Batteries For HO Locomotive Operation

Small scale locomotives have very little physical space available for extra stuff. What space is available is typically taken up with motors, drive shafts, decoders, lights, wiring and extra weight. A dummy locomotive can accept a small battery and possible the AirWire C15 CONVRTR. But a piece of rolling stock can be used to hold the battery and the CONVRTR.

Most Popular Battery Voltage for Small Scale Locomotives

A popular battery voltage for HO locomotives is the 11.1V rechargeable Lithium-Ion battery pack. You will probably see them advertised as LiPo battery packs. This battery can direct drive an AirWire M15 motion decoder or the C15 CONVRTR.The battery voltage is close to the recommended HO voltage of 12 volts. Your locomotive's top speed might be slightly slower, but for most hobbyists, the locomotive's top speed is more than adequate for their layout. These batteries come in many different dimensions and capacities. A boxcar or dummy locomotive is used to hold the battery and an AirWire CONVRTR.

11.1V 1300mAh

The LiPo batteries are relatively inexpensive due to their widespread use in cars, drones, boats and planes. Many local R/C hobbyshops sell these batteries and chargers. These packs have some disadvantages. The pack does not have any built in protection. Later this lack of protection will be discussed and tips to insure safe operation and charging will be provide.

LiPo battery packs require a specialized charger. This type of battery usually has two different connectors - one for charging and one output connector.

Other Suitable Batteries

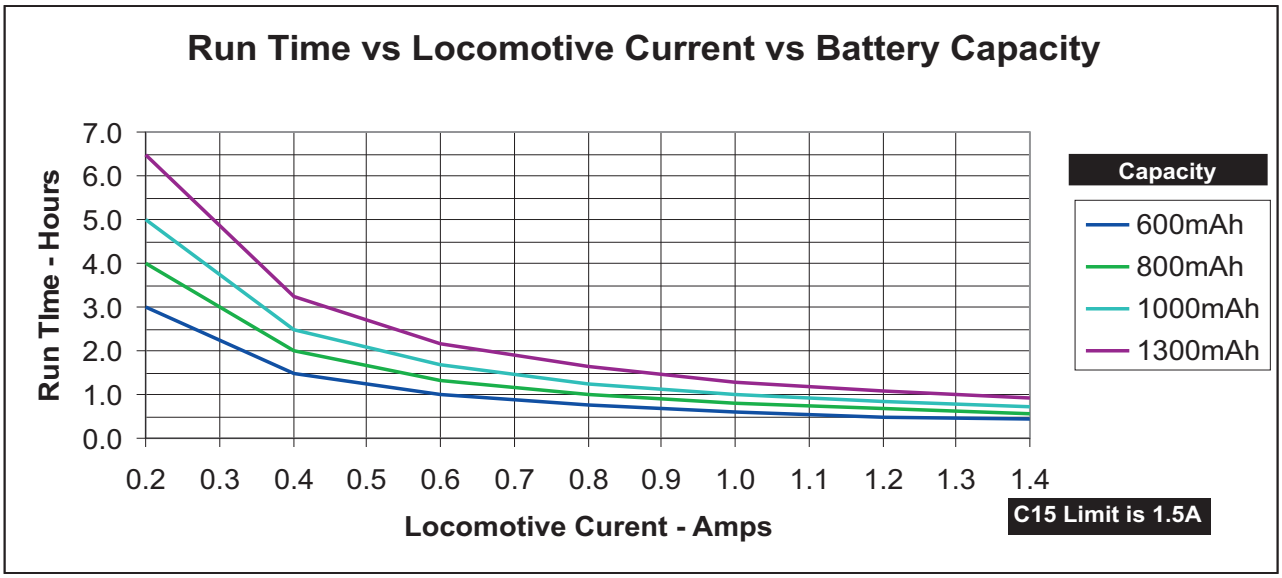
Another type of battery is the single cell Lithium-Ion flat battery. These come in many different sizes and capacities. However, their voltage is only 3.7 volts. This voltage is too low for locomotives. They are easily connected in series and their biggest benefit is they include built-in protection. A inexpensive Lithium-Ion charger is needed. A JST-2 type connector is commonly used.

A 3.7V Lithium-Ion battery requires a voltage boost module to boost the 3.4V up to 12V for use with AirWire equipment. This will be covered later in this paper.


3.7V 2000mAh

How Long Does The Battery Last?

This is easy for 11.1V batteries. Just find the battery capacity rating on the side of the battery. For small batteries it will be a numeric value followed by the initials "mAh." The initials mean "milli-Amp-hours." In the photo above, the LiPo battery is rated at 1300mAh, this means that a load of 1300mA (or 1.3A) can be drawn from the battery for ONE hour before the battery is depleted. The graph below shows the run time on the vertical axis and

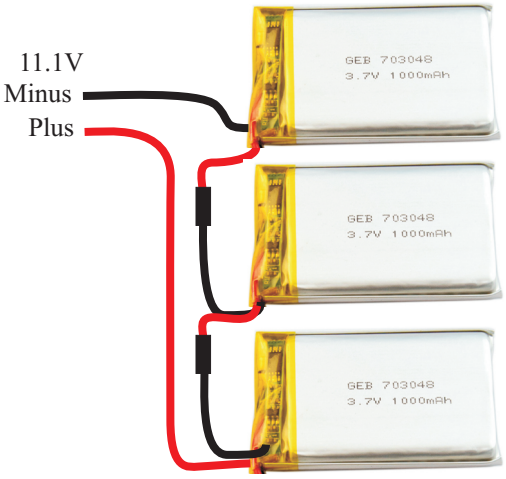


the locomotive current on the horizontal axis. Locate your locomotive motor current on the horizontal axis. Run your finger vertical until it intersects the appropriate battery capacity. Move your finger to the left and read the run time in hours. For example, if your locomotive averages about 300mA when running with the lights on and sound at full volume, an 800mAh battery will last about 3 hours. This is strictly an average. Heavier loads, steep grades and/or high speed running will deplete the battery quicker. That is why any quoted battery run time must always be prefaced with "It depends on..."

The conclusion to take from the graph on page 1 is that battery selection is a compromise between run time, average locomotive current and battery capacity. The battery capacity dictates the required space needed for the battery.

Using Low Voltage Batteries

The small flat cell or cylindrical 3.4V batteries can be wired in series to create whatever voltage is desired. Two cells in series create 7.4 volts. Three cells in series creates 11.1V. The drawing shows 3 cells in series to create an 11.1V battery pack.



11.1V Battery Stack
Each Cell is 3.7V

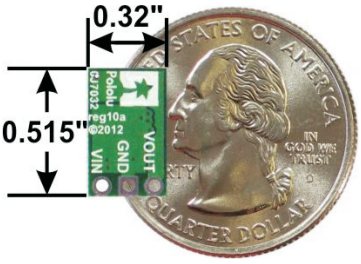
Individual cells do not have to be physically next to each other. They may be distributed in the available space, a common tactic used with cylindrical cells.

A series stack of 3.4V retains the self- protection features of each cell. The stack capacity rating is the rating of the cell itself. For the stack in the picture, it has an output voltage of 11.1V and a capacity rating of 1000mAh. For the best results, use cells that have the same capacity rating.

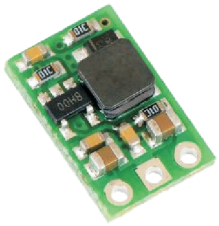
Charging the Lithium-Ion battery pack created with stacked cells is easy. Set the charger to the sum of the battery voltages. For the 3 cells shown, the charger is set to 11.1V. Beware that it will take 3 times as long to fully charge the stack of batteries compared to charging a single cell. Always use a Lithium-Ion rated charger. A charger with a 1.5A rating insures a long battery lifetime.

Boosting A Low Voltage To A High Voltage

For applications where the battery voltage is lower than the desired voltage, a boost module is needed. The DC-DC boost module takes a low voltage DC input and "boosts" it to a higher output voltage. Some boost modules offer a fixed output voltage whereas others offer a variable output voltage. The modules offer different output power levels, efficiencies and come in different sizes. The modules are easy to obtain, small, and are relatively inexpensive.



The small boost module to the right is rated at 1A and accepts voltages as low as 2.5V. It boosts it to 12V. The output voltage is fixed at 12V; it cannot be varied. It is extremely small measuring only 0.3 inches by 0.5 inches and it is only about 0.04 inches thick. This boost module is called a Pololu module.


Pololu 2.5V-12V
1 Amp Boost Module

The larger boost module to the right is called the XL6 module. It is larger because it has a 4A rating. It has the added feature of having a user set variable output voltage. The desired output voltage is set by the small potentiometer circled in red. It has a minimum input voltage of 3V and can boost as high as 35 volts. However, it is optimized for 5V and higher input voltages. Its primary use is with both 7.4V and 11.1V battery packs when a 12V output voltage is desired.

5V - Variable Boost Module

The larger boost module with its variable output can be used to boost an 11.1V battery up to 15V or higher. This is handy if you have the room for a LiPo battery but don't like the 11.1V output.

DC-DC Boost Modules - The Bad News

As good as a boost module appears, you don't get something for nothing. There are some drawbacks to using boost modules. For example, at lower input voltages, the boost module has to work harder and longer to boost

and maintain the desired output voltage. The extra "work" appears as a heavier load current on the source battery. As a result, the battery drains faster, the boost module runs hotter and the locomotive run time drops. The worst case condition is for a 3.7V battery boosted to 12V. In fact, the higher current boost module prefers a minimum of 5V input voltage. It should only be used with battery voltages of 7.4V or higher. .

Test Evaluation of The Two Boost Modules

Two low cost boost modules were evaluated with different battery input voltages. Since the most common question is how long will the locomotive run, an arbitrary battery, rated at 1000mAh was used. The modules were connected to a C15 CONVRTR. The source battery current was measured at different locomotive load currents. The results of the tests were plotted on the graph shown below.

To use this graph, find the locomotive average motor current on the bottom axis. Run your finger upwards until it intersects with the type of battery voltage and module used. Now run your finger to the left and read the loco run time measured in hours.

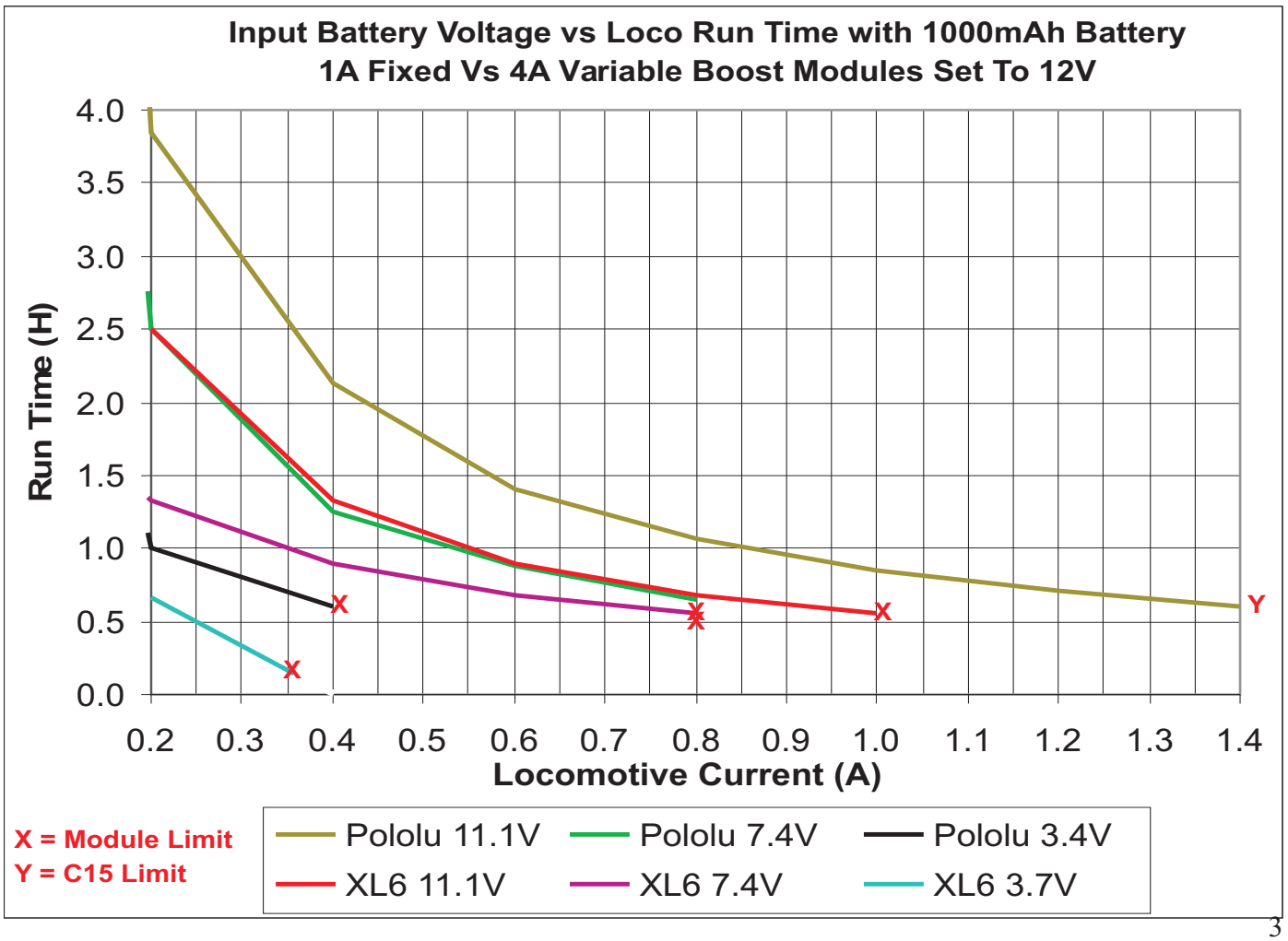
There are two absolute limits on the graph. The first limit, labeled with an X, is the maximum for the boost module. The second limit, which is the right side of the graph, is the C15 itself which is limited to 1.5 amps. If you loco needs more current, use a C25 or a C60.

This graph illustrates two key points about using boost modules.

1. The higher the input voltage, the more efficient is the boost module. In other words the battery will last longer.

2. There are limits to what the boost modules can deliver. As the input voltage drops or the the load current increases, the boost module works harder and harder and it becomes hotter and hotter. Eventually the boost module shuts down due to overheating. Once the module has cooled, it will resume normal operation.

Boost modules can be destroyed by a short circuit on their voltage output. If you accidentally short out a boost module it must be replaced.



LiPo Battery Sources and User Information

11.1V Lithium-Ion Polymer Batteries - "LiPo Batteries"

The 11.1V LiPo battery is very common. They come in a variety of capacities and sizes. They can often be found at R/C hobby shops. The best selection is from online retailers. They are relatively inexpensive due to their high volume use in toys. However, they ***do not*** have internal protection. A LiPo battery has large gauge wire attached to a relatively large connector. It will also have a second connector for charging. The connectors can be removed or changed but you will void the warranty. It is best to get matching connectors for your application. As a result, it is common to see the battery mounted in a boxcar or disguised as flatcar load. The boxcar shell is trimmed so that it can be easily removed. This allows access to the battery for recharging.

Charging LiPo Batteries

LiPo batteries will have two sets of connectors - one for power output and one for the cell-balancing charger. A cell balancing charger is about the same cost as a standard Li-Ion charger. The difference is that the liPo charger will have several sockets to fit the various connectors found on LiPo batteries. The one listed below included a LiPo battery.

Use only a charger designed for a lithium polymer/Li-Ion battery. Be sure to select the Lithium polymer (Lipo) mode on the charger. Always set the battery to the proper (battery pack voltage before charging. Always set the charger to the amperage charge rate as listed on battery label or datasheet. Do not attempt to charge the battery at a rate greater than the capacity of the battery unless the battery datasheet says otherwise. Never overcharge a battery beyond its rated acpacity. Never charge batteries higher than their maximum voltage (4.2V/cell for LiPo). Monitor the charging of a pack. Beware of hot packs - there maybe some kind of fault with the pack or the charger. Disconnect everything and investigate. Disconnect the battery from the charger when charging is complete.

Are Unprotected Lithium Batteries Safe To Use?

The simple answer is yes. If you have some common sense, and know how to follow instructions, you will not have any problems. LiPo batteries have received a lot of bad press simply because the battery was used incorrectly. The user did not follow the instructions. The battery problems are caused by the lack of any type of protection circuit. There is no limit to the load current or the charging current. Batteries can be depleted down to zero volts. Users can also use an incorrect charger. But, if the instructions and precautions are followed, and the correct battery charger is used, you can expect a long and safe lifetime for your LiPo battery.

The list below was compiled from a few hours spent searching various suppliers of LiPo batteries. Their websites are listed at the bottom of the list. Green highlighted items were purchased and evaluated. All were found to be satisfactory for powering HO scale locomotives.

Evaluated **11.1V LiPO Batteries without built-in protection**

As Of Jan 2020

Source	Model Name	Stock #	Volts	mAh	Connector	Price	mm (METRIC) L	W	H	INCHES L	W	H
Amazon	Turnigy 3S 25~40C Lipo Pack	none	11.1V	370	JST-XH	$6.77	*60*	*31*	*13*	2.4	1.2	0.5
Amazon	Onyx 11.1V LiPo: Micro Plug	ONXP1747	11.1V	600	micro	$12.99	52	32	21	2.0	1.3	0.8
Amazon	Gens Ace LiPo Battery JST Plug	EFLB8003SJ30	11.1V	800	JST	$18.03	52	30	23	2.0	1.2	0.9
Amazon	Lancer 11.1v 900mAh LiPO Stick Will not fit narrow hood GP loco	none	11.1V	900	Tamiya	$24.90	63.5	24.5	19	2.5	1.0	0.7
EVIKE	Matrix 11.1V Stick	78858	11.1V	1000	BMS / XH 3-Pin	$24	85	14	15.5	3.3	0.6	0.6
Amazon	FCONEGY 3S 11.1V 1200mAh	none	11.1V	1200	Tamiya	$16.99	129	21	17.5	5.1	0.8	0.7
Amazon	Tattu 11.1V 1200maH Stick 3S Fits boxcar but wires against car end	none	11.1V	1200	Tamiya	$17.99	124	20	16	4.9	0.8	0.6
Amazon	UKARMS AC-221C PEQ Brick	none	11.1V	1200	Deans	$29.95	63.5	25.4	19	2.5	1.0	0.7
EVIKE	Matrix 11.1V Stick	88611	11.1V	1450	BMS / XH 3-Pin	$25	116	21	16.5	4.6	0.8	0.6
Amazon	Turnigy 1800mAh 3S	none	11.1V	1800	XT60	$13.04	104	34	23	4.1	1.3	0.9
Amazon	Zeee 2200mAh 11.1V 35C 3S		11.1V	2200	Deans and XT60	$32.99	102	34	23	4.0	1.3	0.9
					HO dummy A Loco athearn old behind cab to rear		127.0	28.0	25.4	5.0	1.1	1.0
					HO Long Grain Hopper		152.4	30.5	25.4	6.0	1.2	1.0
					HO Athearn 40' box car Interior		140.0	31.8	30.5	5.5	1.3	1.2
					HO Dummy Narrow Hood SD7 behind cab to rear		127.0	17.8	27.9	5.0	0.7	1.1
Tenergy	TN267 1-4 Cells Li-Po/Li-Fe Balance Charger	$24										

The loco and car measurements are approximate. You must measure your unit to insure battery fit. Battery dimensions are from manufacturer's datasheet. Actual size will be slightly different.

Yellow fill indicates fit could be an issue depending on how the battery is positioned.

Source Websites

EVIKE	https://www.evike.com
MAXAMPS	https://www.maxamps.com/
TATTU	https://www.genstattu.com/

AMAZON	https://amazon.com
ADAFRUIT	https://www.adafruit.com/
Tenergy	https://power.tenergy.com

Li-Ion Batteries With Protection

This type of battery includes the protection feature. A protected lithium-ion battery includes an internal circuit board for protection. This internal circuit board protects the battery from an over voltage charge, excessive charge level, excessive discharge, and under voltage operation. When the battery reaches a predetermined voltage, it is declared "discharged" and the battery voltage goes to 0 and stays there until the battery is recharged.

A protected battery is very safe and protects itself from improper charging or use. A protected battery typically has a much longer lifetime compared to a LiPo battery. The batteries are available in 3.7V, 7.4V, 11.1V and higher voltages. Higher voltages are created by placing single cells in series. The protection circuit protects all of the batteries in the pack. There are many different physical sizes and capacities available. The table lists some 3.7V batteries that are easy to get and relatively low cost.

It is this type of battery, along with the 1Amp Pololu boost module, that is used in our trainshow steam engine fleet.

Charging Li-Ion Batteries

Use only a charger with the same voltage rating as the battery. A single battery needs a charger with a 3.7V output. If there are two batteries in series, get a 7.4V charger. If your locomotive fleet uses different voltages, get the charger that has a selectable output voltage. Always use a charger designed for Li-Ion rechargeable batteries. Because of the protection circuit, you can charge this type of battery without any worries. The source websites are on the proceeding page.

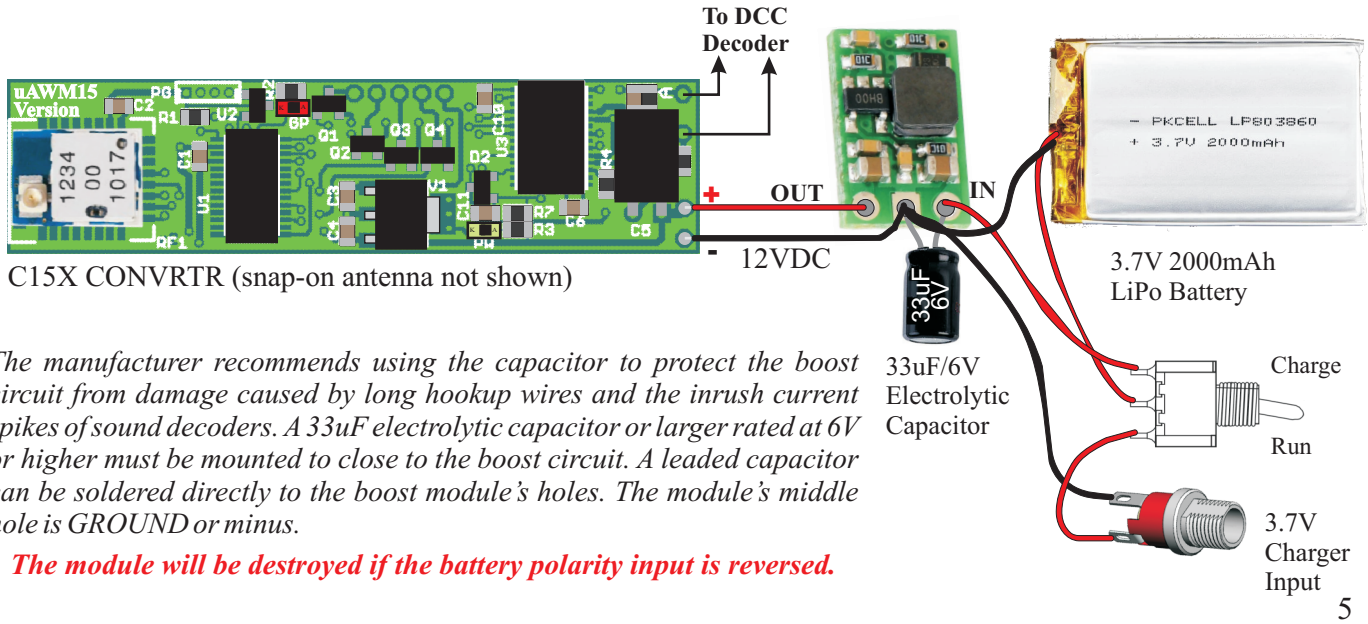
Evaluated	3.7V Lithium-Ion Flat Packs with Built-in Protection							mm (Metric)			Inch		
Source	Model Name	Stock #	Type	Volts	mAh	Connector	Price	L	W	H	L	W	H
Adafruit	3.7V 350mAh	ID: 2750	Flat	3.7	350	JST-2.0	6.95	29	36	4.8	1.1	1.4	0.2
Adafruit	3.7V 400mAh	ID: 3898	Flat	3.7	400	JST-2.0	6.95	62	34	5.0	2.4	1.3	0.2
Adafruit	3.7V 500mAh	ID: 1578	Flat	3.7	500	JST-2.0	7.95	29	36	4.8	1.1	1.4	0.2
Adafruit	3.7V 1200mAh	ID: 258	Flat	3.7	1200	JST-2.0	9.95	34	62	5.0	1.3	2.4	0.2
Adafruit	3.7V 2000mAh	ID: 2011	Flat	3.7	2000	JST-2.0	12.5	60	38	7.0	2.4	1.5	0.3
Adafruit	3.7V 2500mAh	ID: 328	Flat	3.7	2500	JST-2.0	14.95	47	61	6.7	1.9	2.4	0.3
Adafruit	Lithium Ion Clylndrical 3.7V 2200mAh	ID: 1781	Cylindrical	3.7	2200	JST-2.0	9.95	69	18	18	2.7	0.7	0.7
Tenergy	Li-ion 18650 3.6V 2200mAh with / PCB	30011-02	Cylindrical	3.7	2600	Bare Wire	8.99	69	19	19	2.7	0.7	0.7
							HO dummy A Loco athearn old behind cab to rear				127.0	28.0	25.4	5.0	1.1	1.0
							HO Long Grain Hopper				152.4	30.5	25.4	6.0	1.2	1.0
							HO Athearn 40' box car Interior				140.0	31.8	30.5	5.5	1.3	1.2
							HO Dummy Narrow Hood SD7 behind cab to rear				127.0	17.8	27.9	5.0	0.7	1.1

The loco and car measurements are approximate. You must measure your unit to insure battery fit. Battery dimensions are from manufacturer's datasheet. Actual unit may be slightly different.

Battery Charger

Tenergy	TLP-4000 Universal 1A Smart Charger (3.7V-14.8V)

Typical Hookup Diagram With Pololu Module, 3.7V Battery and C15 CONVRTR



C15X CONVRTR (snap-on antenna not shown)

The manufacturer recommends using the capacitor to protect the boost circuit from damage caused by long hookup wires and the inrush current spikes of sound decoders. A 33uF electrolytic capacitor or larger rated at 6V or higher must be mounted to close to the boost circuit. A leaded capacitor can be soldered directly to the boost module's holes. The module's middle hole is GROUND or minus.

The module will be destroyed if the battery polarity input is reversed.