AC POWER SOURCE

SAMLEX AMERICA

PURE SINE WAVE DC-AC INVERTER & CHARGER

(With built-in AC to DC Battery Charger and Transfer Relay)

INVERCHARGE SERIES

MODELS:

S-1012A
S-1012E
S-2012A
S-2012E
S-1024A
S-1024E
S-2024A
S-2024E
S-3024A
S-3024E

OWNER'S MANUAL

Please read this manual before operating the unit.

INDEX

SAFETY INSTRUCTIONS

Please read these instructions before installing or operating the inverter to prevent personal injury or damage to the inverter.

GENERAL

Installation and wiring compliance

- Installation and wiring must comply with the local and National Electrical Codes and must be done by a certified electrician.

Preventing electrical shock

- Always connect the grounding connection on the inverter to the appropriate grounding system.
- Disassembly / repair should be carried out by qualified personnel only.
- Disconnect all AC and DC side connections before working on any circuits associated with the inverter. Turning the on/off switch on the inverter to off position may not entirely remove dangerous voltages.
- Be careful when touching bare terminals of capacitors. The capacitors may retain high lethal voltages even after the power has been removed. Discharge the capacitors before working on the circuits.

Installation environment

- The inverter should be installed indoor only in a well ventilated, cool, dry environment
- Do not expose to moisture, rain, snow or liquids of any type.
- To reduce the risk of overheating and fire, do not obstruct the suction and discharge openings of the cooling fan.
- To ensure proper ventilation, do not install in a low clearance compartment.

Preventing fire and explosion hazards

Working with the inverter may produce arcs or sparks. Thus, the inverter should not be used in areas where there are inflammable materials or gases requiring ignition protected equipment. These areas may include spaces containing gasoline powered machinery, fuel tanks, battery compartments.

Precautions when working with batteries.

- Batteries contain very corrosive diluted sulphuric acid as electrolyte. Precautions should be taken to prevent contact with skin, eyes or clothing.
- Batteries generate hydrogen and oxygen during charging resulting in evolution of explosive gas mixture. Care should be taken to ventilate the battery area and follow the battery manufacturer's recommendations.
- Never smoke or allow a spark or flame near the batteries.
- Use caution to reduce the risk of dropping a metal tool on the battery. It could spark or short circuit the battery or other electrical parts and could cause an explosion.
- Remove metal items like rings, bracelets and watches when working with batteries. The batteries can produce a short circuit current high enough to weld a ring or the like to metal and thus cause a severe burn.
- If you need to remove a battery, always remove the ground terminal from the battery first. Make sure that all the accessories are off so that you do not cause a spark.

INVERTER RELATED

Preventing paralleling of the AC output

The AC output of this inverter cannot be synchronised with another AC source and hence, it is not suitable for paralleling. The AC output of the inverter should never be connected directly to an electrical breaker panel / load center which is also fed from the utility power / generator. Such a connection may result in parallel operation of the different power sources and AC power from the utility / generator will be fed back into the inverter which will instantly damage the output section of the inverter and may also pose a fire and safety hazard. If an electrical breaker panel / load center is fed from an inverter and this panel is also required to be powered from additional alternate AC sources, the AC power from all the AC sources like the utility / generator / inverter should first be fed to a manual selector switch and the output of the selector switch should be connected to the electrical breaker panel / load center.

To prevent possibility of paralleling and severe damage to the inverter, never use a simple jumper cable with a male plug on both ends to connect the AC output of the inverter to a handy wall receptacle in the home / RV.

Connecting to multi-wire branch circuits

Do not directly connect the hot side of the inverter to the two hot legs of the 120 / 240 VAC electrical breaker panel / load centre where multi-wire (common neutral) branch circuit wiring method is used for distribution of AC power. This may lead to overloading / overheating of the neutral conductor and is a risk of fire.

A split phase transformer (isolated or auto-transformer) of suitable wattage rating (25 % more than the wattage rating of the inverter) with primary of 120 VAC and secondary of 120 / 240 VAC (Two 120 VAC split phases 180 degrees apart) should be used. The hot and neutral of the 120 VAC output of the inverter should be fed to the primary of this transformer and the 2 hot outputs (120 VAC split phases) and the neutral from the secondary of this transformer should be connected to the electrical breaker panel / load centre.

Preventing input over voltage

It is to be ensured that the input voltage of the inverter does not exceed 15 VDC to prevent permanent damage to the inverter. Please observe the following precautions:

- Ensure that the maximum charging voltage of the battery charger / alternator / solar charge controller is below 15 VDC
- Do not use unregulated solar panels to charge a battery. Under cold ambient temperatures, the output of the solar panel may exceed 18 VDC for 12 V system. Always use a charge controller between the solar panel and the battery.
- Do not connect the inverter to a battery system with a voltage higher than the rated battery input voltage.

Preventing reverse polarity on the input side

When making battery connection on the input side, make sure that the polarity of battery connection is correct (Connect the positive of the battery to the positive terminal of the inverter and the negative of the battery to the negative terminal of the inverter). If the input is connected in reverse polarity, DC fuse(s) inside the inverter will blow and may also cause permanent damage to the inverter. **DAMAGE CAUSED BY REVERSE POLARITY IS NOT COVERED BY YOUR WARRANTY!**

INVERTERS - GENERAL INFORMATION

Why an inverter is needed
The utility grid supplies you with alternating current (AC) electricity. AC is the standard form of electricity for anything that "plugs in" to the utility power. Direct current (DC) electricity flows in a single direction. Batteries provide DC electricity. AC alternates its direction many times per second. AC is used for grid service because it is more practical for long distance transmission. For more details, read **"Characteristics of Sinusoidal AC Power" on page 7.**

An inverter converts DC to AC, and also changes the voltage. In other words, it is a power adapter. It allows a battery-based system to run conventional AC appliances directly or through conventional home wiring. There are ways to use DC directly, but for a modern lifestyle, you will need an inverter for the vast majority, if not all of your loads (**in electrical terms, "loads" are devices that use electrical energy**).

Incidentally, there is another type of inverter called grid-interactive. It is used to feed solar (or other renewable) energy into a grid-connected home and to feed excess energy back into the utility grid. This inverter is **NOT grid interactive.**

Inverter should meet the application
To choose an inverter; you should first define your needs. Where is the inverter to be used? Inverters are available for use in buildings (including homes), for recreational vehicles, boats, and portable applications. Will it be connected to the utility grid in some way? Electrical conventions and safety standards differ for various applications, so don't improvise.

Electrical Standards
The DC input voltage must conform to that of the electrical system and battery bank. 12 volts is recommended for small, simple systems. 24 and 48 volts are the common standards for higher capacities. A higher voltage system carries less current, which makes the system wiring cheaper and easier.

The inverter's AC output must conform to the conventional power in the region in order to run locally available appliances. The standard for AC utility service in North America is 120 and 240 Volts at a frequency of 60 Hertz (cycles per second). In Europe, South America, and most other places, it is 230 volts at 50 Hertz.

Power capacity – "Continuous" and "Surge"
How much load can an inverter handle? Its power output is rated in Watts. Read details under **"Characteristics of Sinusoidal AC Power" on page 7.** There are two levels of power rating -a **continuous rating** and a **surge rating**. Continuous means the amount of power the inverter can handle for an indefinite period of hours. When an inverter is rated at a certain number of Watts, that number generally refers to its continuous rating. The **"surge power"** indicates the power to handle instantaneous overload of a short duration to provide the higher power required to start certain type of devices and appliances.

Loads that require "surge power" to start

Resistive types of loads (like incandescent lamps, toaster, coffee maker, electric range, iron etc) do not require extra power to start. Their starting power is the same as their running power.

Some loads like induction motors and high inertia motor driven devices will initially require a very large starting or **"surge"** power to start from rest. Once they have started moving and have attained their rated speed, their power requirement reduces to their normal running power. The **surge** may last up to 5 seconds. The manufacturers' specification of the appliances and devices indicates only the running power required. The surge power required has to be guessed at best. See below under **"Sizing of inverter for loads that require starting surge".**

If an inverter cannot efficiently feed the surge power, it may simply shut down instead of starting the device. If the inverter's surge capacity is marginal, its output voltage will dip during the surge. This can cause a dimming of the lights in the house, and will sometimes crash a computer.

Any weakness in the battery and cabling to the inverter will further limit its ability to start a motor. A battery bank that is undersized, in poor condition, or has corroded connections, can be a weak link in the power chain. The inverter cables and the battery interconnect cables must be sized properly. The spike of DC current through these cables is many hundreds of Amps at the instant of motor starting. Please follow the instructions under **"Installation - DC side connections" on pages 36 & 37**.

Sizing of inverter for loads that require starting surge

Observe the following guideline to determine the continuous wattage of the inverter for powering loads that require starting surge. (Multiply the running Watts of the device/ appliance by the Surge Factor).

***NOTE:** **The surge power rating specified for this inverter is valid for duration of less than 2 seconds. This very short duration may not be sufficient to start motor based loads which may require up to 5 seconds to complete starting process. Hence, for purposes of sizing the inverter, use only the continuous power rating of this inverter.**

Type of Device or Appliance	**Surge Factor for Determining the Continuous *Wattage of the Inverter (No. of times the running power rating of the device/appliance)**
Air Conditioner	5
Refrigerator / Freezer (Compressor based)	5
Air Compressors	4
Dishwasher	3
Automatic Washer	3
Sump Pump / Well Pump / Submersible Pump	3
Furnace fans	3
Industrial motors	3
Portable kerosene / diesel fuel heater	2
Circular saw	3
Bench Grinder	3

Power rating of Microwaves

The power rating of the microwave generally refers to the cooking power. The electrical power consumed by the microwave will be approximately 2 times the cooking power. The power rating of the inverter should, therefore, be more than 2 times the cooking power of the microwave. For example, a microwave rated at a cooking power of 800 Watts should be powered from an inverter rated >1600 Watts.

Powering a water supply pump

A water well or pressure pump often places the greatest demand on the inverter. It warrants special consideration. Most pumps draw a very high surge of current during start up. The inverter must have sufficient surge capacity to handle it while running any other loads that may be on. It is important to size an inverter sufficiently, especially to handle the starting surge (If the exact starting rating is not available, the starting surge can be taken as 3 times the normal running rating of the pump). Oversize it still further if you want it to start the pump without causing lights to dim or blink.

In North America, most pumps (especially submersibles) run on 240 VAC, while smaller appliances and lights use 120 VAC. To obtain 240 VAC from a 120 VAC inverter, use a 120 VAC to 240 VAC transformer. If you do not already have a pump installed, you can get a 120 volt pump if you don't need more than 1/2 HP.

Idle power

Idle power is the consumption of the inverter when it is on, but no loads are running. It is "wasted" power, so if you expect the inverter to be on for many hours during which there is very little load (as in most residential situations), you want this to be as low as possible.

Phantom and idling loads

Most of the modern gadgets draw some power whenever they are plugged in. Some of them use power to do nothing at all. An example is a TV with a remote control. Its electric eye system is on day and night, watching for your signal to turn the screen on. Every appliance with an external wall-plug transformer uses power even when the appliance is turned off. These little loads are called "phantom loads" because their power draw is unexpected, unseen, and easily forgotten.

A similar concern is "idling loads." These are devices that must be on all the time in order to function when needed. These include smoke detectors, alarm systems, motion detector lights, fax machines, and answering machines. Central heating systems have a transformer in their thermostat circuit that stays on all the time. Cordless (rechargeable) appliances draw power even after their batteries reach a full charge. If in doubt, feel the device. If it's warm, that indicates wasted energy.

CHARACTERISTICS OF SINUSOIDAL AC POWER

The following definitions are used in the explanation given in the succeeding paragraphs:

Polar Co-ordinate System. It is a two-dimensional coordinate system for graphical representation in which each point on a plane is determined by the radial coordinate and the angular coordinate. The radial coordinate denotes the point's distance from a central point known as the pole. The angular coordinate (usually denoted by è or t) denotes the positive or anticlockwise (counter-clockwise) angle required to reach the point from the polar axis.

Vector. It is a varying mathematical quantity that has a magnitude and direction. The voltage and current in a sinusoidal AC voltage can be represented by the voltage and current vectors in a Polar Co-ordinate System of graphical representation.

Phase, (φ). It is denoted by "φ" and is equal to the angular magnitude in a Polar Co-ordinate System of graphical representation of vectorial quantities. It is used to denote the angular distance between the voltage and the current vectors in a sinusoidal voltage.

Power Factor, (PF). It is denoted by "PF" and is equal to the Cosine function of the Phase, φ (denoted Cos φ) between the voltage and current vectors in a sinusoidal voltage. It is also equal to the ratio of the Active Power (P) in Watts to the Apparent Power (S) in VA. The maximum value is 1. Normally it ranges from 0.6 to 0.8.

Voltage (V), Volts It is denoted by "V" and the unit is "Volts" – denoted as "V". It is the electrical force that drives electrical current (I) when connected to a load. It can be DC (Direct Current – flow in one direction only) or AC (Alternating Current – direction of flow changes cyclically).

Current (I), A. It is denoted by "I" and the unit is Amperes – denoted as "A". It is the flow of electrons through a conductor when a voltage (V) is applied across it.

Frequency, Hz. It is a measure of the number of occurrences of a repeating event per unit time. For example, cycles per second (or Hertz) in a sinusoidal voltage.

Resistance, R. It is the property of a conductor that opposes the flow of current when a voltage is applied across it. In a resistance, the current is in phase with the voltage. It is denotes by "R" and its unit is "Ohm" - also denoted as "Ω".

Reactance, X. It is the property of capacitors and inductors in a circuit that opposes the flow of current due to AC voltage applied across the circuit. The phase of the current will either lead or lag the voltage in time. It will lead if the net reactance is capacitive and will lag if the net reactance is inductive.

Impedance, **Z**. It is the vectorial sum of Resistance and Reactance in a circuit.

Peak Value. It is the maximum value. For a sine wave, it is equal to 1.414 times the RMS value. For example, in a 120 VAC sine wave voltage, the RMS value is 120 V and the peak value is 120 X1.414 = 169.68 or approximately 170 V.

RMS Value. Root Mean Square – a statistical average value of a varying quantity that changes between positive and negative values with respect to time. For example, in a 120 VAC system, the RMS value is 120 V.

Active Power (P), Watts. It is denoted as "**P**" and the unit is "**Watt**". It is the power which is dissipated in the load due to the resistance. The Energy Meter (Kilo Watt Hour Meter) measures the Active Power consumed in Watts and the utility companies bill the users based on this power consumption. This power **P** = RMS Voltage X RMS current X Power Factor (Cos φ).

Reactive Power (Q), VAR. Denoted as "**Q**" and the unit is **VAR**. Mathematically, this power **Q** = RMS Voltage "V" X RMS current "A" X Sin φ (Sine Function Value of the Phase φ between the voltage and the current vectors). The magnitude of this power will be 0 if the Phase φ between the voltage and the current vectors is 0 degrees or the Power Factor is unity (1). This power will increase as the Power Factor decreases below unity (1). This power is not consumed by the load but travels to the load in the positive half cycle of the sinusoidal voltage and is returned back to the load in the negative half cycle of the sinusoidal voltage. This back and forth flow of energy is due to the capacitive and inductive reactances in the load. Hence, when averaged over a span of one cycle, there is no consumption of power. However, on an instantaneous basis, this power has to be provided by the AC source and the AC source, the transmission lines and the gear have to be sized accordingly. The Energy Meter (Kilo Watt Hour Meter) does not measure this power but the Utility Companies have to provide this additional power. Hence, the Utility Companies require that the Power Factor of the load should be very close to unity (1) so that they do not have to transmit this additional reactive power that is not being paid for. To bring the low Power Factor of the load to near unity (1), the Utility Companies require use of Power Factor correction devices at the load location.

Apparent Power, VA. This power is the vectorial sum of the Active Power in Watts and the Reactive Power in "VAR". In magnitude, it is equal to the RMS value of voltage "V" X the RMS value of current "A". The AC power source is required to provide this power. Please note that this power is more than the Active Power in Watts.

Load. Electrical device to which an electrical voltage is fed.

Linear Load. A load which draws sinusoidal current when a sinusoidal voltage is fed to it. For example incandescent lamp, heater, electric motor, etc.

Non Linear Load. A load which does not draw a sinusoidal current when a sinusoidal voltage is fed to it. For example non power factor corrected Switched Mode Power Supplies used in computers, audio video equipment, battery chargers, etc.

Resistive Load. A load that consists of pure resistance (like incandescent lamps, heaters, etc.)

Reactive Load. A load that consists of resistance and reactance like electric motor driven loads, fluorescent lights, computers, audio / video equipment, etc.

Sine Wave. In a voltage that has a sine (sinusoidal) wave-form (see Fig.1 below), the instantaneous value and polarity of the voltage varies cyclically with respect to time. For example, in one cycle in a 120 VAC, 60 Hz system, it slowly rises in the positive direction from 0 V to a peak positive value "Vpeak" = + 170 V, slowly drops to 0 V, changes the polarity to negative direction and slowly increases in the negative direction to a peak negative value "Vpeak" = —170 V and then slowly drops back to 0 V. There are 60 such cycles in 1 sec. Cycles per second is called the "Frequency" and is also termed "Hertz (Hz)".

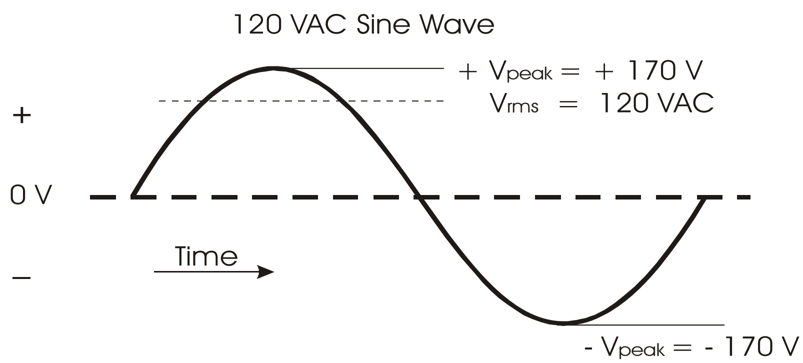


Fig.1

Cycle. For a sine wave (see Fig.1 above), it is the complete event starting with a rise from zero to a maximum amplitude, its return to zero, the rise to a maximum in the opposite direction, and then its return to zero.

The waveform of the electrical voltage distributed by the grid / the utility companies is like a sine wave. For example, in North America, the grid / utility voltage for residential use is single phase, 120 / 240 VAC, 60 Hz. and consists of two 120 VAC, 60 Hz Line Voltages (also called "Lines" or "Legs") and a common "Neutral". The two 120 VAC, 60 Hz. Lines (Legs) are 180 degrees apart in phase. The voltage between each Line (Leg) and the Neutral is 120 VAC and between the two Lines (Legs) is 240 VAC.

When a voltage is applied to a load, a current flows. If a Linear Load is connected to this type of voltage, the load will draw current which will also have the same sine wave-form. However, the peak value of the current will depend upon the impedance of the load. Also, the phase of the sine wave-form of the current drawn by the Linear Load may be the same or lead / lag the sine wave-form of the voltage. This phase difference determines the Power Factor of the load. In a resistive type of load, the sine wave-form of the current drawn by the load has 0 degrees phase difference with the sine wave-form of the voltage of the AC power source. The Power Factor of a resistive load is unity (1).

The rated output power (in Watts) of the inverters is normally specified for resistive type of loads that have unity (1) Power Factor. In a reactive type of load , the phase angle φ of the sine wave-form of the current drawn by the load may lead or lag the sine wave-form of the AC voltage source. In this case, the power factor of reactive loads is lower than unity (1) – generally between 0.8 and 0.6. **A reactive load reduces the effective power that can be delivered by an AC power source.**

RMS and peak values

As explained above, in a sine wave, the values of AC voltage **(Volt, V)** and current **(Ampere, A)** vary with time. Two values are commonly used – Root Mean Square **(RMS)** value and peak value. **The values of the rated output voltage and current of an AC power source are their RMS values.**

AC Power – VA / VAR / Watts and Sizing of Inverter

The power rating of an AC power source should normally be designated as Apparent Power in Volt Amperes (VA).

Sometimes, the power rating of the inverter is designated as Active Power in Watts (W) at Power Factor = Unity (1). This rating will be equivalent to the Apparent Power Rating in VA (Because at Power Factor = unity (1), the Apparent Power = The Active Power).

If the power rating of the inverter has been designated as Active Power in Watts (W) and the Power Factor has not been indicated, it should be assumed as unity (1).
Please note that in cases where the Power Factor is less than unity (1), the Apparent Power (VA) is higher than the Active Power (Watts) because the Apparent Power (VA) is the vectorial sum of the Active Power (Watts) and the Reactive Power (VAR). Instantaneously, the AC power source has to provide the total Apparent Power (VA) of the load and, therefore, should be sized based on the Apparent Power (VA) of the load and not on the Active Power (Watts) of the load.

If the power consumed by the load is designated as Active Power (Watts), it should be converted to the Apparent Power (VA) by dividing the Active Power (Watts) of the load by the Power Factor of the load. For example, a load rated at Active Power consumption of 600 W at Power Factor = 0.8 will require an Apparent Power of 750 W (Active Power of 600 W divided by Power Factor of 0.8 = Apparent Power of 750 Watts).

ADVANTAGES OF A PURE SINE-WAVE INVERTER OVER A MODIFIED SINE-WAVE INVERTER

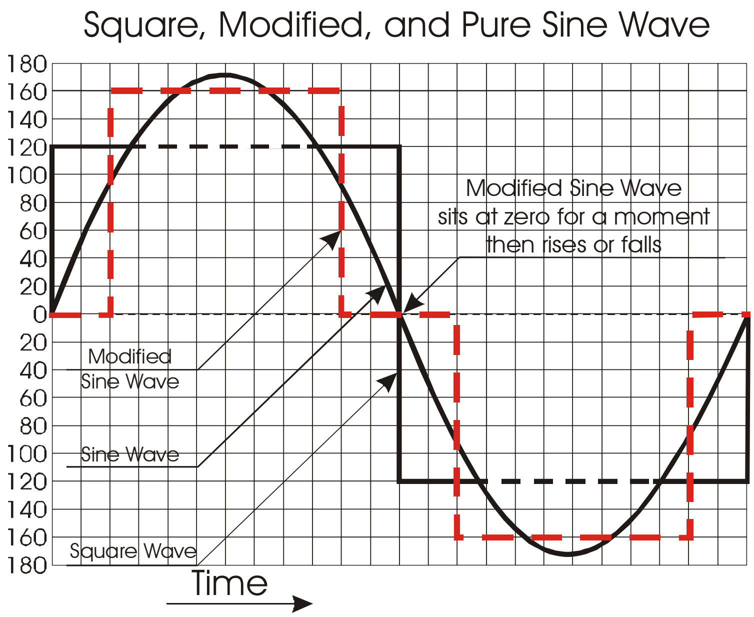


Fig.2

The output voltage of a sine-wave inverter has a sine wave-form like the sine wave-form of the mains / utility voltage. (Please see sine-wave represented in the Fig.2 above and also in Fig.1 on Page 9. Fig.2 above also shows modified sine-wave and square sine-wave for comparision).

In a sine wave, the voltage rises and falls smoothly with a smoothly changing phase angle and also changes its polarity instantly when it crosses 0 Volts. In a modified sine wave, the voltage rises and falls abruptly, the phase angle also changes abruptly and it sits at 0 Volts for some time before changing its polarity. Thus, any device that uses a control circuitry that senses the phase (for voltage / speed control) or instantaneous zero voltage crossing (for timing control) will not work properly from a voltage that has a modified sine wave-form.

Also, as the modified sine wave is a form of square wave, it is comprised of multiple sine waves of odd harmonics (multiples) of the fundamental frequency of the modified sine wave. For example, a 60 Hz. modified sine wave will consist of sine waves with odd harmonic frequencies of 3rd (180 Hz), 5th (300 Hz.), 7th (420 Hz.) and so on. The high frequency harmonic content in a modified sine wave produces enhanced radio interference, higher heating effect in motors / microwaves and produces overloading due to lowering of the impedance of low frequency filter capacitors / power factor improvement capacitors.

Advantages of sine-wave inverters

- The output wave-form is a sine-wave with very low harmonic distortion and clean power like utility supplied electricity.
- Inductive loads like microwaves and motors run faster, quieter and cooler.
- Reduces audible and electrical noise in fans, fluorescent lights, audio amplifiers, TV, fax and answering machines.
- Prevents crashes in computers, weird print outs and glitches in monitors.

Some examples of devices that may not work properly with modified sine wave and may also get damaged are given below:

- Laser printers, photocopiers, magneto-optical hard drives.
- The built-in clocks in devices such as clock radios, alarm clocks, coffee makers, bread-makers, VCR, microwave ovens etc may not keep time correctly.
- Output voltage control devices like dimmers, ceiling fan / motor speed control may not work properly (dimming / speed control may not function).
- Sewing machines with speed / microprocessor control.
- Transformer-less capacitive input powered devices like (i) Razors, flashlights, night-lights, smoke detectors etc (ii) Re-chargers for battery packs used in hand power tools. **These may get damaged. Please check with the manufacturer of these types of devices for suitability.**
- Devices that use radio frequency signals carried by the AC distribution wiring
.
- Some new furnaces with microprocessor control / Oil burner primary controls.
- High intensity discharge (HID) lamps like Metal Halide lamps. **These may get damaged. Please check with the manufacturer of these types of devices for suitability.**
- Some fluorescent lamps / light fixtures that have power factor correction capacitors. **The inverter may shut down indicating overload.**

AC POWER DISTRIBUTION AND GROUNDING

CAUTION! PLEASE NOTE THAT THE AC OUTPUT CONNECTIONS AND THE DC INPUT CONNECTIONS ON THIS INVERTER ARE NOT CONNECTED (BONDED) TO THE METAL CHASSIS OF THE INVERTER. BOTH THE INPUT AND OUTPUT CONNECTIONS ARE ISOLATED FROM THE METAL CHASSIS AND FROM EACH OTHER. SYSTEM GROUNDING, AS REQUIRED BY NATIONAL / LOCAL ELECTRICAL CODES / STANDARDS, IS THE RESPONSIBILITY OF THE USER / SYSTEM INSTALLER.

Conductors for electrical power distribution

For single phase transmission of AC power or DC power, two conductors are required that will be carrying the current. These are called the "current-carrying" conductors. A third conductor is used for grounding to prevent the build up of voltages that may result in undue hazards to the connected equipment or persons. This is called the "non current-carrying" conductor (will carry current only under ground fault conditions)

Grounding terminology

The term "grounded" indicates that one or more parts of the electrical system are connected to earth, which is considered to have zero voltage or potential. In some areas, the term "earthing" is used instead of grounding.

A "grounded conductor" is a "current-carrying" conductor that normally carries current and is also connected to earth. Examples are the "neutral" conductor in AC wiring and the negative conductor in many DC systems. A "grounded system" is a system in which one of the current-carrying conductors is grounded

An "equipment grounding conductor" is a conductor that does not normally carry current (except under fault conditions) and is also connected to earth. It is used to connect the exposed metal surfaces of electrical equipment together and then to ground. Examples are the bare copper conductor in non-metallic sheathed cable (Romex ®) and the green, insulated conductor in power cords in portable equipment. These equipment-grounding conductors help to prevent electric shock and allow over-current devices to operate properly when ground faults occur. The size of this conductor should be coordinated with the size of the over-current devices involved

A "grounding electrode" is the metallic device that is used to make actual contact with the earth. Other types of grounding electrodes include metal water pipes and metal building frames.

A "grounding electrode conductor" is the conductor between a common single grounding point in the system and the grounding electrode

"Bond" refers to the connection between the "grounded conductor", the "equipment grounding" conductors and the "grounding electrode" conductor. Bonding is also used to describe connecting all of the exposed metal surfaces together to complete the equipment-grounding conductors.

Grounded Electrical Power Distribution System

The **N**ational **E**lectrical **C**ode (NEC) requires the use of a "grounded electrical distribution system". As per this system, one of the two current-carrying conductors is required to be grounded. This grounded conductor is called the "Neutral / Cold / Return". As this conductor is bonded to earth ground, it will be at near zero voltage or potential. There is no risk of electrical shock if this conductor is touched. The other current carrying conductor is called the "Line / Live / Hot". The connection between the "Neutral" and the grounding electrode conductor is made **only at one point in the system**. This is known as the **system ground**. This single point connection (bond) is usually made in the service entrance or the load center. If this connection is inadvertently made in more than one place, then unwanted currents will flow in the equipment grounding conductors. These unwanted currents may cause inverters and charge controllers to be unreliable and may interfere with the operation of ground-fault detectors and over-current devices.

NOTE: A current-carrying conductor that is not bonded to the earth ground can not be called a "Neutral". This conductor will be at an elevated voltage with respect to the earth ground and may produce electrical shock when touched.

Polarity and color codes for power cords and plugs for AC devices and appliances

Single phase 120 VAC, 60 Hz AC devices and appliances use 2 pole, 3 wire grounding configuration for connection to the AC power source. The plug of the power cord has three pins – two flat pins (also called poles) that are connected to the two current-carrying conductors and a round pin which is connected to a non-current carrying conductor (this will carry current only during ground fault conditions) . One flat pin is connected to a black current-carrying conductor which is also called "Line/Live/Hot" pole. The other flat pin is connected to the white current-carrying conductor also called the "Neutral / Return / Cold" pole. The third round pin is connected to the non-current carrying green "equipment grounding conductor". This green "equipment grounding conductor" is bonded to the metal chassis of the device or appliance.

AC Input and AC Output Connections

Barrier type of terminal strip is used for the AC input and AC output connections (The screw size is M5)

The AC input terminals are marked "HOT IN" for the Line and "NEU IN" for the Neutral. The AC output terminals are marked "HOT OUT" and "NEU OUT" for the two current carrying conductors. The "Equipment Grounding Connection" is marked "CHASSIS GROUND".

CAUTION!

In this unit, the AC output connectors marked "HOT OUT" and "NEU OUT" are isolated from the chassis of the unit.

Normally, the Primary AC source will be the AC power from the Utility. As explained on page 13 under "AC Power Distribution and Grounding", one of the two AC current carrying conductors of the Utility AC power is bonded to the Earth Ground (At the Service Entrance) and is called the Neutral. Hence, there will be no appreciable voltage between the Neutral and the Earth Ground terminals of the AC outlets in residential / industrial wiring system. As the chassis of the devices connected to the Utility power is also connected to the Earth Ground through the "Equipment Grounding Conductor", there will be no appreciable voltage between the Neutral and the chassis of the device.

When the AC input from the Primary AC Source (Utility or other AC source) is available and is within the upper and lower programmed limits of voltage and frequency, the internal Transfer Relay will connect the load directly to Primary AC Source. In this condition, the output current carrying conductor connected to the connector marked “NEU OUT” will get bonded to the chassis of the inverter and also to the Earth Ground through the bonding connections at the Service Entrance. Hence, in this condition, there will be negligible voltage between the terminal marked “NEU OUT” and the chassis of the inverter.

When the AC input from the Primary AC Source (Utility or other AC source) has failed or when the AC input from the Primary Source (Utility or other AC source) is outside the upper and lower programmed limits of voltage and frequency, the internal Transfer Relay will transfer the internal DC to AC inverter. In this condition, the terminal marked “NEU OUT” will be **ISOLATED** from the chassis of the inverter and this terminal will be at an elevated voltage. **Please do not touch this terminal to prevent against electrical shock!**

Grounding to earth or to other designated ground

For safety, the metal chassis of the inverter is required to be grounded to the earth ground or to the other designated ground (For example, in a mobile RV, the metal frame of the RV is normally designated as the negative DC ground). An equipment grounding connector marked "CHASSIS GROUND" has been provided for grounding the metal chassis of the inverter to the appropriate ground. (Located on the Input/Output Terminal Strip).

When using the inverter in a building, connect a # 6AWG insulated stranded copper wire from the above equipment grounding connector to the earth ground connection (a connection that connects to the ground rod or to the water pipe or to another connection that is solidly bonded to the earth ground). The connections must be tight against bare metal. Use star washers to penetrate paint and corrosion.

When using the inverter in a mobile RV, connect a # 6 AWG insulated stranded copper wire from the above equipment grounding bolt to the appropriate ground bus of the RV (usually the vehicle chassis or a dedicated DC ground bus). The connections must be tight against bare metal. Use star washers to penetrate paint and corrosion.

LIMITING ELECTRO-MAGNETIC INTERFERENCE (EMI)

The inverter contains internal switching devices which generate conducted and radiated electromagnetic interference (EMI).

The magnitude of EMI is limited to acceptable levels by circuit design but can not be entirely eliminated. The effects of EMI will also depend upon a number of factors external to the inverter like proximity of the inverter to the EMI receptors, types and quality of connecting wires and cables etc. EMI due to factors external to the inverter can be reduced as follows:

- Ensure that the inverter is firmly grounded to the ground system of the building or the vehicle
- Locate the inverter as far away from the EMI receptors like radio, audio and video devices as possible
- Keep the DC side cables between the battery and the inverter as short as possible.
- Twist the DC side cables. This will partially cancel out the radiated noise from the cables
- Shield the DC side cables with metal sheathing / copper foil / braiding
- Use co-axial shielded cable for all antenna inputs (instead of 300 ohm twin leads)
- Use high quality shielded cables to attach audio and video devices to one another
- Do not operate other high power loads when operating audio / video equipment

Crest Factor

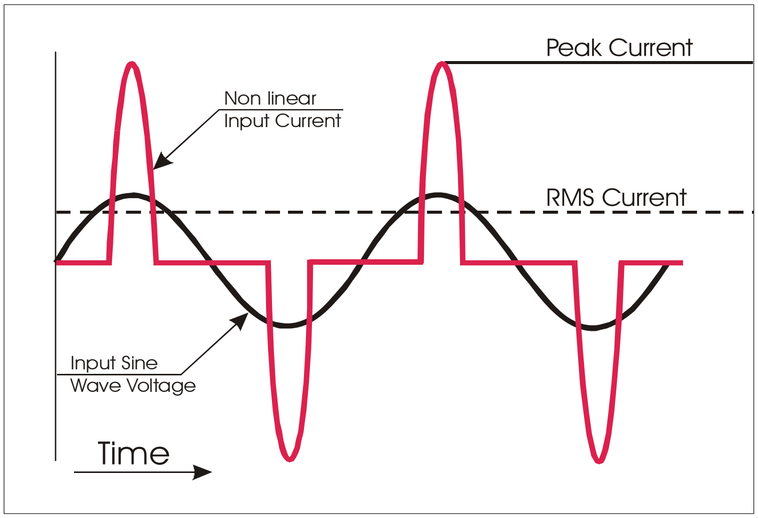


Fig.3

Non-linear nature of current drawn by Switched Mode Power Supplies

Power supplies are used to convert AC voltages like 120 VAC to various DC voltages like 3.3 V, 5 V, 12 V, 24 V, 48 V etc. Majority of modern day electronic devices use embedded general purpose **S**witch **M**ode type of **P**ower **S**upplies (SMPS) to drive the electronic circuitry. General purpose **S**witch **M**ode **P**ower **S**upplies (SMPS) (**excepting those that have power factor correction**) have one major disadvantage – the current drawn by them from the AC power source has a **non linear waveform** (the waveform is not sinusoidal as the input voltage waveform but is in the form of short, larger value pulses around the area of + Vpeak and -Vpeak; please see Fig.3 above). This is due to the charging of the input filter capacitor(s) mostly around the positive and negative peak portions of the sinusoidal input voltage. The degree of non-linearity of the current is measured by the "**Crest Factor**":

Crest Factor for Current = Peak Current / RMS Current

In a linear sinusiodal load, the Crest Factor is 1.414. However, in a general purpose non power factor corrected SMPS, due to its non linear nature, this factor will be much higher - in the region of up to 4. This will mean that for a particular rated RMS current (applicable for a linear load), the non power factor corrected general purpose SMPS will draw much larger peak currents – approx. up to 4 times more than its rated RMS current.

Inverters are protected against over current (also called overloading) by either clipping the peaks of the output voltage (this will result in a sine wave becoming a square wave, reduction in the RMS value of the output voltage and generation of harmonics and electrical noise) or by shutting down the output voltage of the inverter completely. Thus, if an inverter / generator is used to power a general purpose SMPS, it will be forced to deliver higher peak currents resulting in wave form distortion, drop in voltage and premature triggering of the inverter's / generator's over current protection circuits. Thus, for safe operation, the continuous RMS current rating of the inverter / generator should be at least 2.8 times the continuous RMS current rating of the general purpose SMPS it is required to power:

Peak current of inverter = Peak current of SMPS

or

RMS current of inverter X 1.414 = RMS current of SMPS X 4

or

RMS current of inverter = 4/1.414 X RMS current of SMPS

or

RMS current of inverter = 2.8 X RMS current of SMPS)

Alternatively, the continuous power rating of the inverter / generator in Watts / VA should be at least 2.8 times the continuous power rating of the SMPS in Watts / VA

SPECIFYING BATTERIES, CHARGERS & ALTERNATORS

The InverCharge will require Deep **Cycle Lead Acid Batteries** of appropriate capacity. Lead-acid batteries can be categorized by the type of application: **Automotive service** - **S**tarting/**L**ighting/**I**gnition (**SLI**, a.k.a. cranking) and **Deep cycle service.**

SLI Batteries

Everybody is familiar with the SLI batteries that are used for automotive starting and powering vehicular accessories. SLI batteries are designed to produce high power in short bursts but must be constantly recharged (normally with an alternator while driving). Vehicle starting typically discharges 1%-3% of a healthy SLI battery's capacity.
The automotive SLI battery is not designed for repeated deep discharge where up to 80 % of the battery capacity is discharged and then recharged. If an SLI battery is used for this type of application, its useful service life will be drastically reduced.

Deep Cycle Batteries

Deep cycle batteries are designed with thick-plate electrodes to serve as primary power sources, to have a constant discharge rate, to have the capability to be deeply discharged up to 80 % capacity and to repeatedly accept recharging. They are marketed for use in recreation vehicles (RV), boats and electric golf carts – so they may be referred to as RV batteries, marine batteries or golf cart batteries. There are two categories of deep cycle lead acid batteries – wet and sealed (also known as **S**ealed **L**ead **A**cid or **SLA**). A wet cell battery has a high tolerance to overcharging. However, it will release hydrogen gas when charging that must be properly vented and the water level must be checked frequently. Sealed (SLA) batteries can either be Gel Cell or AGM (**A**bsorbed **G**lass **M**at). Both the Gel Cell and AGM are maintenance free, have no liquid to spill and gassing is minimal. The Gel Cell is the least affected by temperature extremes, storage at low state of charge and has a low rate of self discharge. An AGM battery will handle overcharging slightly better than the Gel Cell.

Units of Battery capacity

The battery capacity is the measure of the energy the battery can store and deliver to a load. It is determined by how much current any given battery can deliver over a stipulated period of time. The energy rating is expressed in **A**mpere **H**ours (AH). As a bench mark, the battery industry rates batteries at 20 hour rate i.e. how many Amperes of current the battery can deliver for 20 hours at 80 º F till the voltage drops to 10.5 Volts for 12 V battery and 21 V for 24 V battery. For example, a 100 AH battery will deliver 5 Amperes for 20 hours. Battery capacity is also expressed as **Reserve Capacity (RC)** in minutes. Reserve capacity is the time in minutes for which the battery can deliver 25 Amperes at 80 º F till the voltage drops to 10.5 Volts for 12 V battery and 21 V for 24 V battery. Approximate relationship between the two units is as follows:
Capacity in AH = Reserve Capacity in RC minutes x 0.6

Typical battery sizes

Below is a chart of some battery sizes applicable for powering inverters:

BCI * Group	Battery Voltage, V	Battery AH
27 / 31	12	105
4 D	12	160
8D	12	225
GC2**	6	220

* Battery Council International
** Golf Cart

Reduction in usable capacity at higher discharge rates

As stated above, the rated capacity of the battery in AH is normally applicable at a discharge rate of 20 Hours. As the discharge rate is increased, the usable capacity reduces due to "Peukert Effect". This relationship is not linear but is more or less according to the table below:

TABLE 1. Battery Capacity versus Rate of Discharge

Hours of Discharge	Usable Capacity
20	100%
10	87%
8	83%
6	75%
5	70%
3	60%
2	50%
1	40%

Using the above table will show that a 100 AH capacity battery will deliver 100% (i.e. full 100 AH) capacity if it is slowly discharged over 20 hours at the rate of 5 Amperes. However, if it is discharged at a rate of 50 Amperes then theoretically, it should provide 100 AH ÷ 50 = 2 hours. However, the Table above shows that for 2 hours discharge rate, the capacity is reduced to 50% i.e. 50 AH. Therefore, at 50 Ampere discharge rate the battery will actually last for 50 AH÷50 Amperes = 1 Hour.

State of Charge (SOC) of a battery

The "Standing Voltage" of a battery can approximately indicate the State of Charge (SOC) of the battery. The "Standing Voltage" is measured after disconnecting any charging device(s) and the battery load(s) and letting the battery "stand" idle for 3 to 8 hours before the voltage measurement is taken. Voltages given below are for a 12 volt battery system at around 80 F. For 24-volt systems, multiply by 2; for 48-volt systems, multiply by 4. Check the individual cell voltages. If the inter cell voltage difference is more than a 0.2, the battery will have to be equalized. **Please note that only the wet cell batteries are equalized**. **Do not equalize sealed AGM or Gel Cell Batteries.**

Percentage of Full Charge	Standing Voltage of 12 V Nominal Battery	Cell Voltage (12 V battery has 6 cells)
100%	12.7 V	2.12 V
90%	12.6 V	2.10 V
80%	12.5 V	2.08 V
70%	12.3 V	2.05 V
60%	12.2 V	2.03 V
50%	12.1 V	2.02 V
40%	12.0 V	2.00 V
30%	11.8 V	1.97 V
20%	11.7 V	1.95 V
10%	11.6 V	1.93 V
0%	= / < 11.6 V	= / < 1.93 V

Depth of discharge and battery life

The more deeply a battery is discharged on each cycle, the shorter the battery life. Using more batteries than the minimum required will result in longer life for the battery bank. A typical cycle life chart is given at Table 2 below:

TABLE 2. Typical Cycle Life Chart

Depth of Discharge % of AH Capacity	Cycle Life Group 27 / 31	Cycle Life Group 8D	Cycle Life GC2
10	1000	1500	3800
50	320	480	1100
80	200	300	675
100	150	225	550

It is recommended that the depth of discharge should be limited to 50%.

Loss of battery capacity at low temperatures

Batteries lose capacity in low temperatures. At 32 º F, a battery will deliver about 70 to 80 % of its rated capacity at 80 º F. If the air temperature near the battery bank is lower than 80 º F, additional batteries will be needed to provide the same usable capacity. For very cold climates, an insulated / heated battery compartment is recommended.

Series and Parallel Connection of Batteries

Series Connection

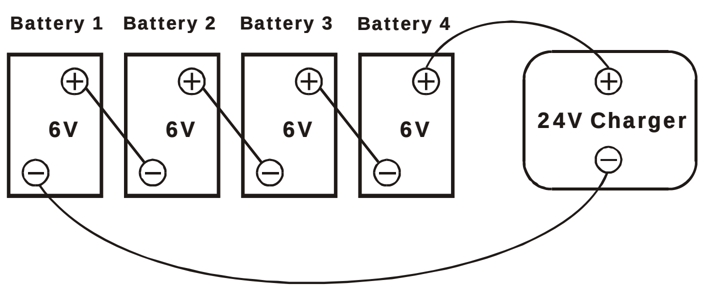


Fig. 4. Series Connection

When two or more batteries are connected in series, their voltages add up but their AH capacity remains the same. Fig. 4 above shows 4 pieces of 6 V, 200 AH batteries connected in series to form a battery bank of 24 V with a capacity of 200 AH. The positive terminal of Battery 4 becomes the positive terminal of the 24 V bank. The negative terminal of Battery 4 is connected to the positive terminal of Battery 3. The negative terminal of Battery 3 is connected to the positive terminal of Battery 2. The negative terminal of Battery 2 is connected to the positive terminal of Battery 1. The negative terminal of Battery 1 becomes the negative terminal of the 24 V battery bank.

Parallel Connection

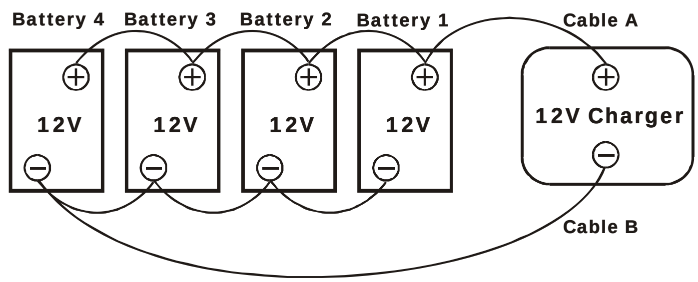


Fig. 5. Parallel Connection

When two or more batteries are connected in parallel, their voltage remains the same but their AH capacities add up. Fig. 5 above shows 4 pieces of 12 V, 100 AH batteries connected in parallel to form a battery bank of 12 V with a capacity of 400 AH. The four positive terminals of Batteries 1 to 4 are paralleled (connected together) and this common positive connection becomes the positive terminal of the 12 V bank. Similarly, the four negative terminals of Batteries 1 to 4 are paralleled (connected together) and this common negative connection becomes the negative terminal of the 12 V battery bank.

Series – Parallel Connection

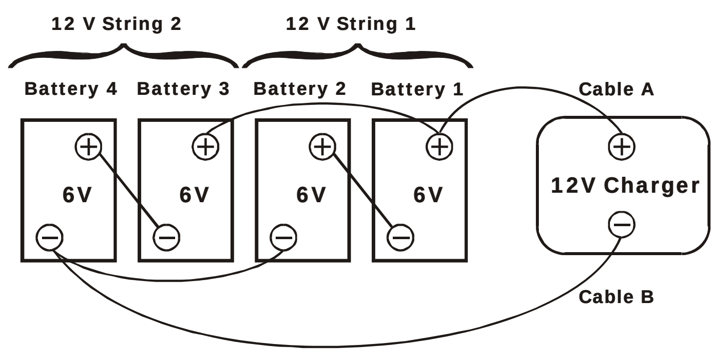


Fig. 6. Series-Parallel Connection

Figure 6 above shows a series – parallel connection consisting of four 6V, 200 AH batteries to form a 12 V, 400 AH battery bank. Two 6 V, 200 AH batteries, Batteries 1 and 2 are connected in series to form a 12 V, 200 AH battery (String 1). Similarly, two 6 V, 200 AH batteries, Batteries 3 and 4 are connected in series to form a 12 V, 200 AH battery (String 2). These two 12 V, 200 AH Strings 1 and 2 are connected in parallel to form a 12 V, 400 AH bank.

CAUTION!

When 2 or more batteries / battery strings are connected in parallel and are then connected to a charger (See Figs. 5 and 6 given above), attention should be paid to the manner in which the charger is connected to the battery bank. Please ensure that if the positive output cable of the battery charger (Cable "A") is connected to the positive battery post of the first battery (Battery 1 in Fig. 5) or to the positive battery post of the first battery string (Battery 1 of String 1 in Fig. 6), then the Negative output cable of the battery charger (Cable "B") should be connected to the Negative battery post of the last battery (Battery 4 as in Fig. 5) or to the Negative Post of the last battery string (Battery 4 of Battery String 2 as in Fig. 6). This connection ensures the following:

- The resistances of the interconnecting cables will be balanced.
- All the individual batteries / battery strings will see the same series resistance.
- All the individual batteries will charge at the same charging current and thus, will be charged to the same state at the same time.
- None of the batteries will see an overcharge condition.

If the positive output cable of the battery charger (Cable "A") is connected to the positive battery post of the first battery (Battery 1 in Fig. 5) or to the positive battery post of the first battery string (Battery 1 of String 1 in Fig. 6), and the Negative output cable of the battery charger (Cable "B") is connected to the Negative battery post of the first battery (Battery 1 as in Fig. 5) or to the Negative Post of the first battery string (Battery 1 of Battery String 1 as in Fig. 6), the following abnormal conditions will result:

- The resistances of the connecting cables will not be balanced.
- The individual batteries will see different series resistances.
- All the individual batteries will be charged at different charging current and thus, will reach fully charged state at different times.
- The battery with lower series resistance will take shorter time to charge as compared to the battery which sees higher series resistance and hence, will experience over charging and its life will be reduced.

Effect of Temperature on Battery Voltage

The chemical reactions inside the battery change with temperature. The cell voltage has a negative temperature coefficient - the cell voltage drops with increase in temperature. Normally, the battery voltages are specified at a particular temperature, e.g. 25°C.
Some battery chargers come with optional Temperature Sensor that senses the battery temperature & modifies the output voltage of the charger accordingly.

The InverCharge Series comes with an optional Battery Temperature Sensor Model ITC-01 that has a default setting for -25°C & a Temperature Coefficient of -2.3m V/°C/cell (6 cells for 12 V Battery & 12 cells for 24 V Battery).

Sizing the Inverter Battery Bank

One of the most frequently asked question is, "how long will the batteries last?" This question cannot be answered without knowing the size of the battery system and the load on the inverter. Usually this question is turned around to ask “How long do you want your load to run?”, and then specific calculation can be done to determine the proper battery bank size.

There are a few basic formulae and estimation rules that are used:

Formula 1	Power in Watts (W) = Voltage in Volts (V) x Current in Amperes (A).
Formula 2	For an inverter running from a 12 V battery system, the DC current required from the 12 V batteries is the AC power delivered by the inverter to the load in Watts (W) divided by 10 & for an inverter running from a 24 V battery system, the DC current required from the 24 V batteries is the AC power delivered by the inverter to the load in Watts (W) divided by 20.
Formula 3	Energy required from the battery = DC current to be delivered (A) x time in Hours (H).

The first step is to estimate the total AC watts (W) of load(s) and for how long the load(s) will operate in hours (H). The AC watts are normally indicated in the electrical nameplate for each appliance or equipment. In case AC watts (W) are not indicated, formula 1 given above may be used to calculate the AC watts by multiplying 120 VAC / 230 VAC by the AC current in Amperes . The next step is to derive the DC current in Amperes (A) from the AC watts as per formulae 2 above. **An example of this calculation for a <u>12V inverter</u> is given below:**

Let us say that the total AC Watts delivered by the12 V inverter = 1000 W.
Then, using formula 2 above, the DC current to be delivered by the 12 V batteries = 1000 W ÷10 = 100 Amperes.

Next, the energy required by the load in Ampere Hours (AH) is determined. For example, if the load is to operate for 3 hours then as per Formula 3 above:
Energy to be delivered by the 12 V batteries = 100 Amperes × 3 Hours = 300 Ampere Hours (AH).

Now, the capacity of the batteries is determined based on the run time and the usable capacity. From Table 1, (on page 19), the usable capacity at 3 Hour discharge rate is 60%. Hence, the actual capacity of the 12 V batteries to deliver 300 AH will be equal to:
300 AH ÷ 0.6 = 500 AH.

And finally, the actual desired rated capacity of the batteries is determined based on the fact that normally only 80% of the capacity will be available with respect to the rated capacity due to non availability of ideal and optimum operating and charging conditions. So the final requirements will be equal to:
500 AH ÷0.8 = 625 AH (note that the actual energy required by the load was 300 AH).

It will be seen from the above that the final rated capacity of the batteries is almost 2 times the energy required by the load in AH.

Thus, as a thumb rule, the AH capacity of the batteries should be twice the energy required by the load in AH.

For the above example, the 12 V batteries may be selected as follows:

- Use 6 Group 27/31, 12 V, 105 AH batteries in parallel to make up 630 AH, **or**
- Use 3 Group 8D, 12 V, 225 AH batteries in parallel to make up 675 AH.

Charging Batteries

The batteries can be charged by using good quality AC powered battery charger or from alternative energy sources like solar panels, wind or hydro systems. Make sure an appropriate battery charge controller is used. It is recommended that the batteries may be charged at 10% to 13 % of the Ampere Hour capacity (20 hour discharge rate). Also, for complete charging (return of 100 % capacity), it is recommended that a 3 stage charger may be used (Constant current bulk charging followed by constant voltage boost / absorption charging followed by constant voltage float charging).

Batteries, alternators and isolators on vehicles / RVs

It is recommended that for powering the inverter, one or more auxiliary deep cycle batteries should be used that are separate from the SLI batteries. The inverter should be powered from the deep cycle batteries. For charging the SLI and the auxiliary deep cycle batteries, the output from the alternator should be fed to these two sets of batteries through a battery isolator of appropriate capacity. The battery isolator is a device that will allow the alternator to charge the two sets of batteries when the engine is running. The isolator will allow the inverter to be operated from the auxiliary batteries and also prevent the SLI batteries from charging the auxiliary deep cycle batteries when the engine is not running. Battery isolators are available from auto / RV / marine parts suppliers.

A majority of smaller vehicles have 40 to 105 Ampere alternator and RVs have 100 to 130 Ampere alternator. When in use, the alternators heat up and their output current capacity can drop by up to 25%. When heated up, their charging voltage may also not reach the desired absorption voltage and will result in return of only about 80% of the battery capacity. In case the current output of the standard alternator is not adequate to charge the two sets of batteries rapidly and fully to 100% of their capacity, use heavy duty alternator that can produce higher current and voltage required to charge multiple battery systems. These alternators are available with auto / RV parts suppliers.

GENERAL DESCRIPTION AND THEORY OF OPERATION

1.1. InverCharge Series is a pure sine wave, bi-directional, single phase Inverter Charger with a powerful built in smart AC Battery Charger and a Transfer Relay. It functions as an AC UPS (Un-interruptible Power Supply). It uses a high performance microprocessor and pulse width modulated (PWM) power conversion circuits to convert DC voltage from a battery to regulated AC voltage (DC Mode-Inverter) and also to convert AC voltage to DC voltage to charge the battery (AC Mode-Charger)

1.2. It consists of three modules – Inverter Module, Battery Charger Module and Transfer Relay Module. The unit is fed with the following inputs:

- Primary AC Power Source – Can be the Grid AC power or AC power from a generator
- DC Battery Source - Two versions of InverCharge are available. One version is for a 12 VDC battery input & the other is for a 24 VDC battery input

1.3. As long as the AC input power from the Primary AC Power Source is available and is within the programmed limits of voltage and frequency, it is passed through to the AC load through the Transfer Relay Module. At the same time, the Battery Charger Module converts the AC voltage from the Primary AC Power Source to DC voltage to charge the DC Battery Source. This mode is termed as the "**AC Mode-Charger**". The Inverter Module is always working and is in a Standby Mode. In the Standby Mode, the Inverter Module converts the DC voltage from the DC Battery Sourse to AC voltage and remains synchronized with the frequency and the phase of the Primary AC Power Source. In case of loss of the Primary AC Power Source or if the Primary AC Power Source is not within the programmed limits of voltage and frequency, the Transfer Relay Module almost instantaneously (within approximately 16 ms) transfers the AC load to the Inverter Module. The AC load is now fed by the Inverter Module & the DC Battery Source starts discharging. This is termed as "**DC Mode-Inverter**". When the Primary AC Power Source returns to normal, the phase and frequency of the Inverter Module is slowly synchronized with the Primary AC Power Source and then, the Transfer Relay once again transfers the AC load from the Inverter Module to the Primary AC Power Source. At the same time, the DC Battery Source is recharged by the Battery Charger Module. Thus, the unit once again transfers to the "AC Mode-Charger". The transfer time from "DC Mode-Inverter" to "AC Mode-Charger" is selectable with the help of DIP Switch1 - either 5 sec or 30 sec. Hence, the unit serves as an AC UPS.

1.4. The Inverter Module is a heavy-duty, continuously working microprocessor controlled inverter generating a Pure Sine Wave output of 120 VAC, 60 Hz (120 VAC version models with suffix "A") or 230 VAC, 50 Hz (230 VAC version models with suffix "E") from the DC Battery Source. It is able to supply AC power to various types of AC loads such as resistive loads (heaters, incandescent lamps etc) or reactive loads (motors, air conditioners, refrigerators, vacuum cleaners, fans, pumps, Switched Mode Power Supplies (SMPS) used in audio / video equipment and computers etc.).

1.5. Principle of inverting from DC to AC: The low DC voltage from the DC Battery Source is inverted to the AC voltage in two steps. The low DC voltage from the DC Battery Source is first converted to low frequency (50 Hz or 60 Hz), low voltage synthesized sine wave AC using an H-bridge configuration and high frequency PWM (Pulse Width Modulation) technique. In order to create this low voltage, low frequency synthesized sine wave, a reference low frequency sine wave and a high frequency carrier wave are generated. The low frequency, low voltage synthesized sine wave is then stepped up to pure sine wave AC voltage using a low frequency Isolation Transformer and filtration circuit. This type of DC to AC inversion is called **Hybrid Type** – a combination of low frequency and high frequency implementation.

1.6. The Battery Charger Module is a microprocessor controlled smart charger. The same Isolation Transformer and the H-Bridge configuration are used to work in the reverse direction – rectify the AC voltage from the Primary AC Power Source to controlled low voltage DC to charge the DC Battery Source. That is why it is called a **bi-directional** device. This Battery Charger Module can be set with different Float Voltages (DIP Switch 5) and maximum charging currents (DIP Switches 6,7,8) to match various types and sizes of batteries. The charger works on the principle of "taper charging" in which the charging current is not constant but is proportional to the difference of the voltage between the voltage of the charger and the voltage at the battery terminals. As the charger voltage is kept constant, the voltage difference will be higher when the battery is discharged and hence, there will be higher charging current. As the battery is charged, its voltage rises, the voltage difference reduces and consequently, the charging current reduces. Please note that the maximum charging current set by DIP Switches 6, 7, 8 will determine the maximum charging current at the lowest battery voltage and the charging current will continuously reduce as the battery is charged and its voltage rises.

Caution!

Please note that this charger is not designed to operate in parallel with an external charging device like solar / wind / hydro charge controller. As explained above, the charging current provided by this charger is proportional to the difference of the voltage between the voltage of the charger and the voltage at the battery terminals. This charger will, thus, not see the actual voltage of the battery but the voltage put out by the external charger and hence, may stop charging if the voltage of the external charger is equal to or higher than the voltage of this charger.

1.7. The Transfer Relay Module is used to either pass through the AC power from the Primary AC Power Source to the load (As long as the AC input power from the Primary AC Power Source is available and is within the programmed limits of voltage and frequency) or to transfer the load to the Inverter Module (In case of loss of the Primary AC Power Source or if the Primary AC Power Source is not within the programmed limits of voltage and frequency). **The transfer time from the Primary AC Power Surse to the Inverter Module is approximately 16 ms.** The transfer time from Inverter Module to the Primary AC Power Source can be selected to be either 5 sec or 30 sec with DIP Switch1.

1.8. Power Save Mode (Search Load Mode)

When the unit is operating as an inverter (DC Mode-Inverver), it requires some minimum input power from the battery to keep all the sections inside the unit alive and ready to deliver power to the AC load when the load is switched on. This power is called the "No Load Draw" or the "Idle Power". If the unit is on, is in "DC Mode-Inverver" and is not powering any load, this "No Load Draw" or the "Idle Power" is wasted and unnecessarily drains the battery and hence, should be minimized, if possible. This unit has a provision to reduce this "No Load Draw" or the "Idle Power", if required (Applicable only when the unit is in "DC Mode-Inverver"). This is achieved by activating the "Power Save Mode (Search Load Mode)". When in "Power Save Mode (Search Load Mode)", the output voltage is pulsed between a reduced voltage of around 65 VAC and the full voltage of 120 VAC in order to reduce the "No Load Draw" or the "Idle Power" and at the same time a circuitry keeps on searching if a preset value of load (> 220 W) has been switched on. If the load is < 150 W the output voltage keeps on pulsing as given above. If a load of >220 W is detected, the pulsing is terminated and full output voltage of 120 VAC is restored.

When the inverter is operating in "Power Save Mode (Search Load Mode)", the orange LED marked "DC Mode – Inverter" (LED 1) will be lighted as follows:

- Will blink when the output voltage is the reduced voltage of approximately 65 VAC
- Will be lighted continuously when the output voltage is 120 VAC

The "No Load Draw" or the "Idle Power" power draw will be as follows:

- Normal Mode 50 W
- "Power Save Mode (Search Load Mode)" 20 W

"Power Save Mode (Search Load Mode)" is selected by DIP Switch 4. Please see details in the subsequent section. Do not use "Power Save Mode (Search Load Mode)" if a load is required to be powered all the time.

LAYOUT AND FUNCTIONS OF CONTROLS AND LED INDICATORS

2.1. The Control & LED Indication Panel on the top cover of the unit is shown in Fig.7a &7 b on page 28. The details of DIP Switch settings and LED indications are given in the succeeding paragraphs.

2.2. The lighted condition of the LEDs is shown as follows:

- Continuously lighted condition is shown as a fully filled black circle: ●
- Blinking condition is shown as a half filled black circle: ⊖

2.3. Button marked "Power On-Off, Reset"

The "Power On-Off, Reset" Button is located on the left of the panel. This button acts as a toggle switch. Every time this button is pressed for > 3 sec and released, it will toggle the unit between on and off conditions.

NOTE:

a) The unit can be switched on only if the DC input voltage from the battery is available at its DC input terminals.

b) The unit can be switched on even if no AC input is available at its AC input terminals.

2.3.1. Switching on: Press the button for > 3 sec till a beep is heard. Release the button after the beep. If the button is kept pressed and not released after the beep, the switching on action will not take place.

2.3.2. Switching off: Press the button for > 3 sec till a beep is heard. Release the button after the beep. If the button is kept pressed and not released after the beep, the switching off action will not take place.

2.4. LED and Buzzer Indications

The following Table shows the status of the LEDs and the buzzer for various operational conditions. **The voltages shown in the Table below are for 12 V battery input version of the unit. For the 24 V input unit, double the value of these voltages.**

INVERTER LED and Buzzer									
LED1	**LED2**	**LED3**	**LED4**	**LED5**	**LED6**	**LED7**	**LED8**	**Buzzer**	**Inverter Status**
		On							Output power has been shut-down due to overload
			On						Output power has been shut-down due to low battery (low DC input) voltage. It will auto re-start when the utility power returns.
		Blink						Continuous beep	Inverter failure - Battery Charger Module has failed in AC Mode.
			Blink					1 beep @ 0.5sec	Inverter failure – battery over voltage (DC input over voltage) of 15 V has been detected
		On						Continuous beep	Inverter failure – short circuit condition has been detected at the output
				10.8-11.5V	11.5-12.5V	12.5-14V	14-15V		The unit is in Bypass Mode
On				10.8-11.5V	11.5-12.5V	12.5-14V	14-15V	2 beeps @ 10 sec	The unit is in DC MODE
Blink				10.8-11.5V	11.5-12.5V	12.5-14V	14-15V	2 beeps @ 10 sec	The unit is in Search Load Mode
On		Blink		10.8-11.5V	11.5-12.5V	12.5-14V	14-15V	On	Inverter has detected over temperature in DC Mode.
On		On		10.8-11.5V	11.5-12.5V	12.5-14V	14-15V	On	Inverter has detected over 150% load in DC Mode.
On		On		10.8-11.5V	11.5-12.5V	12.5-14V	14-15V	1 beep @ 0.5 sec	Inverter has detected over 130% load in DC Mode.
On		On		10.8-11.5V	11.5-12.5V	12.5-14V	14-15V	1beep @ 1 sec	Inverter has detected over 110% load in DC Mode.
On			Blink	10.8-11.5V	11.5-12.5V	12.5-14V	14-15V	1 beep @ 0.5 sec	Inverter has detected battery over voltage (DC input over-voltage) in DC Mode.
On			On	10.8-11.5V	11.5-12.5V	12.5-14V	14-15V	1 beep @ 0.5 sec	Inverter has detected low battery voltage (Low DC input voltage) in DC Mode.
	On			10.8-11.5V	11.5-12.5V	12.5-14V	14-15V		Unit is in AC Mode
	Blink			10.8-11.5V	11.5-12.5V	12.5-14V	14-15V		Inverter is charging the battery in AC mode.
	On	Blink		10.8-11.5V	11.5-12.5V	12.5-14V	14-15V	On	Inverter has detected over temperature in AC Mode.
	On / Blink	On		10.8-11.5V	11.5-12.5V	12.5-14V	14-15V	On	Inverter has detected over 150% load in AC Mode.
	On / Blink	On		10.8-11.5V	11.5-12.5V	12.5-14V	14-15V	1 beep @ 0.5 sec	Inverter has detected over 130% load in AC Mode.
	On / Blink	On		10.8-11.5V	11.5-12.5V	12.5-14V	14-15V	1 beep @ 1 sec	Inverter has detected over 110% load in AC Mode.

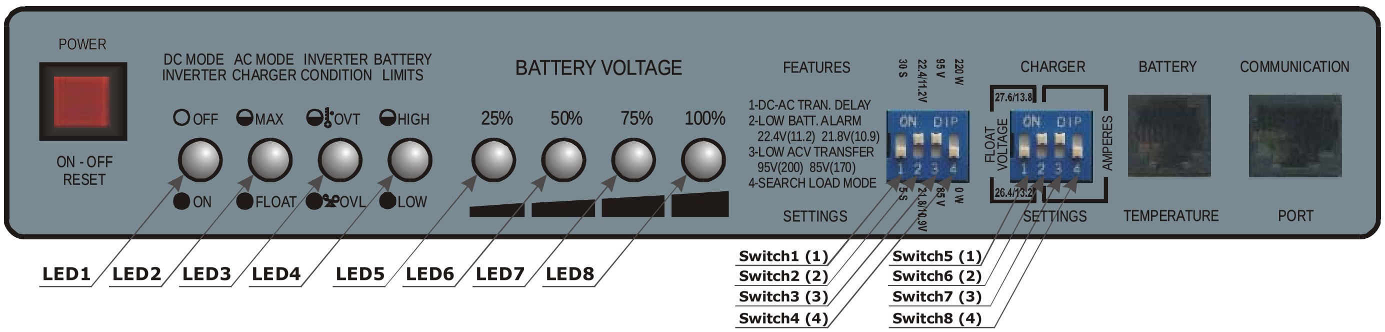


Fig.7a. Control & Indication Panel: S-2012A/E, S-3024A/E

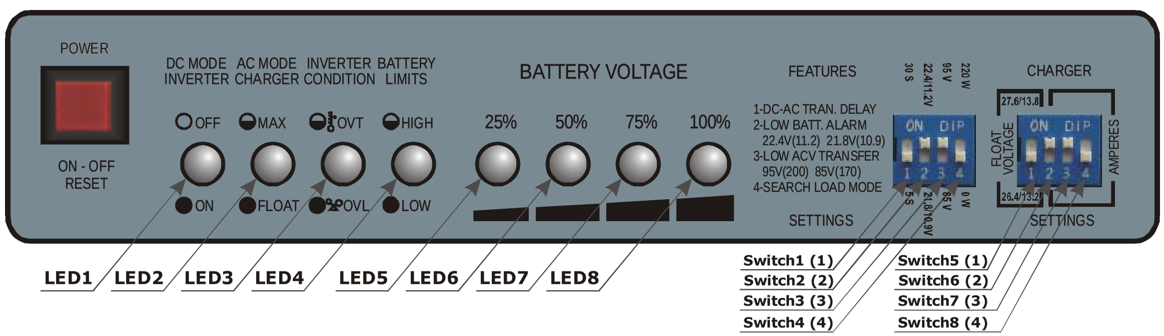


Fig.7b. Control & Indication Panel: S-1012A, S-1024A, S-2024A/E

2.4.1. Orange LED marked “DC Mode – Inverter” (LED 1)

- When lighted continuously (●) , this Orange LED indicates that the system is working in the Inverter Mode and that the Primary AC Power Source (Grid power or generator) is not available. The Orange LED will be on during this period and off when the utility power is restored. When the inverter initially enters the normal Inverter Mode, the buzzer beeps at 2 beeps every 10 second X 5 times and then stops.
- When blinking (◒), it indicates that the inverter is in “Power Save Mode (Search Load Mode)”. When the inverter initially enters the “Power Save Mode (Search Load Mode)”, the buzzer beeps at 2 beeps every 10 second X 5 times and then stops.

Please see details under “Power Save Mode (Search Load Mode)”.

2.4.2 Green LED marked “AC Mode – Charger” (LED 2)

- When lighted continuously “ (●) Float “, this Green LED will indicate that the battery is fully charged and the Battery Charger is in the Float Mode.
- When blinking “(◒) Max” , it will indicate that charging is taking place in the Bulk Charge Mode at the maximum programmed charging current and that the battery is not fully charged.

2.4.3. Red LED marked “Inverter Condition” (LED 3)

This Red LED indicates abnormal operating conditions of over temperature or over load as follows:

2.4.3.1. Over Temperature Protection: When the temperature of a hot spot inside the inverter (in the winding of the output Isolation Transformer) is higher than 120 C, the inverter will shut down and this Red LED will be blinking “(◒) OVT”. **The inverter will be latched in the shut down condition**. **Let the unit cool down. In order to restart, press the Power on/off button to restart the inverter.**

2.4.3.2. Overload Protection: When the load is higher than the default setting of (110%), the Red LED will light up continuously “(●) OVL”. A buzzer will also sound giving a warning to reduce the load. Please refer to the following chart for details:

Load Capacity (DC Mode-Inverter)	LED1	LED 3	Buzzer	INVERTER State
110%	On	On	1beeps/0.5sec	The INVERTER will be shut down after 60 seconds.
130%	On	On	Constant on	The INVERTER will be shut down after 30 seconds.
>150%	On	On	Shutdown	The INVERTER will be shut down after 2 seconds.

CAUTION! Connecting an AC source directly to the AC output of the inverter will cause damage to the inverter.

2.4.4 Red LED marked “Battery Limits” (LED 4)

2.4.4.1 Battery High: In “AC Mode-Charger” , the Red LED 4 will blink “(◒) High”. In “AC Mode-Inverter”, the inverter will be shut down automatically. The buzzer will sound 1 beep every 0.5 sec

2.4.4.2 Battery Low: The Red LED 4 will light up continuously “(●) Low”. The buzzer will sound 1 beep every 0.5 sec. The voltage at which this indication is triggered can be selected between 11.2 V and 10.9 V for 12 V battery version or 22.4 V and 21.8 V for 24 V battery version with the help of DIP Switch 2 as explained subsequently

2.4.5 Green LED marked “Battery Voltage” (LED 5~8)

LEDs 5~8 indicate the battery capacity. Please refer to the details as below.

Battery Voltage & LED	LED 5	LED 6	LED 7	LED 8
25%	On	X	X	X
50%	On	On	X	X
75%	On	On	On	X
100%	On	On	On	On

2.5 DIP Switches for Setting Operating Conditions

A set of 8 DIP switches have been provided for making the following selections explained in the succeeding paragraphs.

There are two clusters of DIP Switches. Each cluster has 4 switches marked 1 to 4 on the actual Control and Indication Panel on the unit. For purposes of explanation in this manual, these switches have been identified as SW1 to SW8 as follows:

Marking used in the Manual	Actual Marking on the Unit
	Left DIP Switch Cluster of Switches
SW1	1
SW2	2
SW3	3
SW4	4
	Right DIP Switch Cluster of Switches
SW5	1
SW6	2
SW7	3
SW8	4

CAUTION!

Please change switch setting only after switching off the unit

DIP Switch 1

Setting the time delay for transfer from Inverter (DC Mode-Inverter) to the Primary AC Source (AC Mode-Charger)

When a generator is started, it needs some time to warm up and stabilize before a load is switched on.

Also, when the Primary AC Power Source fails or is not within the programmed limits of voltage and frequency, the Transfer Relay transfers the load to the Inverter Module. When the Primary AC Power Source is restored, it may take some time before it stabilizes. Thus, a provision has been made to introduce a delay (either 5 sec or 30 sec) when load is being transferred from the inverter (DC Mode-Inverter) to the Primary AC Source (AC Mode-Charger). DIP Switch1 is used to select the time delay as follows:

DIP Switch 1	ON	OFF
Delay in transfer from the Inverter Module to the Primary AC Power Source	30 sec *	5 sec

**** Factory preset***

DIP Switch 2

Setting the DC input voltage for audible alarm at low DC input voltage (Low Battery)

When the unit is in "DC Mode-Inverter", the inverter will be feeding the AC load and this will result in discharging of the battery. As the battery is discharged, its terminal voltage drops. For a longer battery life, the battery should not be discharged completely. The discharge condition of the battery is represented by the Depth of Discharge in percentage and indicates the percentage of the total battery capacity that has been drained. For example, in a 100 AH capacity battery, 80 % Depth of Discharge would mean that 80 AH of capacity has been drained and only 20 AH is remaining. The value of the terminal voltage can be approximately related to the state of charge of the battery. The terminal voltage of a fully charged 12 V battery "at rest" (neither charging nor discharging) is approximately 12.6 V. For example, a 12 V battery that is discharging at a discharge current of C/5 Amperes (where "C" is the AH capacity of the battery), the terminal voltage versus the Depth of Discharge will be as follows:

· 60% Depth of Discharge 11.2 V
· 80% Depth of Discharge 10.9 V

In order to warn against deep discharge, the InverCharge will sound a buzzer alarm (1 beep every 0.5 sec) when the battery terminal voltage has reached the selected threshold low voltage. The following voltage settings for the buzzer alarm are available:

DIP Switch 2	ON	OFF
For 12 V input version	11.2 V*	10.9 V
For 24 V input version	22.4 V*	21.8 V

**** Factory preset***

Automatic setting of low DC input shut-down voltage when setting DIP Switch 2

When the low input voltage alarm level is selected, the low input voltage shutdown is also selected automatically as follows:

Alarm Voltage selected by DIP Switch 2		Corresponding Low Voltage Shutdown
12 VDC input version	10.9 VDC	10 VDC
	11.2 VDC	11 VDC
24 VDC input version	21.8 VDC	20 VDC
	22.4 VDC	22 VDC

DIP Switch 3

Setting the lower threshold voltage (brown out voltage) of the Primary AC Power Source at which the load is transferred to the Inverter Module

As long as the AC input power from the Primary AC Power Source is available and is within the programmed limits of voltage and frequency, it is passed through to the AC load through the Transfer Relay Module. The voltage from the Primary AC Power Source may dip (also called a brown out). A sustained low AC voltage is not tolerated by some loads.

Hence, if the brown out condition persists, the Transfer Relay will switch the load to the inverter. The voltage at which this transfer takes place can be selected between 95 V or 85 V with the help of DIP Switch 3 as follows:

DIP Switch 3	ON	OFF	Version
AC Transfer Voltage	95 V *	85 V	120 VAC
	190 V *	170 V	230 VAC

Factory preset

NOTE:
In order to prevent very frequent transfers around the threshold value of transfer, a hysterisis of 5 V is provided. For example, if the selected threshold is 95 V, the load will be transferred to the inverter if the Primary AC Source drops below 95 VAC. However, the load will be transferred back to the Primary AC Source only when the voltage of the Primary AC Source has risen to 100 VAC.

Nominal Voltage		Threshold of Transfer from the Primary AC power Source (AC Mode-Charger) to the Inverter Module (DC Mode-Inverter)	Threshold of Transfer from the Inverter Module (DC Mode-Inverter) to the Primary AC power Source (AC Mode-Charger)
120 VAC	On *	95 * VAC	100 * VAC
	Off	85 VAC	90 VAC
230 VAC	On *	190 * VAC	200 * VAC
	Off	170 VAC	180 VAC

Factory preset

DIP Switch 4
Selecting "Search Load Mode"
When the unit is operating as an inverter (DC Mode-Inverter), it requires some minimum input power from the battery to keep all the sections inside the unit alive and ready to deliver power to the AC load when the load is switched on. This power is called the "No Load Draw" or the "Idle Power". If the unit is on, is in "DC Mode-Inverter" and is not powering any load, this "No Load Draw" or the "Idle Power" is wasted and unnecessarily drains the battery and hence, should be minimized, if possible.

This unit has a provision to reduce this "No Load Draw" or the "Idle Power", if required (applicable only when the unit is in "DC Mode-Inverter"). This is achieved by activating the "Power Save Mode (Search Load Mode)". For example, for the 120 VAC version ,when in "Power Save Mode (Search Load Mode)", the output voltage is pulsed between a reduced voltage of around 65 VAC and the full voltage of 120 VAC in order to reduce the "No Load Draw" or the "Idle Power" and at the same time a circuitry keeps on searching if a preset value of load (> 220 W) has been switched on. If the load is < 150 W the output voltage keeps on pulsing as given above. If a load of >220W is detected, the pulsing is terminated and full output voltage of 120 VAC is restored.

When the inverter is operating in “Power Save Mode (Search Load Mode)”, the Orange LED marked “DC Mode – Inverter” (LED 1) will be lighted as follows:

- Will blink when the output voltage is the reduced voltage of approximately 65 VAC
- Will be lighted continuously when the output voltage is 120 VAC

The “No Load Draw” or the “Idle Power” power draw will be as follows:

- Normal Mode 50 W
- “Power Save Mode (Search Load Mode)” 20 W

“Power Save Mode (Search Load Mode)” is selected by DIP Switch 4. Please see details in the subsequent section.

Switch 4	Search Load Mode
ON	Enable
OFF *	Disable *

***** Factory preset***

Do not use “Power Save Mode (Search Load Mode)” if a load is required to be powered all the time

DIP Switch 5
Selecting Battery Float Voltage

The Float Voltage of the battery depends upon the type of the battery and the temperature of the battery. The Float Voltage of Lead acid battery has a Negative Temperature Coefficient - it decreases with the rise in temperature and increases with the drop in temperature. For example, a 12 V battery has a Temperature Coefficient of approximately - 16.8 mV/degree F or - 30 mV / degree C. The Float Voltage of a 12 V Lead Acid type of battery at 80 F is around 13.5 to 13.8 V and at 100 F it is approximately 13.2 V.

Note: The above voltage will double for 24 V battery.

The following Float Voltage settings are available on this unit:

Switch 5	Float Voltage (12V Battery)	Float Voltage (24V Battery)
ON*	13.8V*	27.6V*
OFF	13.2V	26.4V

***** Factory preset***

Notes:

a) **For 12 V battery**: The unit will detect the battery voltage before charging in the “AC Mode-Charger”. If the battery voltage is lower than 12 V (It means that the battery capacity is low and needs a full charge), the charger will charge the battery to the Absorption Voltage of 14.5 V and continue for one hour then drop to the Float Voltage of 13.8 V (SW 5 On) / 13.2V (SW 5 Off) .If the battery voltage is more than 12 V, the unit will charge to Float Voltage directly.

b) **For 24 V battery**: The unit will detect the battery voltage before charging in the “AC Mode-Charger”. If the battery voltage is lower than 24 V (It means that the battery capacity is low and needs a full charge), the charger will charge the battery to the Absorption Voltage of 29 V and continue for one hour then drop to the Float Voltage of 27.6 V (SW 5 On) / 26.4 V (SW 5 Off) .If the battery voltage is more than 24 V, the unit will charge to Float Voltage directly.

DIP Switches 6, 7, 8

Setting the Bulk Charge Current (Maximum Charging Current)

The Bulk Charging Current (the maximum charging current) depends upon the AH capacity of the battery. A battery should not be charged at a very high charging current as this will produce excessive heat and will result in premature failure of the battery. Normally, the maximum charging current could be safely limited to C/10 (where C is the AH capacity of the battery). For example, a 100 AH battery could be safely charged at current up to 10 A

WARNING: Please consult the battery manufacturer for the maximum allowable charging current for your battery.

For example, the AC charger in S-2012A can charge a 12 V battery at a maximum charging current of 80 A. Thus, at this maximum charging current of 80 A, the minimum AH capacity of the battery should be 800 AH. For lower AH capacity batteries, select an appropriately lower charging current with the help of DIP Switches 6, 7, 8 as indicated below:

Switch 6	ON	ON	ON	ON	OFF	OFF	OFF	OFF
Switch 7	ON	ON	OFF	OFF	ON	ON	OFF	OFF
Switch 8	ON	OFF	ON	OFF	ON	OFF	ON	OFF
	100%	80%	60%	50%	40%	30%	20%	10%

The maximum charging currents of various models are as follows:

Model#	**Battery Voltage**	**Maximum Charging Current**
S-1012A	12 V	40 A
S-2012A	12 V	80 A
S-1024A	24 V	20 A
S-2024A	24 V	40 A
S-3024A	24 V	60 A

Port marked "Battery Temperature" (For Models S-2012A/E & S-3024A/E)

This port is used for connection of an optional Temperature Sensor for monitoring the battery temperature. It uses an RJ-11 jack. The Model No of the optional Temperature Sensor is ITC-01.

Port marked "Communication Port" (For Models S-2012A/E & S-3024A/E)

This port is used for connection of an optional wired Remote Control for remoting the functions of the Control and Indication Panel. It uses an RJ-45 jack. RS-485 Serial Communication Protocol is used for communicating with the Remote Control. The Model No of the optional Remote Control is IRM-01.

INSTALLATION

GENERAL

Installation and wiring compliance

- Installation and wiring must comply with the local and the national electrical codes and must be done by a certified electrician
- The unit is not provided with internal DC or AC disconnects (switches) for isolating the unit on the DC & AC inputs / AC output sides. These are to be provided by the Installer.
- Over current protection of the cables from the battery to the inverter has to be provided by the installer
- The DC input positive and negative terminals are isolated from the chassis. Similarly, the neutral input & output terminals are not bonded to the chassis. System grounding to suit the national / local electrical codes is to be undertaken by the installer. **Read details under"AC Power Distribution and Grounding" on page 13.**

Preventing electrical shock

- Always connect the grounding connection on the inverter to the appropriate grounding system. **Read details under"AC Power Distribution and Grounding" on page 13.**

Installation environment

- The unit should be installed indoor only in a well ventilated, cool, dry environment
- Do not expose to moisture, rain, snow or liquids of any type.
- To reduce the risk of overheating and fire, do not obstruct the suction and discharge openings of the cooling fan.
- To ensure proper ventilation, do not install in a low clearance compartment.
- Working with the unit may produce arcs or sparks. Thus, the unit should not be used in areas where there are inflammable materials or gases requiring ignition protected equipment. These areas may include spaces containing gasoline powered machinery, fuel tanks, battery compartments.

Mounting position of the unit

- The unit may be mounted horizontally on the top of a horizontal surface or under a horizontal surface. The unit may be mounted on a vertical surface only horizontally **(the fan axis should always be horizontal i.e. the fans should not be pointing up or down).**

Cooling by forced air fan ventilation

The units produce heat when operating. The amount of heat produced is proportional to the amount of power supplied by the unit. Two internal fans are used to provide forced air cooling of this unit. The fans are thermostatically controlled and will be switched on only if the temperature of heat sink inside the unit rises above 35^{o} C. To limit fan noise & save power, the speed of the fans is proportional to the temperature rise of the heat sink. The speed is 25% of the full speed at 35^{o} C of the heat sink & 100% of the full speed at 50^{o} C of the heat sink.**At lower loads and / or at lower ambient temperatures, the fans may not switch on at all. This is normal.** The unit is protected against over-temperature due to failure of the fans / inadequate heat transfer. The AC output will be shut-down if the hot spot inside the inverter reaches a certain higher temperature.

DC SIDE CONNECTIONS

The DC input power to the InverCharge is derived from deep cycle batteries of the required capacity. Read under **"Specifying Batteries, Chargers and Alternators" on page 18** for details on sizing and charging of batteries.

Preventing input over voltage

It is to be ensured that the input voltage fed to the unit does not exceed 15 VDC for 12 VDC input version of the unit and 30 VDC for the 24 VDC input version of the unit to prevent permanent damage to the inverter. Please observe the following precautions:

- Ensure that the maximum charging voltage of the battery charger / alternator / solar charge controller is below 15 VDC for 12 VDC input version of the unit and below 30 VDC for the 24 VDC input version of the unit.
- Some users may connect a solar panel directly to the battery for charging (without using a charge controller). When a battery is not connected to the solar panel or when the battery is fully charged, there is no current drawn from the solar panel and the output voltage of the solar panel is the highest voltage (called the Open Circuit Voltage). For example, in a 12 V solar panel, this Open Circuit Voltage may reach 18 to 21 V in cold conditions. In such cases, InverCharge should be isolated from the battery using a Battery Disconnect Switch when the battery is being charged directly from a solar panel. This will prevent high open circuit voltage of the panel to be fed to the input of InverCharge. For example, the 12 V version of InverCharge should not be fed with a voltage > 15 V. However, due to reasons explained above, it is possible that the open circuit voltage of 18 V to 21 V of the 12 V panel gets fed to InverCharge and this will result in over voltage damage to the input section of InverCharge
- When using Diversion Charge Control Mode in a charge controller, the solar / wind / hydro source is directly connected to the battery bank. In this case, the controller will divert excess current to an external load. As the battery charges, the diversion duty cycle will increase. When the battery is fully charged, all the source energy will flow into the diversion load if there are no other loads. The charge controller will disconnect the diversion load if the current rating of the controller is exceeded. **Disconnection of the diversion load may damage the battery as well as the unit connected to the battery due to high voltages generated during conditions of high winds (for wind generators), high water flow rates (for hydro generators) or cold temperatures (for solar panels). It is, therefore, to be ensured that the diversion load is sized correctly to prevent the above over voltage conditions.**
- Do not connect the unit to a battery system with a voltage higher than the rated battery input voltage.

Preventing reverse polarity on the input side

When making battery connection on the input side, make sure that the polarity of battery connection is correct (Connect the positive of the battery to the positive terminal of the unit and the negative of the battery to the negative terminal of the unit). If the input is connected in reverse polarity, DC fuse(s) inside the unit will blow and may also cause permanent damage to the unit.

Connection from the batteries to the DC input side of the unit – cable and fuse sizes

The flow of electric current in a conductor is opposed by the resistance of the conductor. The resistance of the conductor is directly proportional to the length of the conductor and inversely proportional to its cross-section (thickness). The resistance in the conductor produces undesirable effects of voltage drop and heating. **Thus, thicker and shorter conductors are desirable**.

The size (thickness / cross-section) of the conductors is designated by AWG (**A**merican **W**ire **G**auge). **Please note that a smaller AWG # denotes a thicker size of the conductor up to AWG #1. Wires thicker than AWG #1 are designated AWG 1/0, AWG 2/0, AWG 3/0 and so on. In this case, increasing AWG # denotes thicker wire.**

The DC input circuit is required to handle very large DC currents and hence, the size of the cables and connectors should be selected to ensure minimum voltage drop between the battery and the inverter. Thinner cables and loose connections will result in poor inverter performance and will produce abnormal heating leading to risk of insulation melt down and fire. Normally, the thickness of the cable should be such that the voltage drop due to the current & the resistance of the length of the cable should be less than 2%.

Use oil resistant, multi-stranded copper wire cables rated at 90 º C minimum. Do not use aluminium cable as it has higher resistance per unit length. Cables can be bought at a marine / welding supply store

Fuse protection in the battery circuit

A battery is an unlimited source of current. Under short circuit conditions, a battery can supply thousands of Amperes of current. If there is a short circuit along the length of the cables that connects the battery to the inverter, thousands of amperes of current can flow from the battery to the point of shorting and that section of the cable will become red hot, the insulation will melt and the cable will ultimately break. This interruption of very high current will generate a hazardous, high temperature, high energy arc with accompanying high pressure wave that may cause fire, damage nearby objects and cause injury. To prevent occurrence of hazardous conditions under short circuit conditions, an appropriate fuse should be used in the battery circuit that will limit the current, blow in a very short time and at the same time, quench the arc in a safe manner. For this purpose, **UL Class T fuse** should be used (**As per UL Standard 248-15**). This special purpose current limiting, very fast acting fuse will blow in less than 8 ms under short circuit conditions. Appropriate capacity of the above Class T fuse should be installed within 18" of the battery Plus (+) Terminal. The fuse will require a corresponding fuse holder.

The following sizes of cables and fuses are recommended. The distance of 6 ft / 10 ft is the distance between the battery and the inverter. The recommended size of the cables will limit the voltage drop to 2% (The length of the cable for calculating the voltage drop has been taken as 2 times the distance between the inverter and the battery assuming that 2 cables (one Positive and one Negative) are used for the connection).

Recommended Size of DC Input Cables for 2% voltage Drop:

InverCharge Model No.	**Rated DC Input Current**	**DC Input Side Fuse (Class "T", UL 248-15)**	**Size of DC Input Cable**	
			Up to 6 ft.	**Up to 10ft.**
S-1012	120 A	150 A	AWG #2	AWG #1/0
S-2012	240 A	300 A	AWG #3/0	AWG #4/0
S-1024	60 A	70 A	AWG #6	AWG #4
S-2024	120 A	150 A	AWG #4	AWG #2
S-3024	180 A	200 A	AWG #2	AWG #1/0

CAUTION! **The input section of the inverter has large value capacitors connected across the input terminals. As soon as the DC input connection loop (Battery + ➔ fuse ➔ unit + ➔ unit - ➔ battery negative) is completed, these capacitors will start charging and will momentarily draw very heavy current that will produce sparking on the last contact in the input loop even when the on / off switch on the inverter is in the off position.Ensure that the fuse is inserted only after all the connections in the loop have been completed so that the sparking is limited to the fuse area.**

Using proper DC cable termination

The battery end and the inverter end of the cables should have proper terminals that will ensure a firm and tight connection.

DC input terminals

The DC input terminals consist of M-8 (8 mm diameter) studs. A suitable ring or tab type of copper terminal should, therefore, be used on the cable end. For some models, 2 copper terminals have been provided to fit the M-8 stud & cable recommended for 6ft. length. Crimp these terminals on the inverter end of the cable.

Reducing RF interference

To reduce the effect of radiated interference, twist the DC side cables. To furthur reduce RF interference, shield the cables with sheathing /copper foil / braiding.

Taping battery cables together to reduce inductance

Do not keep the battery cables far apart. In case it is not convenient to twist the cables, keep them taped together to reduce their inductance. Reduced inductance of the battery cables helps to reduce induced voltages. This reduces ripple in the battery cables and improves performance and efficiency.

Typical DC side connections for RV/marine application

A typical connection diagramm for RV/marine application is shown in Fig.8 below:

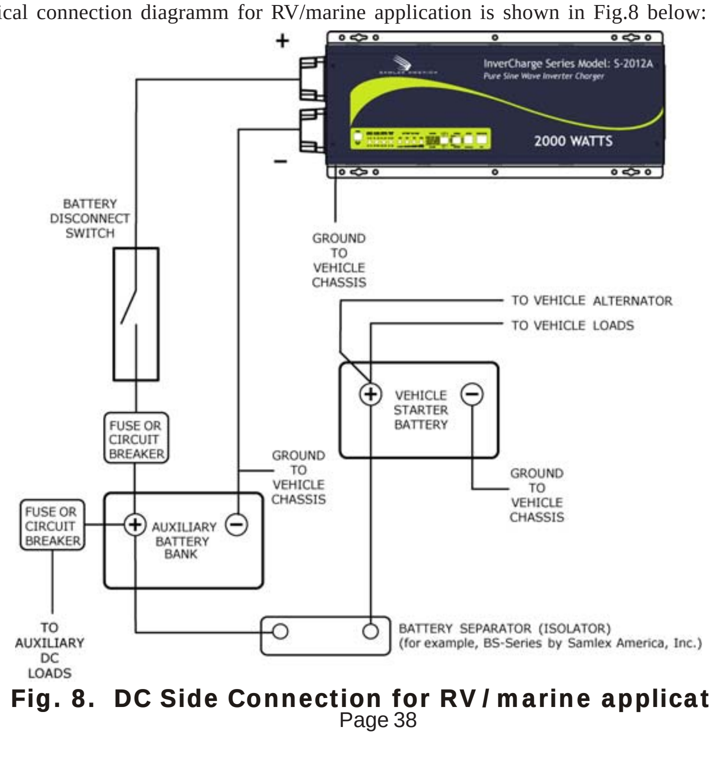


Fig. 8. DC Side Connection for RV / marine application.

AC SIDE CONNECTIONS

Preventing paralleling of the AC output

The AC output of the unit cannot be synchronised with another AC source and hence, it is not suitable for paralleling. The AC output of the unit should never be connected directly to an electrical breaker panel / load center which is also fed from the utility power / generator. Such a connection may result in parallel operation of the different power sources and AC power from the utility / generator will be fed back into the unit which will instantly damage the output section of the unit and may also pose a fire and safety hazard. If an electrical breaker panel / load center is fed from this unit and this panel is also required to be powered from additional alternate AC sources, the AC power from all the AC sources like the utility / generator / inverter should first be fed to a manual selector switch and the output of the selector switch should be connected to the electrical breaker panel / load center.
To prevent possibility of paralleling and severe damage to the inverter, never use a simple jumper cable with a male plug on both ends to connect the AC output of the inverter to a handy wall receptacle in the home / RV.

Connecting to multi-wire branch circuits

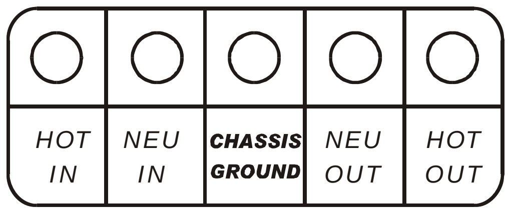
Do not directly connect the hot side of the 120 VAC of the unit to the two hot legs of the 120 / 240 VAC electrical breaker panel / load centre where multi-wire (common neutral) branch circuit wiring method is used for distribution of AC power. This may lead to overloading / overheating of the neutral conductor and is a risk of fire.

A split phase transformer (isolated or auto-transformer) of suitable wattage rating (25 % more than the wattage rating of the unit) with primary of 120 VAC and secondary of 120 / 240 VAC (Two 120 VAC split phases 180 degrees apart) should be used. The hot and neutral of the 120 VAC output of the inverter should be fed to the primary of this transformer and the 2 hot outputs (120 VAC split phases) and the neutral from the secondary of this transformer should be connected to the electrical breaker panel / load centre.

AC Input and Output Connections

The AC input and output connections are located in a pocket with a cover plate. The cover plate has two 7/8" knock-outs for 22.2 mm or ½ inch conduit

Barrier type of Terminal Block is used for the connections. Each terminal is ½" wide and has an M5 screw. Please see the layout given below:



No over current protection for the AC output wiring is provided as an integral part of this inverter. Over current protection of the AC output wiring must be provided as part of the system installation.

AC IN CONNECTION
Use AWG #10 cable for AC input.

Remove the knockout from the inverter chassis and install a strain relief or conduit in which to route the AC cabling in and out.

Connect the black wire from the hot side of the AC power to the terminal labeled ***HOT IN***
Connect the white wire from the neutral side of the AC power source to the terminal labeled ***NEU IN***

Connect the green wire from the ground of the AC power source to the terminal marked **Chassis** ***Ground***

AC OUT CONNECTION

Use AWG #10 cable

Connect the black wire from the terminal marked ***HOT OUT*** to the hot bus of your AC load center or AC sub-panel.

Connect the white wire from the terminal marked ***NEU OUT*** to the neutral bus of your AC load center or sub-panel.

Connect the **Chassis** ***Ground Terminal*** of the inverter to the safety ground bus of the AC load center or sub-panel.

SPECIFICATIONS

SPECIFICATION	Model No. (Suffix "A" for 120 VAC version & suffix "E" for 230 VAC version)				
	S-1012A	**S-2012A**	**S-1024A**	**S-2024A**	**S-3024A**
	S-1012E	**S-2012E**	**S-1024E**	**S-2024E**	**S-3024E**
OUTPUT PARAMETERS					
Continuous power	1000 W	2000 W	1000 W	2000 W	3000 W
Surge power (less than 2 sec)	1500 W	3000 W	1500 W	3000 W	4500 W
Standard output voltage & frequency	120 VAC, 60 Hz / 230 VAC, 50 Hz ± 10%				
Output waveform (DC mode - Inverter)	Pure sine wave (THD < 3.5% @ linear load & < 5% @ non-linear load)				
Power Factor allowed	0.8 to 1				
AC breaker rating on the load side:					
120 VAC version	15 A	30 A	15 A	30 A	40 A
230 VAC version	15 A	15 A	15 A	15 A	20 A
Resistive load	100%				
Inductive load	YES				
Motor load	YES				
Rectifier load	YES				
INPUT PARAMETERS					
DC Current at rated power	120 A	240 A	60 A	120 A	180 A
DC Current at short circuit	360 A	720 A	180 A	360 A	540 A
Nominal DC input voltage	12 VDC		24 VDC		
DC input voltage range	10.0 ~ 15 VDC		20.0 ~ 30 VDC		
Maximum AC input current	15 A	30 A	15 A	30 A	40 A
AC TRANSFER PARAMETERS					
Transfer time	16 ms +/- 4 ms				
Automatic Transfer Relay	16 A	40 A	16 A	40 A	
Upper frequency limit (Grid → Inverter transfer)	65 ± 0.5 Hz @ 60 Hz / 55 ± 0.5 Hz @ 50 Hz				
Upper frequency limit (Inverter → Grid transfer)	63 ± 0.5 Hz @ 60 Hz / 52 ± 0.5 Hz @ 50 Hz				
Lower frequency limit (Grid → Inverter transfer)	55 ± 0.5 Hz @ 60 Hz / 45 ± 0.5 Hz @ 50 Hz				
Lower frequency limit (Inverter → Grid transfer)	57 ± 0.5 Hz @ 60 Hz / 47 ± 0.5 Hz @ 50 Hz				
Upper voltage limit (Grid → Inverter transfer)	135 ± 4 VAC @ 120 VAC / 264 ± 4 VAC @ 230 VAC				
Upper frequency limit (Inverter → Grid transfer)	133 ± 4 VAC @ 120 VAC / 264 ± 4 VAC @ 230 VAC				
Lower frequency limit (Grid → Inverter transfer)	85/95 VAC @ 120 VAC / 170/200 VAC @ 230 VAC (selectable)				
PARAMETERS - INVERTER MODE					
Full load efficiency	85% max.		87% max.		
No load power consumption	26 W	52 W	30 W	73 W	80 W
Power consumption in Search Load Mode	9 W	20 W	12 W	30 W	29 W
Loading required to Search Load Mode	150 W ~ 220 W				
Power Factor Allowed	0.8 to 1				
Overload:					
110%	Shut down after 60 seconds				
130%	Shut down after 30 seconds				
>150%	Shut down after 2 seconds				
PARAMETERS - BATTERY CHARGER SECTION					
Float voltage (selectable)	13.2/13.8 VDC		26.4/27.6 VDC		
Absorption voltage (1 Hour)	14.5 VDC		29 VDC		
Adjustable charging current	4 ~ 40 A	8 ~ 80 A	2 ~ 20 A	4 ~ 40 A	6 ~ 60 A
Number of charging profiles	3				
AC input Power Factor	0.42				
Input AC breaker: 120 VAC version	15 Amps	30 Amps	15 Amps	15 Amps	40 Amps
230 VAC version	15 Amps	15 Amps	15 Amps	15 Amps	20 Amps
Battery charger efficiency: 120 VAC version	81%	80%	84%	86%	83.60%
230 VAC version	80%	80%	83%	85%	83.00%

SPECIFICATIONS

<table>
<tr><th>PROTECTIONS</th><th colspan="5"></th></tr>
<tr><td rowspan="2">Overload (Typ.)</td><td colspan="5">130% for 10 seconds</td></tr>
<tr><td colspan="5">Protection Type: Shutdown</td></tr>
<tr><td>Low battery protection (Heavy / Light Load)</td><td colspan="2">10.0/11.0 VDC</td><td colspan="3">20.0/22.0 VDC</td></tr>
<tr><td>DC Input reverse polarity</td><td colspan="5">Internal Fuse</td></tr>
<tr><th>SAFETY & EMI / EMC</th><td colspan="5"></td></tr>
<tr><td>EMC Conduction & Radiation</td><td colspan="5">Compliance to FCC Class A</td></tr>
<tr><td>Safety Standards</td><td colspan="5">UL 1741 Pending</td></tr>
<tr><th>GENERAL</th><td colspan="5"></td></tr>
<tr><td>Operating Temperature</td><td colspan="5">0ºC – 40ºC</td></tr>
<tr><td>Operating Humidity</td><td colspan="5">10% - 95% RH</td></tr>
<tr><td>Forced Air Cooling</td><td colspan="5">2 Fans, Variable Speed</td></tr>
<tr><td>Wall Mounting</td><td colspan="5">YES</td></tr>
<tr><td>Shipping Weight (kg)</td><td>16.12</td><td>23.21</td><td>15.79</td><td>20.21</td><td>25</td></tr>
<tr><td>Dimensions (WxDxH) mm</td><td>540x325x310</td><td>650x320x295</td><td colspan="2">540x325x310</td><td>650x320x295</td></tr>
</table>

2 YEAR Limited Warranty

The InverCharge Series manufactured by Samlex America, Inc. (the “Warrantor”) is warranted to be free from defects in workmanship and materials under normal use and service. This warranty is in effect for 2 years from the date of purchase by the user (the “Purchaser”).

For a warranty claim, the Purchaser should contact the place of purchase to obtain a Return Authorization Number.

The defective part or unit should be returned at the Purchaser’s expense to the authorized location. A written statement describing the nature of the defect, the date of purchase, the place of purchase, and the Purchaser’s name, address and telephone number should also be included.

If upon the Warrantor’s examination, the defect proves to be the result of defective material or workmanship, the equipment will be repaired or replaced at the Warrantor’s option without charge, and returned to the Purchaser at the Warrantor’s expense.

No refund of the purchase price will be granted to the Purchaser, unless the Warrantor is unable to remedy the defect after having a reasonable number of opportunities to do so.

Warranty service shall be performed only by the Warrantor. Any attempt to remedy the defect by anyone other than the Warrantor shall render this warranty void.

There shall be no warranty for defects or damages caused by faulty installation or hook-up, abuse or misuse of the equipment including exposure to excessive heat, salt or fresh water spray, or water immersion.

No other express warranty is hereby given and there are no warranties which extend beyond those described herein. This warranty is expressly in lieu of any other expressed or implied warranties, including any implied warranty of merchantability, fitness for the ordinary purposes for which such goods are used, or fitness for a particular purpose, or any other obligations on the part of the Warrantor or its employees and representatives.

There shall be no responsibility or liability whatsoever on the part of the Warrantor or its employees and representatives for injury to any persons, or damage to person or persons, or damage to property, or loss of income or profit, or any other consequential or resulting damage which may be claimed to have been incurred through the use or sale of the equipment, including any possible failure of malfunction of the equipment, or part thereof.

The Warrantor assumes no liability for incidental or consequential damages of any kind.

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