitors should be added to the input. The values shown are for a 13.7 V charger. For other voltages, V = 1.25(1+ R2/R1). Vin should be 18 V or greater. (from LM317 data sheet)

The LM317 has a 3 V drop out voltage and if a series diode is added, Vin should be 17.3 Volts or greater. Use an 18 V supply. The LM317 should be heat sunk. If the charger is located far away from the voltage source, the input should be bypassed with a 0.1 uF tantalum capacitor to prevent possible HF oscillations.

Constant Current Charger
The ubiquitous LM317 can also be used as a constant current charger. The LM317 regulates such that 1.25 volts is maintained between the Vout and ADJ terminals. If the ADJ terminal is floated and a resistor placed between the Vout and ADJ terminals then the regulated current is given by I=1.25V/R. A 50 mA charger based on this principle is shown in Figure 5.

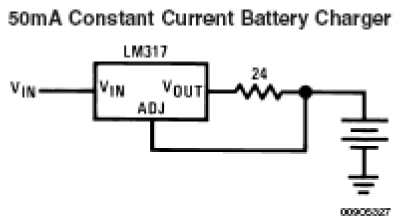

Figure 5 – Constant current charger made with LM-317 regulator chip. It is advisable to add a series diode between the battery and the 24 Ohm resistor. A 50 mA charger suitable for Ni-Cd AAA cells is shown, the 24 Ohm resistor can be changed for other charging currents using R=1.25V/I, where I is the charging current desired. Be sure to use a resistor of adequate power rating, $P = I^2R$. Vin should take into account the voltage drops for the regulator, 3V, the resistor, IR, the diode, and the battery. For a 12 V AAA Ni-Cd battery this will be 19 V, assuming a fully charged voltage of 14 V for a 12 V battery. (from LM317 data sheet)

This technique can be used with other regulators as well. A five volt regulator such as the 78L05 can be used by tying the Vout to Gnd with a resistor such that I=5V/R. Larger resistors are required for these regulators than for the LM317 and hence, more power dissipation in the resistor and a higher Vin is required.

Multimode (Constant Current/Constant Voltage) Charger
While it is probably better to use a commercial chip for multi-mode chargers, it is possible to use commonly available parts to make a simple multi-mode charger for charging SLA batteries. Combining the constant current and constant voltage chargers above, Marvin Harner described a simple charger in the July 1987 Sky and Telescope. This charger is shown in Figure 6.

The charger in Figure 6 uses an SCR to disconnect and connect the LM317 so that it switches between constant current charging and constant voltage charging. A low drop out voltage regulator can be substituted for the LM317 and a Schottky diode for D5. These changes will result in less power dissipation.

PARTS LIST

	Item	No.
R1	(See text)	—
R2	220-ohm ½-watt resistor	271-1313
R3,4	10K-ohm multiturn potentiometers	271-343
R5	1K-ohm ¼-watt resistor	271-1321
R6	330-ohm ¼-watt resistor	271-1315
C1	2,200-mfd 5-volt electrolytic capacitor	272-1020
C2	0.1-mfd ceramic-disk capacitor	272-1069
C3	100-mfd 35-volt electrolytic, radial lead	272-1028
D1-5	1N4001 silicon diodes	276-1101
D6	1N4742 zener diode, 12-volt, 1-watt	276-561
IC1	LM-317T adjustable voltage regulator	276-1778
LED1	Standard light-emitting diode	276-041
SCR1	1-amp, 50-volt silicon-controlled rectifier	276-1662

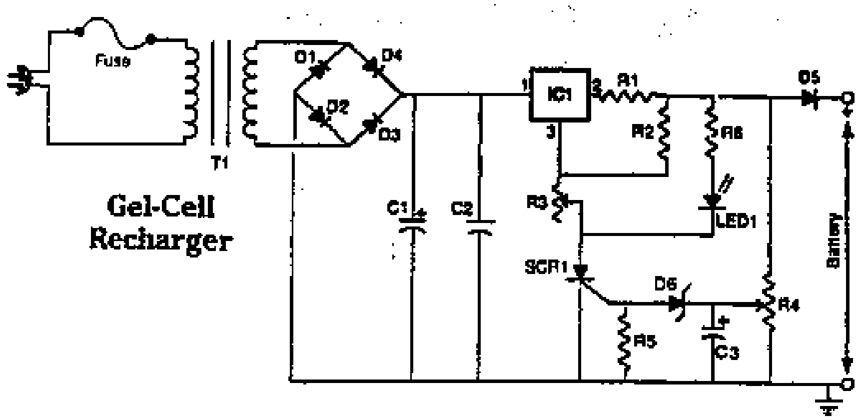

Figure 6 - Constant Current/Constant Voltage Charger for SLA batteries. R1 is given by 1.25/Icharge, and should have a power rating of I^2R1. When connected to a discharged battery, the SCR is off, and the charger functions like the constant-current charger in Figure 5. When the battery approaches full charge, the SCR turns on and the charger functions as a constant-voltage trickle-charger similar to that shown in Figure 4. R4 sets the trip point for the SCR and should be set to 13.8 V to 14.4 V, and R3 sets the trickle charge voltage, which should be 13.2 V to 13.8 V. If the battery manufacturer specifies different values, these should be used. LED1 indicates that the battery is charged. When this circuit was presented in Sky and Telescope, all of the parts were available from Radio Shack. Unfortunately, the SCR is no longer carried at local stores, but the rest of the parts remain available. The LM317 should be adequately heat sunk.

Chargers Based on Commercial Chips
In addition to the PB137 described above, excellent chargers can be built based on the UC3906 for SLA batteries and the MAX712/713 for Ni-CD and Ni-MH respectively. These chips are available in DIP packages from Digi-Key and other suppliers. The data sheets, included on this CD, show how to design and build chargers based on these versatile chips. In addition, QST carried articles on how to build a charger based on the UC3906 in June 1987, pp 26 – 29 and on a charger based on the MAX712/713 in September 1994, pp. 40-42. The handbook carried these charger circuits for many years, but they are no longer in the current edition. The UC3906 based charger is available in kit form from A&A Engineering. The kit makes a 1A charger.

There are other custom battery charging chips available, but I have suggested the two above for two reasons: they are widely available; Digi-Key stocks both, and they are available in DIP packages for those who don't want to deal with surface mount devices.

Using a Solar Panel to Charge Batteries
It is easy to use a solar panel to charge a battery in the field. This is attractive from the point of being self contained and many contests offer an additional multiplier for solar power. Visitors to a portable site are often impressed by the solar panel powering a ham radio station that is working other stations all over the country.

Small solar panels can often be found surplus or at ham fests. A 3 to 5 Watt size is a good choice for most portable operations. Such a panel will produce 250 mA to 300 mA at 18V in full sun and is a good mate to a 7 AH SLA battery. Some foreign car manufacturers ship their cars with a small solar panel on the dash to keep the battery charged. These panels are sold or given away after the car is received. Check with your local VW dealer, or they can often be found on e-bay. Harbor Freight has several solar panels which go on sale form time to time. When on sale these are usually good deals.

A solar panel is a constant current device and can be thought of as a constant current charger. SLA batteries and Ni-Cd batteries lend themselves to constant current charging and hence to simple charging by the solar panel. In the simplest arrangement the panel is simply hooked up to the battery, observing polarity, and allowed to charge. This works best if the panel output is less than 0.1C or if the current drawn by the rig is less than the current supplied by the panel. If either of these two conditions are not present it is wise to use a Zener diode or a charge controller. The Zener diode should have a voltage rating higher than the highest expected fully charged battery voltage. A 15 V Zener is adequate for 12 V Ni-Cd or SLA batteries. The power rating should be the same as the panel. The full power of the panel will be dissipated by the Zener when the battery is fully charged.

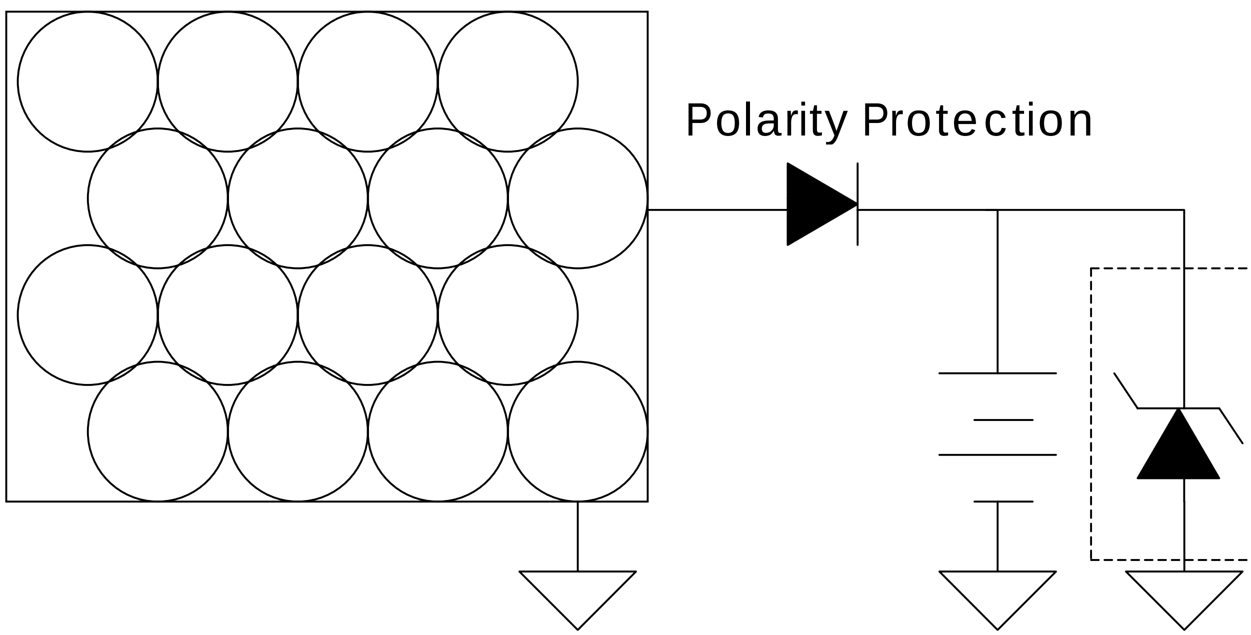

Figure 7 Simplest solar charging setup. The solar panel is a constant current device and can charge Ni-Cd and SLA batteries. The Zener diode is provided for over-voltage protection to the battery and should be a slightly higher value than the fully charged battery potential. It can be omitted if the charging rate is less than 0.1C or if the current drawn by the transceiver is equal to or greater than the current supplied by the panel. The series diode is often built into solar panels and avoids discharging the battery into the solar cell at night.

If the solar panel is to be used long term in a fixed location, or if the current supplied by the panel is higher than 0.1C, or the power consumed by the attached rig is less than the panel can supply, a charge controller should be used to avoid damage by overcharging the battery. A shunt controller is preferred to a series controller. A series controller will often have significant voltage drops that will limit the amount of power the solar panel can deliver to the battery.

There are a number of shunt controller designs, some with elaborate microprocessor control and others using exotic switching devices. A simple and straight forward design from commonly available parts is shown in Figure 8. This design is from the ARRL Publication “QRP Power”, p 3-24, and is simple, easy to build, and simple to setup. It is capable of handling charge currents of up to 1A. Alternate component values are given in the figure for lower current applications. The only adjustment is the voltage trip point when the current is shunted through the transistor and load resistor. This should be set with a fully charged battery. As the transistor and R3 have the entire panel’s output across them when the battery is fully charged, they should be well heat sunk.

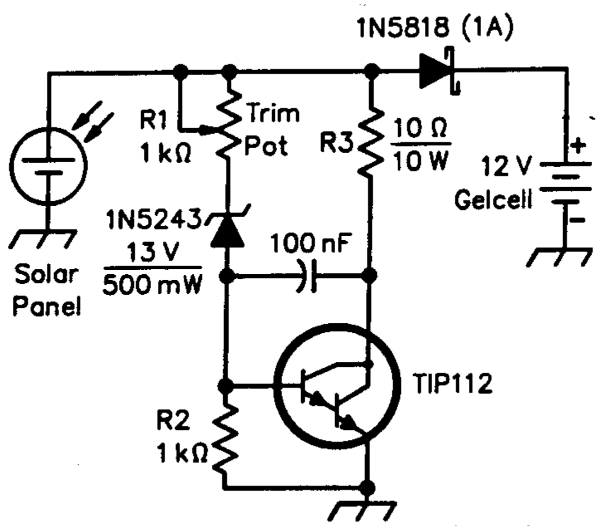

Figure 8 – This simple charge controller will handle charging currents up to 1 A. When the battery is fully charged, all of the current from the panel will be going through R3 and the Darlington transistor TIP112, so these must be well heat sunk. Adjust R1 for the trip point, usually 14.4 V – 15 V for a 12 V SLA or a 12 V Ni-Cd battery. (From “QRP Power” p 3-24)

A Strategy for Using Batteries

It is useful to develop a strategy for using batteries in your QRP shack and portable rig. If you do not, you can end up needing many different size batteries, connectors, and chargers. For fixed station use, this is not so bad, for portable operation, it always seems like you will be missing a crucial battery for a crucial application, or you will end up needing to use different battery types in a single application.

For rigs that have low-power consumption and lightweight requirements, like backpacking with the NE602 based SW-XX rigs, KD1JV’s ATS rigs and K-1s, standardizing on AA cells is a good strategy. A 12 V AA pack made of either alkaline or rechargeable Ni-Cd/Ni-MH cells is a good idea. You should power any accessories, keyers, or tuners with additional AA batteries, or from the same battery pack. Choose AA battery based flashlights so you can scavenge batteries from them if you need to. Encourage others who go camping with you to do the same. You can make up a battery pack using"solder tab" cells. Heat-shrink tubing can be used to hold it all together or you can use battery holders. As 10 Ni-Cd/Ni-MH cells make up the nominal 12 V required for most rigs, use a 10 cell holder, Mouser 12BH310A. Or you can make up a custom holder using an eight cell (or 2-4s) holder in series with a two cell holder. That way, if your Ni-Cd/Ni-MH cells get exhausted, you can replace them with eight easily available alkaline cells.

For rigs that require more power or where weight is not a concern, like the OHRs I am fond of, or a K2, a lead acid battery is a good choice. Power all of the accessories from the same battery. If the voltages required are different, use the same battery and power them with a low-dropout micropower regulator if they need a lower voltage. The 78L0X series is not a good choice , here, good choices include the LP2951 (adjustable), LP2950-X (X is the specified voltage), and Lt-1121CZ-X.

The 2.1mm coaxial power connector center pin positive is pretty much standard on most QRP rigs these days. It is a good idea to use it on all of your equipment. I use power cords with this connector on one end and alligator clips on the other end, so I don't need to worry about matching connectors on the batteries. I have a few cords that have the Radio Shack/Molex connector on the battery end. The ARRL was pushing this as a standard a few years back. I prefer the alligator clips. The Anderson Power Pole connectors are now becoming standard and they are a very effective system. There are a number of power distribution stations available, including one from Saratoga Systems that has voltage regulators (and fuses) built in to supply voltages at other (lower) than 12 V. This is a very convenient device.

It is pretty much a tautology that you should have spare batteries for each battery powered device. But we have all been caught short with a dead keyer battery and no spare at one time or another. Now is the time to raid all of those battery powered devices for a spare. Flashlights are an obvious choice, as are Walkman tape players and CD players, but we often overlook garage door openers and multimeters. You might want to raid those AA cells in your handie-talkie for another use. But the best idea is to bring spares. I carry a small 4.5 AH SLA cell as a back up to my standard 7 AH SLA, and often an alkaline 9 volt battery as well. Having 8 alkaline AA cells as backup is a good idea. If you go with a group, invariably someone will show up with a dead battery and no spare. If you can supply a spare, you will be a hero. It is not a bad idea to carry spares not only for your own gear, but also for others. Be prepared.

A voltmeter is a good device for checking the health of a battery, but 12 V light bulbs are probably more useful as they provide a load. Twelve volt lamps are available in a wide variety of sizes; pick one with a current draw roughly equal to your rig to test your battery. Radio Shack has a wide variety of 12 V bulbs, as does your auto parts store. The bulbs are also good for checking those surplus batteries often available at swap meets. In the field, I find it enlightening to make periodic measurements with a voltmeter over the course of operating to determine how the battery is really holding up. It gives me an idea if I really need a battery that big, or if I can get away with a slightly smaller one next time.

If you use a rechargeable battery to operate your rig in the shack, you should keep it charged. For an evening or afternoon of operating I operate from the battery and connect the charger at the end of the operating session. For longer sessions, like in a contest, I keep the charger connected to the battery.

If you only operate from batteries occasionally, you should top off your batteries from time to time. Ni-MH should be topped off once every two weeks, Ni-Cds once a month and SLA batteries once every six months. Always top off a battery before going to the field.

Summary and Conclusions
So what battery technology should you chose?

If you only go to the field occasionally, or want to try portable operation without a lot of expense, alkaline cells are probably the best choice. If weight is not a factor, you can operate a typical QRP rig from alkaline D-cells for months of casual operating and from a pair of lantern cells for almost a year

For portable operations where weight is not a concern, sealed lead-acids are probably the best bet. They are relatively inexpensive, particularly if you can get a pull, and are easy to charge. Do some homework first to size the battery properly.

For backpacking with efficient low power rigs, where low weight is paramount, use a battery pack made from Ni-MH AA cells. If the capacity of an AA cell is not sufficient, use the larger sizes available in Ni-Cd cells. Ni-MH cells must be charged with care, they are no where as forgiving as Ni-Cd cells.

If you want to try solar power, SLA batteries and Ni-Cd batteries are the easiest to use with solar panels and the most forgiving to charge.

Cold weather operation favors lithium, Ni-Cd, and Ni-MH cells. SLA batteries and alkaline cells are definitely poor choices for FYBO.

In order to make your rechargeable batteries last the longest, do not overcharge them, do not discharge them fully, store them fully charged, top them off as required, and avoid long term trickle charging of Ni-Cd cells.