Battery Information

Battery Type
The following section will help you make the correct choice.
Use only Deep cycle batteries for extended use. These batteries are designed to be repeatedly discharged to 50% of their capacity then fully recharged. If used in this manner they will last through hundreds of charge, discharge cycles.

Most people are familiar with lead acid batteries in their vehicles. These batteries are designed to output a large amount of current for a short period of time then be completely recharged. Deep discharging of these batteries seriously degrades their life.
They are not recommended for powering inverters for any length of time.

There are many types of Deep Cycle batteries available from distributors. A 105AH Deep cycle battery is used in the sample calculations below.

Watt-Hour conversion

All the calculations will be in Watts and Watt-Hours since this makes calculations independent of input voltage. Most batteries however are rated in amp-hours. It will be necessary to convert this to Watt-Hours.

From OHM's Law :
Voltage is equal to current times resistance V = I x R
and Power is equal to current times voltage P = I x V

Watt-Hours = Amp-Hours x Battery Voltage

for example: to find out how many Watt-Hours in a 100AH 12Vdc battery.

100AH x 12 Vdc = 1200 Watt-Hours

Therefore a 12Vdc 100AH battery has 1200 Watt-Hours of capacity.

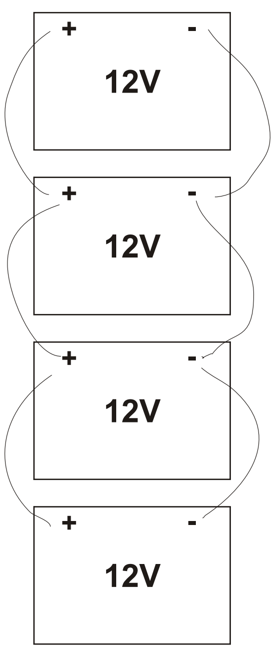


Figure 4a

The Watt-Hour capacity of a battery bank is the sum of all the batteries connected in the system. For example four 100AH batteries (1200 Watt-Hours each) result in a 4800 Watt-Hour battery Bank (4x 1200 = 4800). As shown in figure 4a. This is true despite the terminal voltage of the battery bank, assuming the rules for connecting them described in the next section are followed. These four batteries for instance may be connected for a battery bank terminal voltage of 12 Vdc, 24Vdc or 48Vdc.

Battery Bank configuration

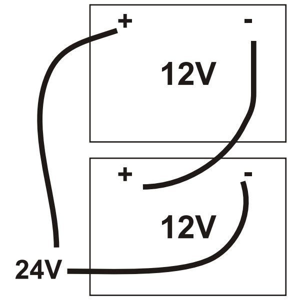


Figure 4b

A battery is typically a collection of cells connected in series to give the desired output voltage and Watt-Hour capacity. For purposes of this manual a battery bank is defined as a series, parallel or series-parallel connection of batteries to give the desired battery bank terminal voltage and Watt-Hour capacity. Again we will use a 100AH battery for our examples. These batteries have a terminal voltage of 12Vdc. They may be connected in series to give higher voltages. Connecting two batteries in series, positive terminal of one battery connected to the negative terminal of the other as shown in figure 4b, will make a battery bank with a 24Vdc terminal voltage. It is important that all batteries in this series connected branches be of exactly the same capacity. If not, the branch will only have the Watt-Hour capacity of the smallest battery. They may also be connected in parallel to give higher capacity. As shown in figure 5 connecting the positive terminal of one battery to the positive terminal of the other. Then similar connecting the negative terminal of the first battery to the negative terminal of the second battery. This results in a 12Vdc battery bank with a capacity of 2400 Watt-Hours. Batteries of dissimilar capacities may be connected in parallel without any detrimental effects. These batteries must however be of the same type. That is to say, they must all be lead acid deep cycle batteries or they must be nickel-cadmium batteries. DO NOT CONNECT DISSIMILAR BATTERIES IN PARALLEL, such as a lead-acid to a nickel-cadmium, damage to the batteries may result. Batteries may also be connected in combinations of series and parallel to get higher voltages and higher capacities. This combination is shown in figure 6. This is just a combination of the above connections with a couple more rules of connection. As shown in figure 6 each series connection of batteries will be referred as a branch. Each of these branches must have the same terminal voltage (ie. 24Vdc, 36Vdc, etc.). The Watt-Hour capacity of each battery in a branch must be the same. Any two branches can be of different Watt-Hour capacity. These branches can then all be connected in parallel to create a battery bank of any size. The diagram in figure 6 shows two (2) branches of two (2) batteries each connected in parallel to give a total of 4800 Watt-Hours of capacity.

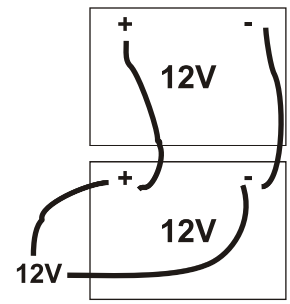


Figure 5

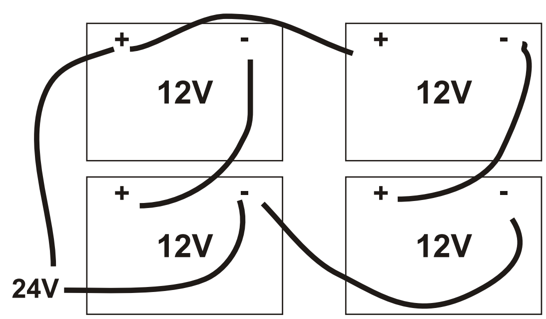


Figure 6

Sizing the battery bank and inverter

Now, determine the size battery bank required for your set of circumstances. Two things determine the size battery bank required, THE TOTAL NUMBER OF WATT-HOURS REQUIRED and THE MAXIMUM NUMBER OF WATTS THAT WILL RUN AT ONE TIME.

Item	Running Power	Starting Power	Simultaneous Starting Power	Continuous Running	Time	Watt-Hours
CRT	40	N/A	40	40	3	120
A/D CONVERTER	30	N/A	40	30	3	90
COMPUTER	100	N/A		100	3	300
HEATER	900	N/A	900		0.3	270
OSC.	70	N/A			2	140
DRILL	200	N/A			0.2	40
CIRCULATION PUMP	500	2000	2000	500	1.5	750
TOTAL			2980 Worst Case Load	670		1710

Make a list of all the items that will be run on the inverter and the length of time it must run between battery charges. Placing it in grid similar to the example above may be helpful. The first column describes the accessory for identification. The second column is the running watts of the item under steady state conditions. The third column is the maximum starting power required. This is usually only needed on items that use motors such as pumps, refrigerators, power tools, and the like. This data can be found on the product identification label of the item. Usually close to the power cord will be some kind of label or stamp that gives the model number, manufacturer and the power requirements. Sometimes it will state the amps required.

You will then need to convert amps into watts per the following formula.

I (amps) x V (volts) = P (watts)

Example: A circulation pump running at 220 Vac has a running current of 2.2 amps and a Starting Current (sometimes called LRA, locked rotor amps) of 9.0 Amps. Find the running and starting powers.

2.2A x 220V = 484 Watts running power
9.0A x 220V = 1980 Watts starting power

The rest of the columns will require some educated guessing. The fourth column tries to determine the maximum load on the inverter and battery system. In this case we assume it is possible for the TV, VCR, and Microwave oven to be on when the well pump started. This column is used to assure the inverter can meet the demand as well as the battery bank. The next column (5th) is an attempt to find the worst case continuous power draw from the battery bank. For purposes of this manual, continuous will mean the highest load that will be on the battery for more than 15 minutes at a time. Again here we assume the TV, VCR and water pump run a great deal of the time, or are at least representative of the average load on the battery. This column is used to determine if any derating of the battery bank will be required due to too high of power demand.

The next column (6th) is used to calculate the amount of time each load will run between successive battery charges. The assumption is the battery is completely charged at the beginning of this time. This may not be realistic in all situations but is useable for a first pass calculation.

To get the total Watt-Hours multiply the Running Power Watts by the Time columns to get the Watt-Hours needed by each item. Now add the entries in each column to get the total Simultaneous Starting Watts, the total Continuous Running Watts and the total Watt-Hours.

Examining the totals generated in the table usually forces to difficult decisions.

First look at the Simultaneous Starting Watts. Recall from above, this is a list of the worst case load on the inverter. This total must be less than or equal to the inverters surge power. If it is not, then you either need a larger inverter or must reexamine your choices. In the example above the simultaneous starting power came out to 3000 Watts, the surge power of the Exeltech 1000 inverter is 2200 Watts. This means the inverter may not start the circulation pump when the heater is running. After examining the chances of the heater and the pump running simultaneously one may decide that it is not likely or take some action to assure that the two will not run at the same time. So modify the total to be 2100 Watts. The alternative is to add a module to the inverter system. This is within the inverters rating so we may proceed.

Second look at the ratio of the total Watt-Hours to the Continuous Running Watts.

WATT-HOURS ÷ CONTINUOUS-RUNNING-WATTS = LOAD-RATIO

$$1710/670 = 2.5$$

The result of this calculation is 2.5 for our example. Now take this load ratio to the table below. Find the Load Ratio in the left column then read directly to the right of that row to find the corresponding battery ratio.

Load Ratio	Battery Ratio
1 - 5	5
5 - 10	4
10 - 15	3
15 - 20	2.5
Greater than 20	2

Since in our example the load ratio is 2.8, we find this lies between 1 - 5 in the left column. The corresponding battery Ratio for this row is 5. To find the needed battery bank sizes use the following equation.

Battery Ratio x Watt-Hours = Battery Bank Watt-Hours

5 x 1710 = 8550 Watt-Hours

Therefore, in our example, we need 8550 Watt-Hours of battery bank. Assuming we are going to use 100 Amp-Hour 12 Vdc batteries that are 1200 Watt-Hours each from our previous calculation we need to find the number of batteries required.

Battery Bank Watt-Hours ÷ Battery Watt-Hours = # of required batteries

8550/1200 = 7 Batteries

Our example requires seven 100 Amp-Hour batteries. Again this is independent of the battery bank voltage. So if we had a 12 Vdc system we would need seven batteries in parallel. Now, if we had a 24 Vdc system you would find you cannot build a battery bank per the rules stated above because each branch of the battery bank must have the same size batteries. The minimum number of batteries required then is the smallest number over 7 that will build a proper battery bank. In this case it will take 8 batteries configured. Notice in this example that the required battery bank size seems much larger than the total Watt-hours indicates. The reason for this is, the simultaneous running watts in our example places a very heavy current drain on the battery. Most batteries are designed to give their rated charge if discharged at a rate equal to 1/20th of their Amp-Hour capacity. For the case of our 100 Amp-Hour battery this means the battery will only give its full capacity if discharged at a rate of 5 Amps. In the example used, although we did not calculate it directly, it would discharge a single battery system at about 50 Amps. This is 10 times the discharge capacity of the battery. To compensate for this heavy loading, the load factor and corresponding battery factor was used to increase the battery bank size to account for this derating. If the simultaneous running watts were reduced even slightly in this example, it would result in needing a much smaller battery bank.

Cable Sizing

The wiring between the inverter and the battery bank should be as short as possible and of a gauge at least as great as that called for in the chart below. Since this manual covers many different input voltages you need to find the correct row for your inverter. Then read across to the column corresponding to the distance between the inverter and the battery bank.

Power	5 feet	10 feet	15 feet	20 feet
1KW @ 12Vdc	4	2	2	0
1KW @ 24Vdc	8	6	4	2
1KW @ 36Vdc	10	8	8	6
1KW @ 48Vdc	10	10	8	8
1KW @ 66Vdc	12	12	10	10
1KW @ 120Vdc	14	14	14	14

Power	5 feet	10 feet	15 feet	20 feet
2KW @ 12Vdc	0	N/A	N/A	N/A
2KW @ 24Vdc	4	2	0	N/A
2KW @ 36Vdc	6	4	4	2
2KW @ 48Vdc	6	6	4	4
2KW @ 66Vdc	8	8	6	6
2KW @ 120Vdc	10	10	10	10

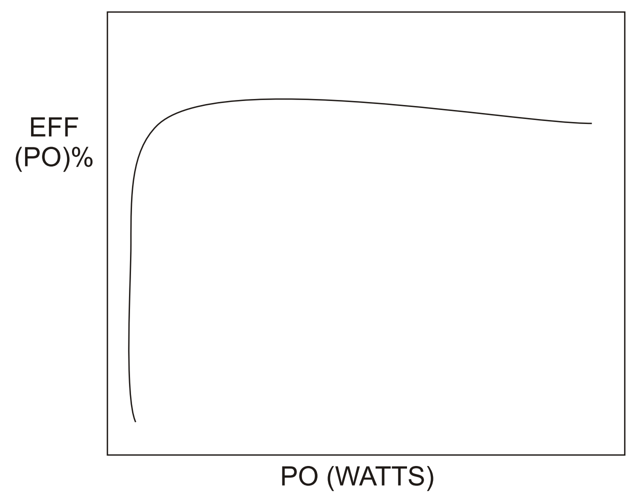
For example a 2KW, 48Vdc with 10 feet of wire requires 7 gauge wire. Since odd gauges are not commonly available a 6 gauge wire would be used. Note: 6 gauge wire is larger than 8 gauge wire.

TO AVOID ANY RADIO FREQUENCY INTERFERENCE IT IS BEST TO KEEP THE LEADS BETWEEN THE BATTERY AND THE INVERTER TWISTED TOGETHER AS TIGHTLY AS POSSIBLE AND AS SHORT AS PRACTICABLE.

Battery Charger
The Exeltech MX Series of inverters are compatible with any commercially available battery charger. The inverter will operate normally and output the correct AC voltage over a very wide range of DC input voltages. The AC output voltage is also totally immune to any amount of ripple or noise on the battery side of the inverter.

Caution: IT IS NECESSARY TO HAVE A BATTERY INSTALLED ON THE INPUT OF THE INVERTER. DO NOT RUN THE INVERTER DIRECTLY OFF A BATTERY CHARGER.

Efficiency
The inverter maintains a very flat efficiency from low output power levels up to its maximum continuous power. The graph shows the inverters efficiency as a function of output power. Also included is an equation from which you can determine the inverters efficiency for any power level.



The following formula can be used to calculate the efficiency of the Exeltech MX Series inverters.

B and M are constants determined by inverter performance which are functions of input voltage, N is the number of 1000 Watt modules.

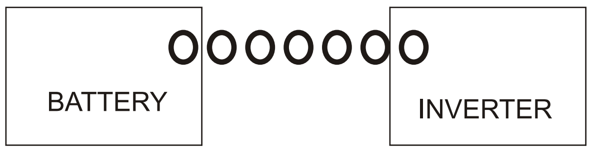
For the:
12Vdc input model: B = 0.95 M = -0.0001
24Vdc to 108Vdc model: B = 0.98 M = -0.0001
PO = Power Out
EFF(PO) = Efficiency as a function of Power Out
PIN (PO) = Power IN as a function of Power Out
PIN(PO) = N x 10.0 + [PO/ (M x PO) + B]
where:
EFF(PO) = [PO/PIN(PO)] x 100

RFI (Radio Frequency Interference)
Many electronic devices are susceptible to electronic interference, but take heart, they can usually be resolved. There are two general ways in which RFI can enter your electronics. **First**, it may be conducted in via the power cord, ground paths or data connections. **Secondly**, it may be radiated into the device from the source.

This note will discuss how to fix RFI problems with inverters in common installations. Most of the techniques are quite general in nature and will work with any inverter, but it is specifically targeted at situations which may occur with the line of Exeltech inverters.

Most RFI issues arise from the battery cables radiating energy to the device in question. The radiation occurs due to the high currents the inverter is drawing from the battery. If there is any loop or aperture formed by the battery cables, it will form a loop antenna and radiate. To fix this problem first **keep the battery to inverter cables as short as possible**.

Second, **twist the positive and negative battery cables together as tightly as possible**. Third, **make sure there is only one ground point for the battery side of the inverter**. There should only be one path for current to flow from the battery to the inverter. For instance, if a metal battery box is connected to ground and the negative terminal of the battery, and the inverter is bolted to the battery box, (not a good location due to corrosion problems) some current may flow through the battery box to the inverter rather than going through the negative lead of the inverter. In this situation, isolate the inverter case from the battery box. The next step would be to keep the inverter and DC cables as far as possible from the device in question. This includes keeping any antenna leads away from the battery/inverter connections. In extreme cases, a toroidal ferrite bead may be installed around the inverter input cable. This step is seldom necessary except in Ham radio operations or sensitive data taking applications.



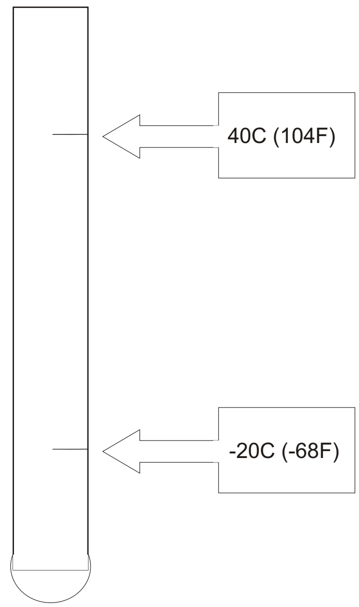
The previous discussion will solve most problems but occasionally there may be a conducted problem at the AC output. A quick way to find out if that is the problem, purchase a good quality (it should cost about $50) EMI/RFI filter at a computer store. Install this filter between the inverter and the device in question.

Location

The inverter is a highly sophisticated piece of electronic equipment. As such, its location warrants some special consideration. A good rule would be to mount the inverter as if it was your favorite piece of stereo equipment. The inverter should be mounted indoors preferably in some type of equipment shed as close to the battery bank as possible. The gasses emanating from the battery can be corrosive and highly flammable. Therefore the inverter should be isolated from the battery bank as much as possible. This can best be achieved by placing the inverter on the opposite side of a wall separating the battery bank from all the other electronics. The inverter can be wall or shelf mounted as indicated in the section above.

The inverter must be sheltered from the weather. Keep it away from condensing water. The inverter will provide its full capability in ambient temperatures from -20°C (-68°F) to 40°C (104°F). As with all electronics, higher ambient temperatures will lead to a shorter life. There is little that can be done about ambient air temperature but make sure that adequate ventilation is provided.

The equipment shed may be as far from the load as necessary. The only limitation is the voltage drop in the AC output between the inverter and the load. Use the table below to size the **wire from the inverter to the load** if necessary.



Feet from inverter to Load

POWER	50’	100’	200’	500’
1KW	12AWG	10AWG	6AWG	2AWG
2KW	10AWG	6AWG	4AWG	0AWG