

MODEL DR2412 #AEO1399

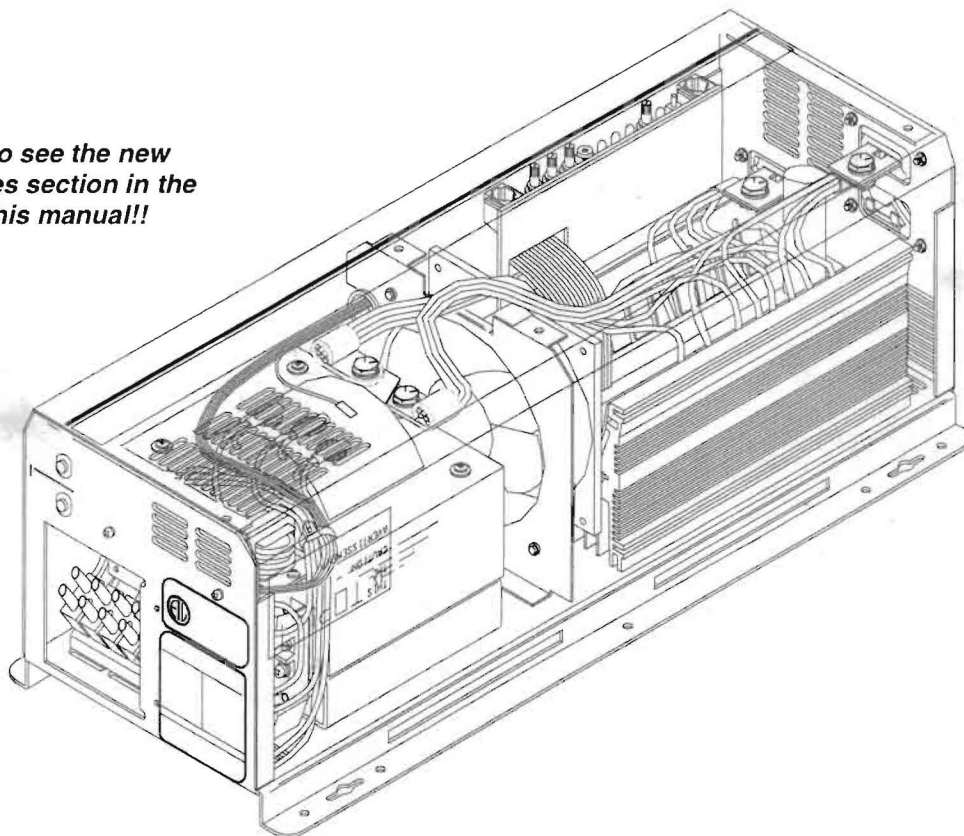


Owner's Manual

V 3.1

DR SERIES INVERTER/CHARGERS

*Be sure to see the new
TechNotes section in the
back of this manual!!*



Effective 2/4/97
PN: 830-5

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Warranty Procedure

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Warranty to Trace Engineering within ten (10) days from the date of purchase. It is also advised that you KEEP YOUR BILL OF SALE as proof of purchase, should any difficulties arise concerning the registration of the warranty card.

Because we take pride in our work, if you encounter any discrepancies, please call or fax us with any questions or comments.

Any service or inquiries made to Trace Engineering must include the model and serial number of the product in question. Be sure to fill in the model and serial number in the space provided below and keep this portion of the warranty card in a safe place for future use.

This Trace Engineering DR series inverter/charger was packaged with the following item(s):

WARRANTY SERVICE must be performed ONLY AT AN AUTHORIZED TRACE SERVICE CENTER OR FACTORY. It is recommended that a return shipping label be provided to the repair facility to avoid the possibility of needless shipment.

UNAUTHORIZED SERVICE AT ANY OTHER LOCATION WILL VOID THE EXISTING FACTORY WARRANTY ON THAT PRODUCT.

FACTORY SERVICE MUST BE PROVIDED IN THE ORIGINAL PACKAGING OR EQUIVALENT. The warranty will be void if the product is damaged through improper packaging. If possible, avoid shipping the product in the original packaging.

Note: TRACE must be serviced by an authorized dealer and be provided with a serial number before any warranty service is performed.

Ship to: Trace Engineering, Attn: Service Dept. RMA #

DECLARATION OF CONFORMITY (IF UNIT IS AN EXPORT MODEL)

TRACE BUMPER STICKER

SERIAL NUMBER:

AE 01399

PACKAGED BY:

MS

DATE:

12-4-97

Be sure to include in the package:

1. Complete return shipping address (P.O. Box numbers are not acceptable) and telephone number where you can be reached during work hours.
2. A detailed description of any problems experienced, including the make and model numbers of any other equipment in the system, types and sizes of loads, operation environment, time of unit operation and temperature.
3. A copy of your proof of purchase (purchase receipt).

Repaired products will be returned freight C.O.D. unless sufficient return shipment funds are included with the unit.

Products sent to the factory from outside the U.S. MUST include return freight funds, and sender is fully responsible for all customs duties and taxes. Make sure to include a copy of your proof of purchase (purchase receipt).

THANK YOU FOR CHOOSING TRACE ENGINEERING TO MEET YOUR INDEPENDENT POWER NEEDS.

Record the model and serial numbers below and retain for your files.



Inverter Model #

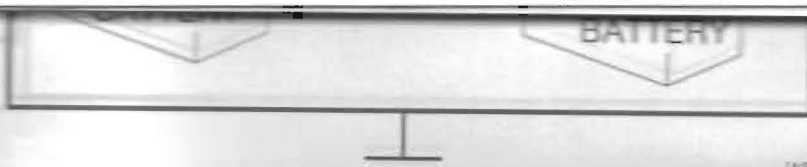
Inverter Serial #

RMA #

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Theory of Inverter Operation

Waveform

The output waveform of the inverter is referred to as a modified sine wave. This waveform is suitable for a wide variety of applications. Induction motors (i.e. refrigerators, drill presses), resistive loads (i.e. heaters, toasters), universal motors (i.e. hand tools, vacuum cleaners) as well as microwave ovens and computers are all suitable loads.

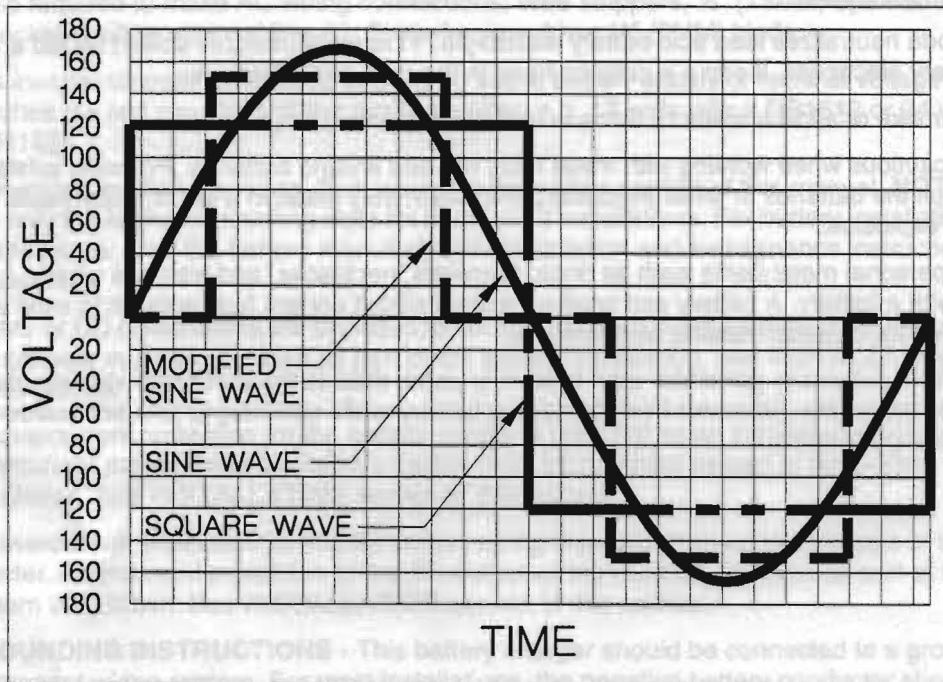


Figure 1 , Comparison of AC Waveforms

The waveform could be more accurately described as a pulse width modified square wave. The accompanying Figure 1 shows the relationships between square wave, sine wave and modified sine wave formats.

Regulation

The inverter is RMS voltage regulated. RMS regulation ensures that loads will always have the same amount of power delivered to them as battery voltage changes. Regulation is achieved by varying the width of each output pulse in the waveform. Peak voltage is the product of the battery voltage times the turns ratio of the inverter's power transformer and is therefore not regulated.

Inverter Operation

Front Panel Controls and LED Indicators

Shown below are the controls and indicator lights on the front of the DR series inverter/charger. These control and provide information when in either inverter or battery charging mode of operation. All models of the DR series operate identically.

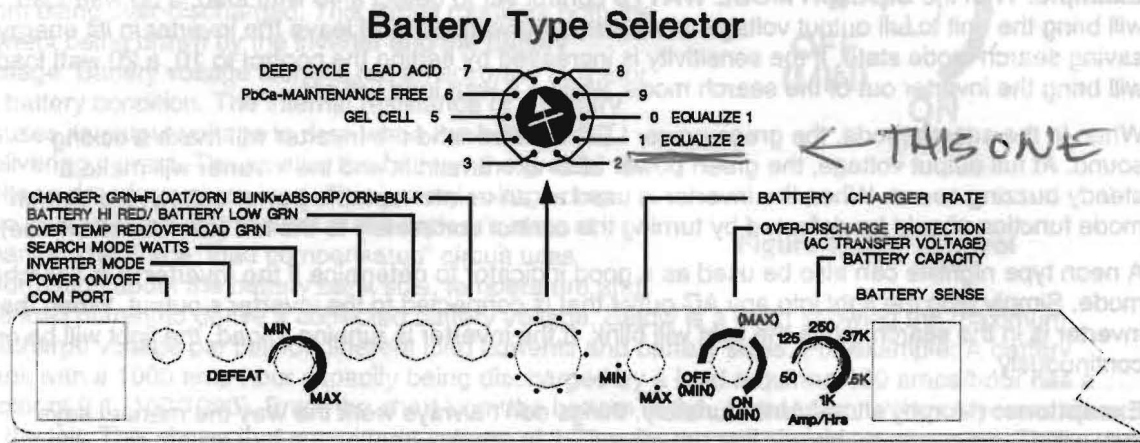


Figure 2, Control Panel

Power On/Off

Located on the left of the panel is the momentary **POWER ON/OFF** button. Once the inverter has been properly installed and the batteries are connected, pressing this button momentarily will alternately turn the inverter on and off. Each time it is pressed the inverter will sound an audible chirp. **Note:** When first connected to batteries, the inverter will run through a self-test, and go to an off state. It may then be activated by pressing the on/off button. **Note:** The self-test consists of the control panel lights lighting up in sequence, the internal cooling fan will run momentarily, and the transfer relay will click three times.

Inverter Mode LED

This green LED indicator lights when the unit is in the inverter mode (not charging batteries) delivering full output voltage. When the inverter is in its search mode the green LED will blink about 2-3 times per second.

Figure 4, Recommended Discharge Cutoff Voltage per Cell

Search Mode Watts

The **SEARCH MODE WATTS** control is used for adjusting the sensitivity of the search mode circuit. The DR Series inverters feature a circuit that minimizes power drain by reducing the inverter's output to small test pulses when there is no load connected to the inverter. These pulses are used to detect the presence of a load. When a load is detected the inverter's output goes to full voltage. The sensitivity of the detection threshold is adjustable. Turning the **SEARCH MODE WATTS** control clockwise decreases the sensitivity. Turning the control full counterclockwise increases sensitivity and at the full counterclockwise position, defeats the search mode feature.

Example: With the **SEARCH MODE WATTS** control set to detect a 40 watt load, a 50 watt load will bring the unit to full output voltage. However, a 30 watt load will leave the inverter in its energy saving search mode state. If the sensitivity is increased by setting the control to 10, a 20 watt load will bring the inverter out of the search mode, while a 5 watt load will not.

When in the search mode, the green power LED will blink and the inverter will make a ticking sound. At full output voltage, the green power LED will remain lit and the inverter will make a steady buzzing sound. When the inverter is used as an uninterruptable power supply, the search mode function should be defeated by turning the control completely to the left (counter clockwise).

A neon type nightlite can also be used as a good indicator to determine if the inverter is in search mode. Simply plug the light into any AC outlet that is connected to the inverter's output. When the inverter is in the search mode the light will blink. If the inverter is running a load, the light will be on continuously.

Exceptions: (Murphy's Law) Unfortunately, things don't always work the way the manual says they will.

Example A: If the **SEARCH MODE WATTS** control is set to detect a 40 watt load and a 30 watt incandescent light is turned on, the inverter will detect the light. The light is a bigger load than 40 watts when its filaments are cold. When the light gets hot it becomes a 30 watt load. Since this is below the control setting of 40, the inverter will not detect it and the light will go out. This will cause the light to cycle repeatedly.

Example B: If the **SEARCH MODE WATTS** control is set to detect a 30 watt load and a 40 watt fluorescent light is turned on, the inverter will not detect the light. The light presents a smaller load than 30 watts until the gas in the fluorescent tube ionizes.

Example C: There are some appliances that draw power even though they are turned off. TVs with instant on circuits, microwave ovens with digital displays and VCRs are examples. These loads present a dilemma. If the sensitivity is set higher than the combination of these loads, then an auxiliary load must be used to bring the inverter out of the search mode before the appliances can be turned on. If the sensitivity is set lower than this combination of loads, the loads will be left on and will put an additional drain on the batteries. (Three such 15 watt loads would amount to an additional 90 amp/hours per 24 hours in a 12 VDC system.)

One solution is to turn these items off at the wall. Use an extension cord with a rocker switch, a switch at the outlet, or the appropriate circuit breaker. Another solution might be to place all these phantom loads on a separate circuit with its own disconnect.

Over Discharge Protection and AC Transfer Voltage

This control enables or disables the over discharge protection system (ODP) and allows adjustment of the AC transfer voltage. With the dial set to either the left or right side of the scale, transfer voltage can be adjusted from minimum to maximum. The voltage will vary depending on the model of inverter you have. See the chart on the next page for transfer voltage values.

ODP (AC Transfer Voltage) Control

Located on the right of the control panel is the **OVER-DISCHARGE PROTECTION** control. This circuit is unique to Trace Inverters. Its purpose is to protect the batteries from being over-discharged. This circuit monitors both the current being drawn by the inverter and the battery voltage. Battery voltage alone is not an accurate indicator of battery condition. The internal resistance of a battery causes its output voltage to drop when the battery is delivering current. The smaller the battery, the greater the voltage drop for a given load. This battery voltage drop due to load is not an indicator of the battery's state of charge. The Trace "load compensated" circuit uses information about the battery bank size, temperature and the load current to derive a corrected battery voltage. Below is a chart showing the maximum discharge voltage per cell for different load currents and battery sizes. For example: A battery bank with a 1000 amp-hour capacity being discharged by a load requiring 100 amps/hour has a factor of 0.1 (100/1000). Enter the chart from the bottom at 0.1, proceed up to the curve and then to the left. This shows that a minimum voltage of 1.73 volts per cell should be observed. This chart is useful when customizing the DR inverter to different size systems.



Figure 3, ODP Control

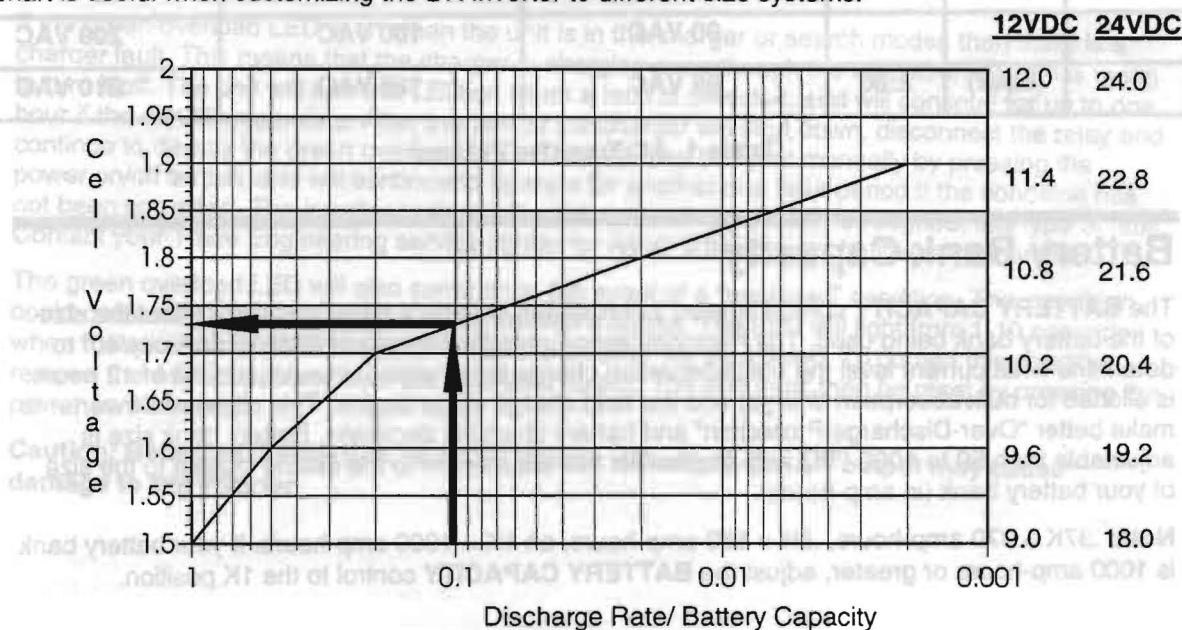


Figure 4, Recommended Discharge Cutoff Voltage per Cell

The over discharge protection control is turned clockwise to activate the circuit. It is defeated by turning the control fully counterclockwise. If the over discharge circuit is defeated, the inverter itself is protected from low battery voltage conditions by an additional low battery protection circuit which has a threshold of 8.2 volts DC.

AC Transfer Voltage

When the AC source (either public power or a generator) fails or falls to a low level (browns out), the unit changes from battery charger mode to inverter mode. The AC voltage point at which the inverter decides to change modes is called the AC transfer voltage. It is adjustable from minimum to maximum. The adjustment is made by rotating the ODP knob between the 9:00 and 1:00 o'clock position if you want the ODP defeated, or by rotating the knob between 2:00 and 5:00 o'clock if you want the ODP enabled. As the knob is turned clockwise the transfer voltage increases if the ODP is defeated, or decreases if the ODP is enabled. It is best to set the transfer voltage by first rotating the control all the way to the left (off position), then to the desired position. See Figure 3.

Below is a chart showing the AC transfer voltages depending on the particular AC input/output voltage of the unit. Note that adjusting the dial to a higher voltage setting results in slightly faster transfer times, since it will take less of a voltage drop to trigger the transfer. Lower settings are less likely to cause a transfer due to voltage fluctuations.

ODP ADJUSTMENT			AC TRANSFER VOLTAGE		
ODP OFF		ODP ON	100 - 105 VAC UNITS (J OR K)	120 VAC UNITS (USA)	220 - 240 VAC UNITS (W OR E)
9:00	(MIN)	5:00	36 VAC	40 VAC	80 VAC
			77 VAC	85 VAC	170 VAC
			81 VAC	90 VAC	180 VAC
			86 VAC	95 VAC	190 VAC
			90 VAC	100 VAC	200 VAC
1:00	(MAX)	2:00	95 VAC	105 VAC	210 VAC

Table 1, AC Transfer Voltage

Battery Bank Capacity

The **BATTERY CAPACITY** control is used to inform the inverter's microprocessor about the size of the battery bank being used. The microprocessor uses the formula of "battery capacity/40" to determine what current level the bulk/absorption charge terminates (a maximum time of 12 hours is allotted for bulk/absorption charge) and the float charge stage begins. This allows the inverter to make better "Over-Discharge Protection" and battery charging decisions. Battery bank size is adjustable from 50 to 1000 (1K) amp-hours. Set this adjustment to the setting closest to the size of your battery bank (in amp-hours).

Note: .37K = 370 amp-hours, .5K = 500 amp-hours, an 1K = 1000 amp-hours. If your battery bank is 1000 amp-hours or greater, adjust the **BATTERY CAPACITY** control to the 1K position.

Protection Circuitry

The inverter will **automatically** restart itself from the following overload conditions: low battery, high battery, shorted output, over current, and over temperature.

The inverter will turn itself off and require a **manual** restart if it encounters an overload for approximately 10 seconds (a prolonged short circuit), or if AC output is directly connected to an AC power source (public power or generator).

Two LED's are provided to report on error conditions:

BATTERY HI RED/ BATTERY LOW GRN - This LED lights red when battery voltage is too high for safe operation, and is green when voltage is too low for safe operation. When the voltage returns to a safe level, the inverter restarts automatically.

Note: In alternative energy applications (solar, wind, hydro) all DC charge controllers must be set to a level below the inverter's **MAXIMUM INPUT VOLTAGE** or the inverter may shut off unexpectedly. The maximum input voltage for DR series inverters is, 15.5 volts DC for 12 volt inverters, and 31.0 volts DC for 24 volt models.

Note: The battery charger control circuit operates from battery voltage. If battery voltage falls below 7 volts, neither the charger nor the inverter will operate. In this situation, a small charge from a stand-alone charger will be required to bring the battery to a high enough voltage for the inverter/charger to resume operation.

OVERTEMP RED / OVERLOAD GRN- This LED lights red when the inverter's temperature is too high for safe operation and is green if the load is too large for the inverter to safely operate. When the temperature returns to a safe level, the inverter restarts. The inverter will restart automatically if the overload condition lasts for less than 10 seconds.

If the green overload LED is on when the unit is in the charger or search modes then there is a charger fault. This means that the charger is charging even though the regulation system is trying to turn it off. The unit will turn this LED on when a fault is detected, and will continue for up to one hour if the condition persists. After this period the charger will shut down, disconnect the relay and continue to display the green overload LED. The unit may be reset manually by pressing the power on/off switch, and will continue to operate for another one hour period if the condition has not been corrected. The inverter portion will continue to work normally throughout this type of fault. Contact your Trace Engineering service center for repair if this type of fault is encountered.

The green overload LED will also come on in the event of a "backfeed" condition. This condition could occur if AC power is applied to the inverter's output. The LED will light from 1-10 seconds when the condition is detected, after which the inverter will shut down. To correct this condition remove the AC input power from the inverter's output. The unit must then be reset by pressing the power on/off switch.

Caution: Repeated connection of an AC source directly to the AC output may cause damage to the inverter.



Battery Charger

Theory of Operation

Inverter to Charger Transition

The internal battery charger and automatic transfer relay allows the unit to operate as either a battery charger or inverter (but not both at the same time). An external source of AC power (e.g., shore power or generator) must be supplied to the inverter's AC input in order to allow it to operate as a battery charger. When the unit is operating as a charger, AC loads are powered by the external source (i.e. generator or public power).

The inverter automatically becomes a battery charger whenever AC power is supplied to its AC inputs. There is a 40 second time delay from the time the inverter senses that AC is present at its input and when the transfer is made. This delay is built in to provide time for a generator to spin-up to a stable voltage and avoid relay chattering. The inverter's AC input is internally connected to the inverter's AC output while in the battery charger mode. The maximum power that can be handled by the inverter's internal wiring and transfer relay is 30 amps (20 amps for export models).

Transfer Switching Speed

While this inverter is not designed specifically to operate as an uninterruptable power supply (UPS) system, its transfer time is normally fast enough to hold up computers. The transfer time is a maximum of 32 milliseconds. Success as a UPS will vary with computer models, and cannot be guaranteed.

Charger Terminology

- **Bulk Voltage**- This is the maximum voltage at which the batteries will be charged during a normal charging cycle. The normal range is 2.367 to 2.4 volts per cell. For a 12 VDC battery (6 cells) this is 14.2 to 14.4. Liquid electrolyte batteries are usually set to the higher voltage, while gel cell batteries are set to the lower voltage. (See page 19, **Battery Care and Maintenance**, "Bulk Voltage").
- **Absorption** - During this part of the charge cycle, the batteries are held at the bulk voltage and accept whatever current is required to maintain this voltage. This ensures full charging.
- **Float Voltage** - This is the voltage at which the batteries will be maintained after they have been charged. A range of 13.2 -13.4 for 12 volt systems is appropriate for most sealed and non-sealed batteries. 13.2 volts is appropriate for gel cell batteries, and 13.4 volts is common for liquid lead acid types. Check with the specific battery manufacturer for actual float voltage figures.
- **Equalize** - The batteries are held above 15.0 Volts DC for a period to "boil" or mix the cells thus reducing stratification and lead sulfate build-ups. **This is not necessary or safe with sealed batteries.**

Three Stage Battery Charging

The battery charger in the Trace DR series inverters, charges in three stages - **BULK**, **ABSORPTION**, and **FLOAT** - to provide rapid and complete charge cycles without undue battery gassing. A manually operated equalize stage is provided for periodic battery maintenance. The time diagram at the bottom of this page shows how DC voltage and AC current change with time through the different charge stages.

Stage One - Constant Current (Bulk Charge)

This stage is initiated when AC is applied to the AC input of the inverter, and is terminated when the batteries reach the **BULK CHARGE VOLTAGE**. During this stage the Charger LED glows steady orange.

Stage one charges the batteries at a constant current. The level of charge for this phase is set using the **BATTERY CHARGER RATE** control on the front panel.

Stage Two - Constant Voltage (Absorption Charge)

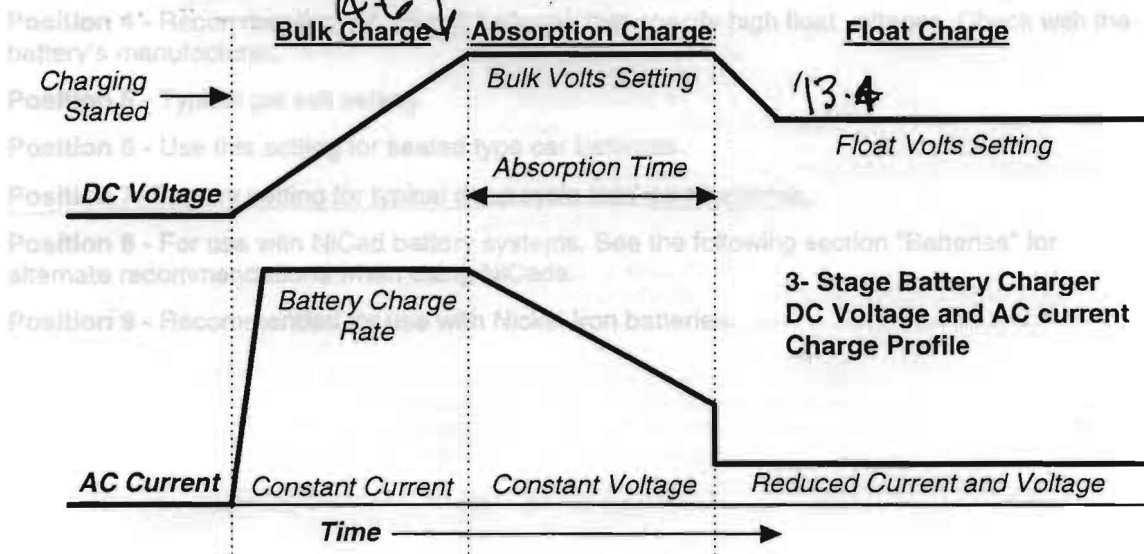
Absorption is initiated when the Bulk Voltage setting is reached. At this point the charge current begins to taper off at whatever rate is required to hold the voltage constant. During this stage the Charger LED blinks orange. The absorption charge phase is terminated in one of two ways.

1. Normally, as the charge cycle progresses, the current required to hold the battery voltage constant gradually reduces. When this current equals the programmed return amps setting (battery bank capacity/40), the voltage is allowed to fall to the **FLOAT** (float voltage) setting - stage three.
2. If there are DC loads on the batteries, the current may never fall to a level low enough to initiate the float voltage stage. A timer is used to ensure that the battery voltage does not remain indefinitely at the Bulk Charge Voltage. The timing circuit is activated by the onset of stage two, it terminates stage two if the charge current does not reach the return amps value setting within 12 hours.

Stage Three - Maintenance Voltage (Float Charge)

The charger remains in the float stage until the unit is turned off or loses AC input power (i.e. generator or grid). During this stage the Charger LED glows steady green. The purpose of stage three is to maintain the batteries at a voltage that will hold full charge but not gas the batteries.

Note: When DC loads are placed on the battery, the charger will deliver currents up to the Maximum Charge Rate setting while maintaining the float voltage.



Battery Charger Controls and LED Indicator

A three state LED reports on the activity of the battery charger. Controls are provided that make it simple to tailor the charger's characteristics for various types of batteries.

Charger LED

Labeled "**CHARGER: GRN=FLOAT/ORN BLINK=ABSORP/ORN= BULK**", this bi-color LED indicates charge status as follows:

- **Orange** - this indicates that the charger is in the bulk charging stage.
- **Blinking Orange** - this indicates that the charger is in the absorption stage.
- **Green** - this indicates that the charger is in the float stage.

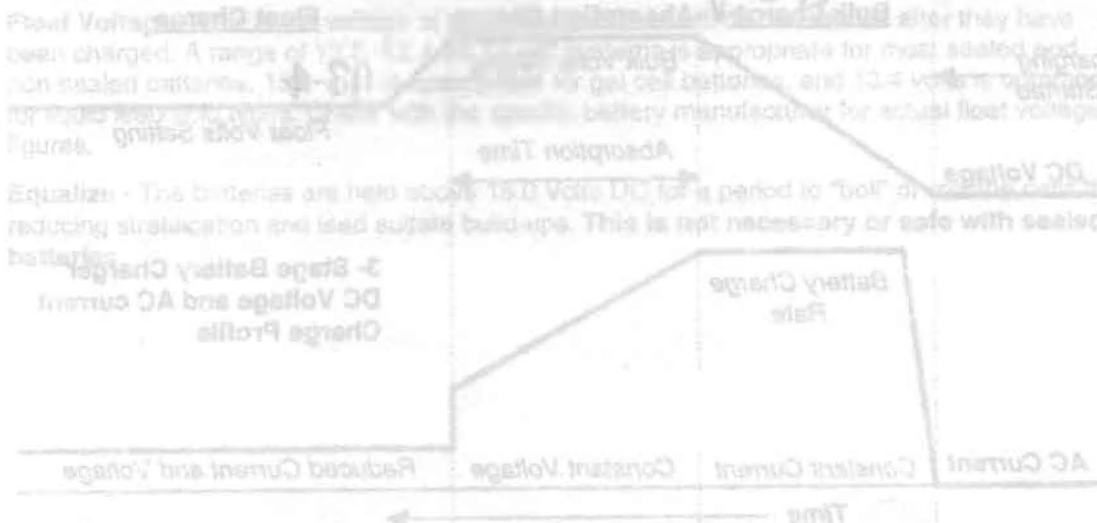
Note: The bi-color LED used has the ability to show red, green, or orange in color. By simultaneously showing red and green the orange color is obtained. To avoid confusion as to which color is being displayed, view the LED from directly in front of the unit. Do not view it at an angle.

Battery Charger Rate

This control sets the maximum charge rate in amps. The highest charge rate recommended is determined by dividing the battery bank's total amp hour capacity by a factor between 3 and 5 (3 for gel cell - 5 for lead acid). Setting the **BATTERY CHARGER RATE** at the highest recommended level is best when the objective is to charge the batteries as quickly as possible. A much lower setting can be used in installations where AC power is typically available for periods of several hours. For example: there is more than sufficient time for a 400 amp/hr battery bank to be recharged in 24 hours at a 25 amp setting - 25 amps X 24 hours = 600 amp-hours.

Caution: Excessively high charge rates can overheat a battery. If a small battery capacity is used, set the battery charger rate to the minimum setting.

$$\frac{600}{5} = 120 \text{ AMPS}$$



Battery Type Selector

This control automatically sets the correct bulk and charge voltages according to the type of battery selected. The switch has ten positions. Each position provides different charge parameters. Select the correct position according to the following table. (See the section "Battery Charger Setting" on the next page, for specific applications and hints.)

Switch Position	Description	12 VOLT MODELS		24 VOLT MODELS		Equalize Rate
		Float Voltage	Bulk Voltage	Float Voltage	Bulk Voltage	
0	Equalize 1	13.2	15.0	26.4	30.0	c/40
1	Equalize 2	13.2	15.5	26.4	31.0	manual
2	Deep Cycle Lead Acid 2	13.3	15.0	26.6	30.0	N/A
3	Not Specified	13.6	14.3	27.2	28.6	N/A
4	Gel Cell 2	13.7	14.4	27.4	28.8	N/A
5	Gel Cell	13.5	14.1	27.0	28.2	N/A
6	PbCa- Lead Calcium	13.2	14.3	26.4	28.6	N/A
7	Deep Cycle Lead Acid	13.4	14.6	26.6	29.2	N/A
8	NiCad 1	14.0	16.0	28.0	32.0	N/A
9	NiCad 2	14.5	16.0	29.0	32.0	N/A

Table 2, Bulk, Float, and Equalize Voltages for DR Series Inverters

Position 0 and 1 - These positions may be used to equalize lead acid batteries. Equalizing is discussed in the next chapter "Batteries". These positions are unique in that the batteries are held at the bulk voltage for a minimum of six hours. Position 0 equalizes at a rate equal to the battery capacity in amp hours divided by 40. Position 1 charges at a rate set by the **BATTERY CHARGER RATE** control. **DO NOT USE THESE POSITIONS WITH SEALED BATTERIES!**

Position 2 - Provides different bulk and float settings for deep cycle lead acid batteries as compared to position 7. Consult the battery manufacturer for recommended bulk and float settings.

Position 3 - Provides an additional set of bulk and float voltages.

Position 4 - Recommended for gel cell batteries that specify high float voltages. Check with the battery's manufacturer.

Position 5 - Typical gel cell setting.

Position 6 - Use this setting for sealed type car batteries.

Position 7 - Factory setting for typical deep cycle lead acid batteries.

Position 8 - For use with NiCad battery systems. See the following section "Batteries" for alternate recommendations when using NiCads.

Position 9 - Recommended for use with Nickel Iron batteries.

Battery Charger Settings

BATTERY TYPE AND MANUFACTURER	BULK VOLTAGE	FLOAT VOLTAGE	DR BATTERY SELECTOR POSITION
----------------------------------	-----------------	------------------	---------------------------------

GEL CELL BATTERIES

East Penn/Sonnenschein/Prevailer Series	14.1	13.8	5 GEL
Interstate SG type	14.4	13.6	4 (gel cell 2)
Johnson Controls/Dynasty GC series	14.4	13.6	4 (gel cell 2)
East Penn/Deka 8G series	14.1	13.8	5 GEL
GNB		Not yet determined	
JCI		Not yet determined	

ABSORBED ELECTROLYTE BATTERY

Generic Absorbed Electrolyte	14.5	13.8	4 (gel cell 2)
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LIQUID LEAD ACID BATTERY

Rolls 4000 or Surrete 400	?14.4	?13.8	4 (gel cell 2)
Generic Automotive	14.4	13.6	4 (gel cell 2)

LIQUID LEAD CALCIUM (FLOODED) TELEPHONE BATTERY

C and D Powerco	14.3	13.4	4 (gel cell 2)
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General Guidelines

EQUALIZATION-

- Do not equalize gel types or starved electrolyte types (Starved electrolyte batteries are batteries such as absorbed glass mat (AGM) batteries in which the electrolyte is minimal and is contained in the plate separators).
- Equalize once every 30 days if medium cycled service. Less if battery spends most of time in Float mode.

CHARGING-

- Max charge current is typically 20-30% of batteries total capacity
- Do you think the charger is going to float stage too soon? --
 - ♦ Turn battery size pot CCW to decrease return amps.
 - ♦ Decrease charge rate if on grid power.
 - ♦ Make sure battery reaches gassing point if liquid type.
 - ♦ Turn charge pot down below 70% of max to disengage sync FETS to aid charging.

Generator Requirements

The maximum charge rate of the battery charger is dependent upon the peak AC voltage available. Since the battery charger uses only the top portion of the input sine wave, small variations in peak voltage result in large variations in the amount of energy to the charger*. This charger's output is rated on the basis of public power input which has a peak voltage of 164V (230V AC power has a peak voltage of 330).

It takes a powerful AC generator set to maintain the full 164 volt peak while delivering the current necessary to operate the charger at its maximum rate (typically 5KW for 12 volt models and 2.5KW for 24 volt models). Smaller generators will have the tops of their waveform clipped under such loads. Running at these reduced peak voltages will not harm the charger, but it will limit the maximum charge rate. Large auxiliary AC loads may exacerbate this problem.

Peak Voltage Available vs. Charge Rate Amps

PEAK VOLTAGE AVAILABLE	DR1512	DR2412	DR1524	DR2424	DR3624
170 VOLTS	70Amps	120Amps	35Amps	70Amps	70Amps
160 VOLTS	35Amps	60Amps	17.5Amps	35Amps	35Amps
145 VOLTS	15Amps	25Amps	7Amps	15Amps	15Amps

Table 3, Peak Voltage vs. Charge Rate Amps

Generator Examples: Typical Maximum Charge Rate Amps

Table 4, Maximum Charge Rate with some Typical Generator Models

GENERATOR TYPE	INVERTER TYPE	TYPICAL MAX CHARGE RATE AMPS
Honda 800	Trace DR1512	43 Amps
Honda 2200	Trace DR1512	57 Amps
Homelite 2500	Trace DR1512	11 Amps
Honda 3500	Trace DR1512	39 Amps
Honda 6000	Trace DR1512	70 Amps
Honda 1600	Trace DR1524	25 Amps
Westerbeke 7.0KW	Trace DR1512	About 45 Amps
Westerbeke 12.5KW	Trace DR1512	About 65 Amps
Generac	To be determined	To be determined

*This characteristic is due to the fact that the battery charger's DC output is the dividend of the transformer turns ratio. In example, if a transformer has a 10:1 turns ratio, a 164 volt AC input voltage shows up as approximately 16.4 volts at the low DC side of the charger after rectification and filtering (164/10), 140 volts AC becomes approximately 14.0 volts DC, etc. Any peak AC voltage below about 130 volt AC is pretty much useless for charging as it only provides roughly 13.0 volts DC.

Batteries

Batteries come in different sizes, types, amp hours, voltages and chemistries. There are nearly as many descriptions of exactly how batteries should be charged as there are people willing to offer explanations. It is not possible here to discuss all aspects in detail. However, there are basic guidelines you can follow that will help in battery selection and ensure that your batteries are better maintained than the majority.

Note: The battery manufacturer is the final authority as to the care and application of any battery.

Battery Terminology

A description of battery types and care requires the use of terms with which you may not be familiar. The following terms will be referred to in the description of battery types, care, and connection.

- **Electrolyte-** Typically a mixture of water and sulfuric acid, it is commonly referred to as battery acid.
- **Plates-** Originally made of lead, they are now made of lead oxide. Plates are the part of the battery that collect current and are connected to the battery terminals. There are several plates in each cell, each insulated from the other by separators.
- **Sulfating -** As a battery discharges, its plates are progressively covered with lead sulfate. During recharging, the lead sulfate is removed from the plates and recombined with the electrolyte. If the lead sulfate remains on the plates for an extended period of time (over two months), it hardens, and recharging will not remove it. This reduces effective plate area and the battery capacity is diminished.
- **Stratification -** Over time the batteries' electrolyte (liquid) tends to separate. The electrolyte at the top of the battery becomes watery while at the bottom it becomes more acidic. This effect is corrosive to the plates and reduces battery life.
- **Deep Cycle -** A deep cycle occurs when a battery has been discharged such that less than 20% of its capacity remains (80% discharge).
- **Temperature Compensation -** The optimum full charge voltage is temperature dependent. As temperature decreases the proper voltage for each charge stage needs to be increased. The optional temperature probe will automatically re-scale charge voltage settings for ambient temperature. The compensation slope based on cell voltage is -2.17mv per degree F. per cell. This also decreases the charge voltage when the battery is hot to reduce gassing.

Selection of Battery Type

Starting Batteries

These are designed for high cranking power, but not deep cycling. Don't use them. It does not hurt the inverter - they simply will not last long in a deep cycle application. The way they are rated should give a good indication of their intended use. - "Cold Cranking Amps", a measure of the amperage output that can be sustained for 30 seconds. Starting batteries use a lot of thin plates to maximize the surface area of the battery. This allows very high starting current but lets the plates warp when the battery is cycled.

Telephone Company Batteries

Second-hand telephone company batteries are often available at far below original cost. They are often used to power the telephone system for short power outages. They are sometimes used successfully in remote home systems. Typically, they are a lead calcium type battery, similar in

construction to a starting battery. Therefore, they should not be repeatedly discharged more than 20% of their amp-hr rating. Keep this in mind when evaluating their amp/hr to cost ratio.

Deep Cycle Batteries

This is the type of battery best suited for use with inverters. They are designed to have the majority of their capacity used before being recharged. They are available in many sizes and types. The most common type is the non-sealed, liquid electrolyte battery. Non-sealed types have battery caps. The caps should be removed periodically to check the level of electrolyte. When a cell is low, distilled water should be added. The electrolyte level should be checked monthly and **distilled water** added if needed after recharging.

The most common deep cycle battery is the type used with boats and motor homes. They typically are called "Group 27" batteries and are similar in size to a large truck battery. They are 12 volt batteries rated at 80 to 100 amp-hours (20 hour rating). Often the deep cycle claim is over-stated. They do work better than a car battery, but are not recommended for anything but the smallest systems.

Another popular and inexpensive battery of this type is the "golf cart" battery. It is a 6 volt battery rated at 220 amp-hours. They can be cycled repeated to 80% of their capacity without being damaged. This is the minimum quality of battery that should be used with DR series inverter applications.

Many systems use the L16 type of battery. These are 6 volt batteries rated at 350 amp-hours and are available from a number of manufacturers. They are 17 inches in height and weigh up to 130 pounds each - which may be troublesome in some applications such as RV or marine installations.

Type 8D batteries are available with either cranking or deep cycle construction. The deep cycle versions are 12 volt batteries rated at around 200 amp hours. Since they are most commonly used to start truck engines, you should make sure you purchase the deep cycle version.

Sealed Gel Cell

Another type of battery construction is the sealed gel cell. They don't have battery caps. The electrolyte is in the form of a gel rather than a liquid which allows the batteries to be mounted in any position without spilling. The advantages are no maintenance, long life (800 cycles claimed) and low self discharge. The disadvantage is high initial cost and the possibility of damage from overcharging.

While there are many manufacturers of quality non-sealed batteries, there are only a few manufacturers of suitable gel cells. Don't confuse sealed batteries with maintenance free batteries - the latter is typically a standard liquid electrolyte type battery without caps for adding water - when the electrolyte gets low you replace the battery.

AGM (absorbed glass mat) batteries are similar to gel cells and may be used in inverter applications.

NiCad and Nickel Iron (NiFe)

Trace inverters and battery chargers are optimized for use with lead acid batteries which have a nominal voltage of 2.0 volts per cell. NiCad/NiFe batteries (also called alkaline batteries) have a nominal cell voltage of 1.2 volts per cell. The nominal voltage of a NiCad/NiFe battery bank can be made the same as a lead acid bank just by juggling the number of cells (10 cells for 12 volts, 20 cells for 24 volts and 40 cells for 48 volt systems) However, the NiCad/NiFe battery bank must be charged to a higher voltage to fully recharge and will drop to a lower voltage during discharging compared to a similarly sized lead acid type battery. This makes the job for the inverter/charger much more difficult.

One way to use NiCad/NiFe batteries with a 24 volt DR series inverter is to use nineteen NiCad/NiFe cells in the battery bank instead of the usual twenty. This will reduce the battery bank charging voltage requirements to about the same level as a lead-acid bank, so more standard charger settings can be used. The problem with this approach is that the battery voltage will drop

as low as 18 volts to fully discharge the battery. When nineteen cells are used set the **BATTERY TYPE SELECTOR** to position #2.

Battery Sizing

Batteries are the inverter's fuel tank. The larger the batteries, the longer the inverter can operate before recharging is necessary. An undersized battery bank results in reduced battery life and disappointing system performance.

Batteries should not be regularly discharged to more than 50% of their capacity. Under extreme conditions (such as a severe storm or a long utility outage) cycling to a discharge level of 80% is acceptable. Totally discharging a battery may result in permanent damage and reduced life.

For stand-alone applications, it is common to size a battery to provide between 3 and 5 days worth of storage before the battery requires recharging. The power contribution from other charging sources is not included in this calculation to duplicate the conditions present during a cloudy or windless period. This is often referred to as the "number of days of autonomy". If the system is a hybrid system with daily generator run periods, then the battery size may be smaller. During cloudy periods the generator would be expected to run longer.

Utility back up applications often have very small batteries. The minimum battery capacity recommended is 200 amp-hours @ 12vdc and 100 amp-hours @ 24 vdc.

Estimating Battery Requirements

In order to determine the proper battery bank size, it is necessary to compute the number of amp-hours that will be used between charging cycles. When the required amp-hours are known, size the batteries at approximately twice this amount. Doubling the expected amp-hour usage ensures that the batteries will not be overly discharged and extends battery life. To compute total amp-hours usage, the amp-hour requirements of each appliance that is to be used is determined and then added together.

You can compute your battery requirements using the nameplate rating of your appliances. The critical formula is **WATTS = VOLTS X AMPS**. Divide the wattage of your load by the battery voltage to determine the amperage the load will draw from the batteries.

If the AC current is known, then the battery amperage will be:

$$\frac{\text{AC Current} \times \text{AC Voltage}}{\text{Battery Voltage}} = \text{DC amps}$$

Multiply the amperage by the number of hours the load will operate and you have, reasonably enough, amp-hours.

Motors are normally marked with their running current rather than their starting current. Starting current may be 3 to 6 times running current. Manufacturer literature may provide more accurate information compared to the motor nameplate. If large motors will be started, increase the battery size to allow for the high demand start-ups require.

Follow this procedure for each item you want to use with the inverter. Add the resulting amp-hour requirements for each load to arrive at a total requirement. The minimum properly sized battery bank will be approximately double this amount. This will allow the battery to be cycled only 50% on a regular basis.

Battery Care and Maintenance

If you have read the battery charger section of this manual, you already have a good idea of the stages of battery charging that combine to promote fast charging and ensure long battery life. Basically, there are five charger related considerations to properly care for your batteries.

- **Charge Rate** - The maximum safe charge rate is related to the size and type of your batteries. Standard vented lead acid batteries (with battery caps) should be charged at 20% of their capacity (capacity/5). Small batteries may require a lower charge rate. **Check with the battery manufacturer.**
- **Bulk Voltage** - This is the maximum voltage the batteries reach during the normal charging process. Gel cell batteries are usually set to a lower voltage, while non-sealed batteries are set to a higher voltage.
- **Float Voltage** - The batteries experience less gassing if they are maintained at a lower voltage than the voltage at which they are charged. This voltage is called the float voltage.
- **Temperature Compensation:** Temperature affects the optimum voltage values for the bulk and float charging stages. The optional temperature probe automatically fine tunes these voltages for you (Trace part number **BTS** and **BTS/35ft**).
- **Equalization (Non-Sealed Batteries Only)** - Every month or two batteries may need to be "equalized." (A fancy term for over-charged.) Since the individual battery cells are not exactly identical, some may still have sulfate on their plates after a complete charge cycle. Or, if the batteries never received a full charge, all plates will have sulfate left on them. If the sulfate remains on the plates for an extended period of time, it will harden and seal off a percentage of the plate area, reducing the capacity of the battery. By equalizing the batteries, all the sulfate is removed from the plates. Additionally, the gassing that results stirs up the electrolyte which tends to stratify. Stratification concentrates the sulfuric acid in the bottom of the cell while the top becomes watery. This corrodes the plates. Equalization is accomplished by charging batteries above a voltage of 2.5 VDC per cell. This is over 15 VDC for a 12 VDC system, 30 for a 24 VDC system and 60 for a 48 VDC system.

CAUTION: Equalization should be done only with standard electrolyte batteries. If you have sealed or gel cell batteries, check first with the battery manufacturer before equalizing. **DC loads should be disconnected before equalization to protect appliances from damage by the high battery voltage involved.**

Monthly Maintenance

At the minimum, check the level of the electrolyte in each battery cell once a month after the batteries have been charged, not before. It should be about 1/2" above the top of the plates, but not completely full. Most batteries have a plastic cup which the electrolyte should just touch when full. Don't overfill the batteries or the electrolyte will spill out of the batteries during charging. Only refill the batteries with distilled water - "spring" water and regular tap water may have high mineral levels which can poison the battery chemistry and reduce battery life.

Check the battery interconnections for tightness and corrosion. If any corrosion is found, disconnect the cables and carefully clean with a mild solution of baking soda and water. **DO NOT ALLOW THE SOLUTION TO ENTER THE BATTERY.** Rinse the top of the battery with clean water when finished (Replace the caps first).

To reduce the amount of corrosion on the battery terminals, coat them with a thin layer of petroleum jelly or anti-corrosion grease available from automotive parts stores or battery suppliers. Do not apply any material between the terminal and the cable lugs - the connection should be metal to metal. Apply the protective material after the bolts have been tightened.

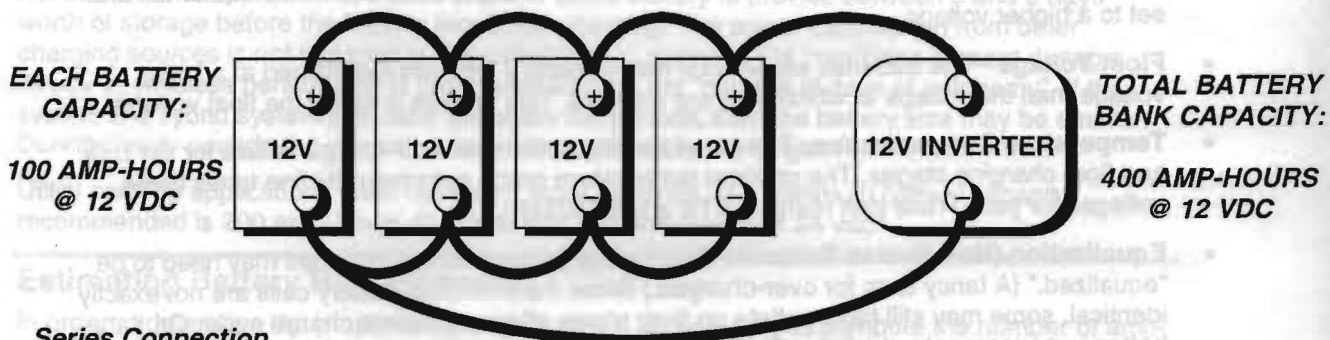
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POSITION
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Battery Hook-up Configurations

Battery banks of substantial size are generally created by connecting several smaller batteries together. There are three ways to do this. Batteries can be connected in parallel, series, or series - parallel.

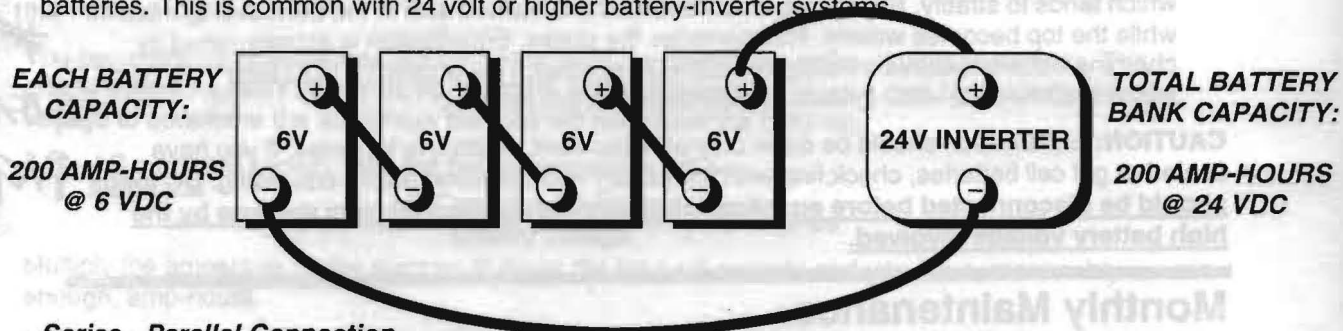
Parallel Connection

Batteries are connected in parallel when all the positive terminals of a group of batteries are connected and then, separately, all the negative terminals are connected. In a parallel configuration, the battery bank has the same voltage as a **single** battery, and an amp/hour rating equal to the **sum** of the individual batteries. This is usually only done with 12 volt battery-inverter systems.



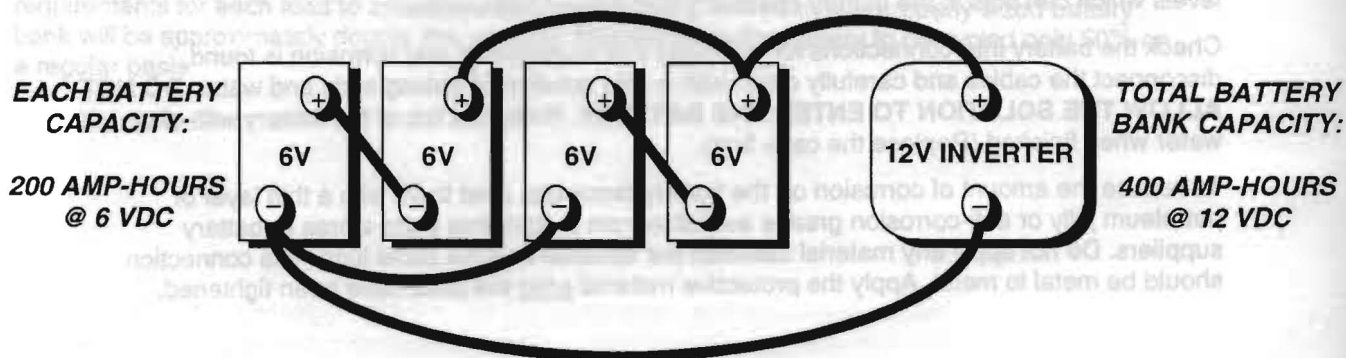
Series Connection

When batteries are connected with the positive terminal of one to the negative terminal of the next, they are connected in series. In a series configuration, the battery bank has the same amp/hour rating as a **single** battery, and an overall voltage equal to the **sum** of the individual batteries. This is common with 24 volt or higher battery-inverter systems.



Series - Parallel Connection

As the name implies, both of the above techniques are used in combination. The result is an increase in **both** the voltage and the capacity of the total battery bank. This is done very often to make a larger, higher voltage battery bank out of several smaller, lower voltage batteries. This is common with all battery-inverter system voltages.



Battery Installation

CAUTION: Batteries can produce extremely high currents if they are short circuited. Be very careful when working around them. Read the important safety instructions at the start of this manual and the battery suppliers precautions before installing the inverter and batteries.

Battery Location

Batteries should be located in an accessible location with nothing restricting the access to the battery caps and terminals. At least 2 feet of clearance above is recommended. They must be located as close as possible to the inverter, but can not limit the access to the inverter and the inverter's disconnect. With the DR series inverter, the batteries are best located to the left end. This is where the DC connections are located. Do not locate the inverter in the same compartment with non-sealed batteries (sealed batteries are all right). The gasses produced by these batteries during charging are very corrosive and will shorten the life of the inverter.

Battery to inverter cabling should be only as long as required. For 12 VDC systems, do not exceed 5 feet (one way) if 4/0 AWG cables are used. For 24 VDC systems, do not exceed 10 feet (one way) if 4/0 AWG cables are used.

Battery Enclosures

The batteries must be protected inside of a ventilated, lockable enclosure or room to prevent access by untrained personnel. The enclosure should be ventilated to the outdoors from the highest point to prevent accumulation of hydrogen gasses released in the battery charging process. An air intake should also be provided at a low point in the enclosure to allow air to enter the enclosure to promote good ventilation. For most systems, a 1 inch diameter vent pipe from the top of the enclosure is adequate to prevent accumulation of hydrogen. A sloped top can help direct the hydrogen to the vent location and prevent pockets of hydrogen from occurring. The enclosure should also be capable of holding at least one battery cell worth of electrolyte in case a spill or leak occurs. It should be made of acid resistant material or have an acid resistant finish applied to resist the corrosion from spilled electrolyte and fumes released. If the batteries are located outside, the enclosure should be rainproof and include mesh screens over any openings to prevent insects and rodents from entering. Before placing the batteries in the enclosure, cover the bottom of the enclosure with a layer of baking soda to neutralize any acid which might be spilled in the future.

Battery Temperature

The effective capacity of a battery is reduced when cold. This phenomenon is more significant with lead acid type batteries compared to alkaline types. When the internal temperature of a lead acid battery is 32°F (0°C) the capacity can be reduced by as much as 50%. This effectively reduces the size of the system's "gas tank", requiring more frequent "refueling" by the back-up source (usually a generator). This should be considered when designing the system. If extremely cold temperatures are expected at the location of a system, either a heated equipment room or alkaline batteries should be considered.

If the system is located in an unheated space, an insulated enclosure is highly recommended for the batteries. During the charging process, the batteries release heat due to the internal resistance of the battery. If the batteries are insulated, the heat can help keep the batteries warmer. This will substantially increase the performance of the system.

Insulated battery enclosures also ensure that the temperatures of the individual battery cells are more consistent, preventing unequal charging which can cause battery failure (some cells will be overcharged while others are undercharged).

The batteries should also be protected from high temperature as well. This can be caused by high ambient temperatures, solar heating of the battery enclosure, or heat released by a closely located generator. High battery temperatures will result in short battery life and should be avoided by ventilating the enclosure and reducing the external heat sources by shading and insulation.

Battery Cabling

The cables which connect the individual batteries together to make a larger battery bank should be connected together with heavy cables. The actual size of the cable depends upon whether the batteries are connected in parallel or series. Generally, the cables should not be smaller than the main battery cables to the inverter. If the main cables are 4/0 AWG, the battery interconnects should be 4/0 AWG.

It is usually preferable to first connect the batteries in series and then in parallel when connecting smaller batteries together. The best configuration is to connect the batteries both in series and parallel a configuration often called "cross-tying". This requires additional cables but reduces imbalances in the battery and can improve the overall performance. Consult your battery supplier for more information regarding the hook-up configuration required for your system.

EACH BATTERY

CAPACITY:

100 AMP-HOURS
@ 12 VDC

EACH BATTERY

CAPACITY:

200 AMP-HOURS
@ 6 VDC

EACH BATTERY

CAPACITY:

200 AMP-HOURS
@ 6 VDC

BATTERY BANK CAPACITY:

400 AMP-HOURS
@ 6 VDC

Installation

Environment

Inverters are sophisticated electronic devices and should be treated accordingly. When selecting the operating environment for the inverter, don't think of it in the same terms as other equipment that works with it, e.g. batteries, diesel generators, motor generators, washing machines etc. It is a highly complex microprocessor controlled device. Genetically speaking, it is a cousin to stereo equipment, television sets, and computers. The use of conformal coated circuit boards, plated copper bus bars, powder coated metal components, and stainless steel fasteners improves tolerance to hostile environments. However, in a condensing environment (one in which humidity and/or temperature change cause water to form on components) all the ingredients for electrolysis are present - water, electricity and metals. In a condensing environment the life expectancy of the inverter is indeterminate and the warranty is voided.

Caution: It is in your best interests to install the inverter in a dry, protected location away from sources of high temperature and moisture. Exposure to saltwater is particularly destructive and potentially hazardous.

Locate the inverter as close to the batteries as possible in order to keep the battery cables short. However, do not locate the inverter in the same compartment as non-sealed batteries (okay with sealed batteries). Batteries generate hydrogen sulfide gas which is very corrosive to electronic equipment - and everything else. They also generate hydrogen and oxygen. If accumulated, this mixture could be ignited by an arc caused by the connecting of battery cables or the switching of a relay.

Do not mount the inverter in a closed container. To operate at high power for sustained periods of time, unrestricted air flow is required. Without it, the protection circuitry will activate and reduce the maximum power available.

UL standard 1741 (photovoltaic installations) requires that the inverter be mounted on a vertical surface (on a wall) and that more than just the keyhole slots be used for mounting. The purpose of this requirement is to orient the inverter so that its bottom cover has no holes that would allow burning material to be ejected in the event of an internal fire.

System Grounding

System grounding is often misunderstood even by system designers and electricians. The subject is more easily discussed if it is divided into three separate subjects. The grounding requirements vary by country and application. Consult local codes and the NEC for specific requirements.

Equipment or Chassis Grounds

This is the simplest part of grounding. The idea is to connect the metallic chassis of the various enclosures together to have them at the same voltage level. This reduces the potential for electric shock. It also provides a path for fault currents to flow through to blow fuses or trip circuit breakers. The size of the connecting conductors should be coordinated with the size of the overcurrent devices involved. Under some circumstances, the conduit and enclosures themselves will provide the current paths.

Grounding Electrodes / Ground Rods

The purpose of the grounding electrode (often called a ground rod) is to "bleed" off any electrical charge that may accumulate in the electrical system and to provide a path for "induced electromagnetic energy" or lightning to be dissipated. The size for the conductor to the grounding electrode or grounding system is usually based on the size of the largest conductor in the system. Most systems use a 5/8" (16 mm) copper plated rod 6 feet (2 meters) long driven into the earth as a grounding electrode. It is also common to use copper wire placed in the concrete foundation of the building as a grounding system. Either method may be acceptable, but the local code will prevail. Connection to the ground electrode should be done with special clamps located above ground where they can be periodically inspected.

It is often desirable to use multiple ground rods in a larger system or systems. The most common example is providing a direct path from the solar array to earth near the location of the solar array. Most electrical codes want to see the multiple ground rods connected by a separate wire with its own set of clamps. If this is done, it is a good idea to make the connection with a bare wire located outside of the conduit (if used) in a trench - the run of buried wire may be a better grounding electrode than the ground rods!

Well casings and water pipes can also be used as grounding electrodes. Under no circumstance should a gas pipe or line be used. Consult local codes and the NEC for more information.

Bonding the Grounding System to the Neutral and Negative Conductors

This is the most confusing part of grounding. The idea is to connect one of the current carrying conductors (usually the AC neutral and DC negative) to the grounding system. This connection is why we call one of the wires "neutral" in the North American type electrical systems. You can touch this wire and the grounding system and not be shocked. When the other ungrounded conductor (the hot or positive) touches the grounding system, current will flow through it to the point of connection to the grounded conductor and back to the source. This will cause the overcurrent protection to stop the flow of current, protecting the system. The point of connection between the grounding system and the current carrying conductor is often called a "bond". It is usually located in the overcurrent protection devices enclosure. Although it can be done at the inverter, codes do not generally allow it since the inverter is considered a "serviceable" item which may be removed from the system. In residential systems it is located at the service entrance panel, after the power has gone through the kilowatt-hour meter of the utility.

In some countries, the neutral is not bonded to the grounding system. This means you may not know when a fault has occurred since the overcurrent device will not trip unless a "double" fault occurs. In some marine electrical codes this type of system is used.

Bonding must be done at only one point in an electrical system. Our systems inherently have two separate electric systems - a DC system and a AC system. This means that two bonding points will occur in all inverter applications. The bonding point will also be connected to the chassis ground conductors. It is common to have two separate conductors connect the ground electrode and the two bonding points. Each conductor should use a separate clamp.

AC Wiring

Overview

The National Electrical Code (NEC) defines the standards for AC and DC installation wiring in residential, commercial, and RV applications, but there are still many installation variables. Most are determined by the level of automatic switching desired and the amount of external AC power to be switched.

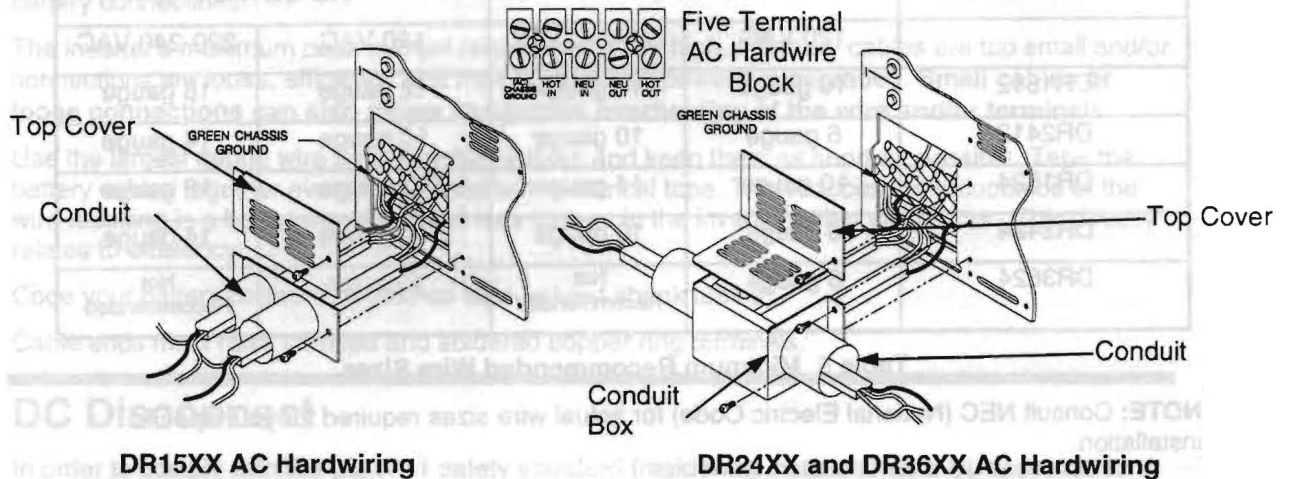


Figure 5, DR Series AC Hardwiring

AC Connections

Installation should be done by a qualified electrician. Consult local code for the proper wire sizes, connectors and conduit requirements.

On the right end of the chassis is the AC hardwire cover or conduit box (dependent on the inverter's power level). A five station terminal block is provided to make the AC connections. The terminal block is used to hardwire the AC input, AC output, and AC safety ground. Table 5 gives suggestions for wire sizing. Code requires that an external disconnect switch be used in the AC input wiring circuit. The AC breakers in a sub panel will meet this requirement.

Step 1 - Disconnect the inverter from the battery either by turning off the battery disconnect or removing the battery cables from the battery. Turning of the inverter power button does not constitute disconnecting from the battery.

Step 2 - Feed the wires through appropriate conduit and through the bottom part of the AC cover. In certain installations, conduit fittings may be replaced with strain reliefs, consult local and national codes. (**Note:** The U.S. requires use of conduit in this installation, consult the NEC. See **Figure 5**.)

Step 3 - Following the wiring guide located in the AC wiring compartment **Figure 5**, connect the safety(green), hot(black), and neutral (white) wires from the AC input (utility, generator, etc) to the terminal block and torque 10-15 **inch-pounds**. **Caution!!** Be sure the AC source is disconnected before attempting to hardwire it to the inverter.

Step 4 - Connect the AC output wiring to the inverter terminal marked AC hot out following the color coding marked on the wiring guide inside the compartment. Connect the AC neutral out to the inverter's AC neutral out terminal and to the AC sub-panel serving the AC loads. Torque the

wires into the terminal block, 10-15 **inch-pounds**. The AC input and output neutrals should be isolated from one another in the subpanel, since they are already tied together in the inverter.

Step 5 - Replace the bottom half of the cover and then the top half. Use the two 6-32 screws and lock washers to secure the covers.

Minimum Recommended Wire Sizes

MODEL	AC INPUT		AC OUTPUT	
	120 VAC	220-240 VAC	120 VAC	220-240 VAC
DR1512	10 gauge	14 gauge	12 gauge	16 gauge
DR2412	6 gauge	10 gauge	10 gauge	14 gauge
DR1524	10 gauge	14 gauge	12 gauge	16 gauge
DR2424	6 gauge	10 gauge	10 gauge	14 gauge
DR3624	6 gauge	Not Recommended	8 gauge	Not Recommended

Table 5, Minimum Recommended Wire Sizes

NOTE: Consult NEC (National Electric Code) for actual wire sizes required for your specific installation.

Important Precautions

The output side of the inverter's AC wiring should at no time be connected to public power or a generator. This condition is far worse than a short circuit. If the unit survives this condition, it will shut down until corrections are made.

Installation should ensure that the inverter's AC output is, at no time, connected to its AC input.

Review the installation diagrams included before you start making connections.

Ground Fault Interrupting Outlets (GFI's)

Trace Engineering has tested the following GFI's and found them to work satisfactorily with our inverters:

LEVITON 6599

PASS & SEYMOR 1591RI 4A957

ACE Hardware ACE 33238 and 33236

DC Wiring

Safety Instructions

THIS INVERTER IS NOT REVERSE POLARITY PROTECTED!! If the positive terminal of the battery is connected to the negative terminal of the inverter and vice versa, the probable result is failure of every power FET. To compound your misfortune, this type of failure is very obvious, and **is not covered under the warranty**, so pay close attention and double-check when making the battery connections.

The inverter's maximum peak current requirements are high. If battery cables are too small and/or connections are loose, efficiency and maximum output power are degraded. **Small cables or loose connections can also cause dangerous overheating of the wire and/or terminals.**

Use the largest gauge wire for the battery cables and keep them as short as possible. Tape the battery cables together every few inches with electrical tape. This reduces the inductance of the wire resulting in a better waveform and less current in the inverter's filter capacitors. This directly relates to efficiency.

Code your battery cables with colored tape or heat shrink tubing.

Cable ends must have crimped and soldered copper ring terminals.

DC Disconnect

In order to comply with the UL 1741 safety standard (residential installations) a UL approved form of battery disconnect is required. These installation parts are not supplied by Trace Engineering as part of the inverter.

Trace Engineering offers a DC rated disconnect designed specifically for the DR series inverters. This disconnect is available in 175 amp (Trace #DC175) or 250 amp (Trace #DC250) size with single or dual pole breakers. See the options section at the end of this manual or the latest Trace Engineering price list for more information.

DC Fusing

The National Electric Code requires that the cables be protected by a fuse or breaker rated to match the cables ampacity at 75 degrees Celsius. Rounding up to the next fuse size is allowed.

Locate the fuse as close as possible to the battery without it being in the battery enclosure. (Unless sealed batteries are used.)

Table 6, Fuse or Breaker Size Required vs. Cable Size

Cable Size	Rating in Conduit	Fuse Size(Amps) (Trace Part #)	Rating in Free Air	Fuse Size (Amps) (Trace Part #)
#2 AWG	115 amps max	TFB110	170 amps max	TFB200
00 AWG	175 amps max	TFB200	265 amps max	TFB300
0000 AWG	250 amps max	TFB300	360 amps max	TFB400

Note: The term in free air is defined by the NEC as not encased in conduit or raceway.

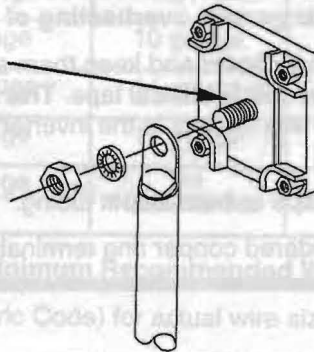
WARNING!! Battery cables that are very small will melt and burn the first time the inverter is asked to produce high power.

Trace offers a class "T" DC rated fuse block designed specifically for DR series inverter/chargers. These are available in 110, 200, 300, and 400 Amp sizes. See the Trace price list or contact your Trace Engineering dealer for more information. (Fuseblocks are Trace part number TFB###. ### is size in amps of required fuse, i.e. TFB400 is a Trace fuseblock with 400 amp class T fuse. Replacement fuses are also available.)

Battery Cable Connection

Observe Battery Polarity! Place the ring terminal over the bolt and directly against the inverter's battery terminal. Tighten the 5/16" nut to 10-15 foot/pounds. **Do not place anything between the flat part of the inverter terminal and the battery cable ring terminal or overheating may occur. DO NOT APPLY ANY TYPE OF ANTI-OXIDANT PASTE TO TERMINALS UNTIL AFTER THE BATTERY CABLE WIRING IS TORQUED!!**

Caution!! Do NOT place anything between battery cable ring terminals and terminals on the inverter. The terminal stud is not designed to carry current. Apply Anti-oxidant paste to terminals AFTER terminals have been torqued.



Verify that cable lugs are flush with the inverter battery terminals. Tighten battery cables to terminals, 10-15 foot-pounds.

Note: Connecting the battery cables to the inverter DC terminals will cause an arc, usually accompanied by a "snap". This is normal don't let it scare you.

Never disconnect the battery cables while the inverter is delivering power or battery charger is operating. Always turn the unit off first.

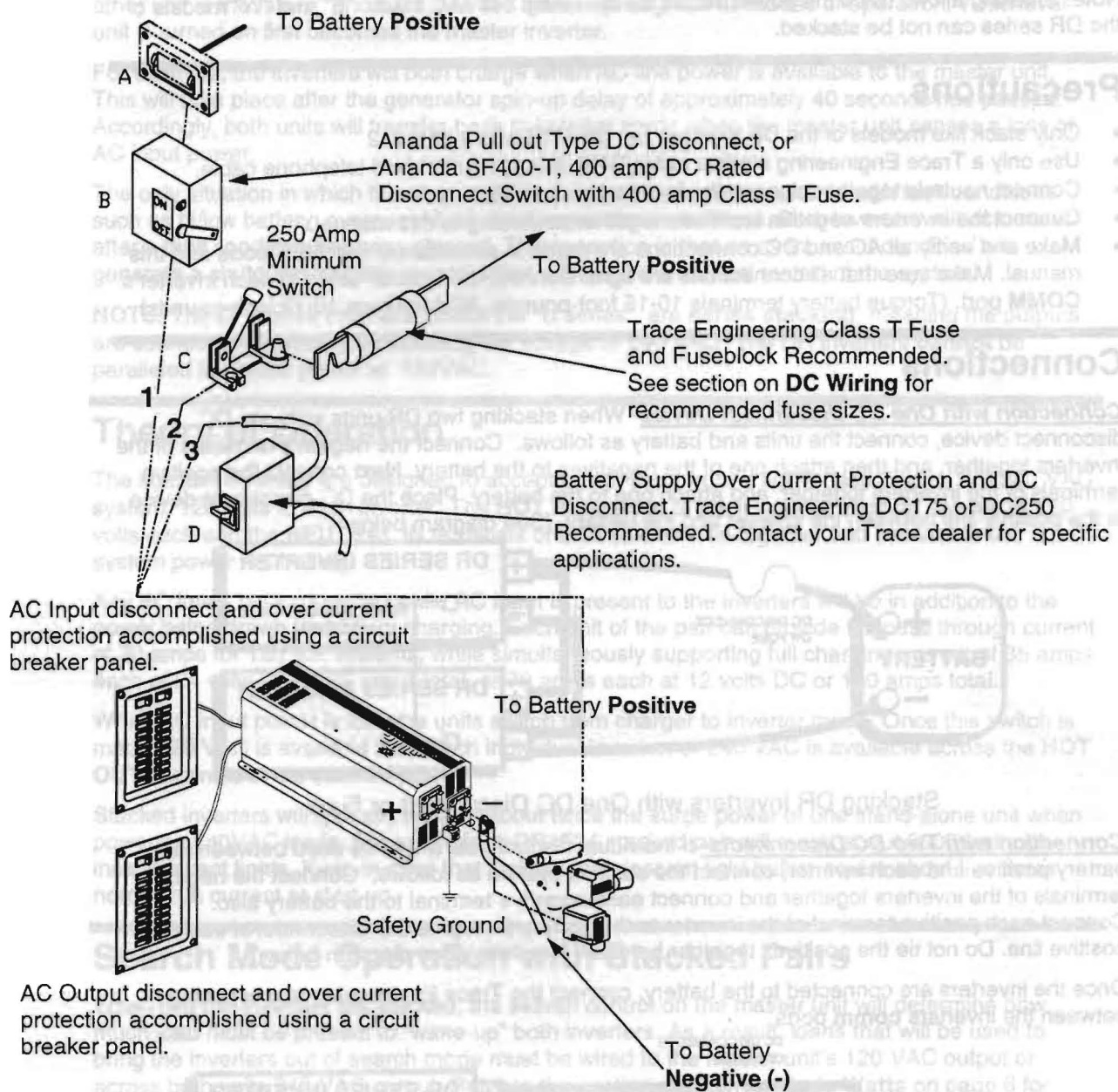
Battery Cable Sizing

The bigger the battery cables the better. Undersized cables result in additional stress on the inverter, lower efficiency, reduced surge power and lower peak output voltage. Don't use cables that are too small in diameter and degrade the efficiency that we have worked so hard to achieve and you have paid to own. The following table gives recommended **minimum** cable sizes for various cable run lengths and inverter voltages.

Table 7, Minimum Recommended Battery Cable Size

Model	Typical Amps	Cable length (one-way)		
		Under 5 ft	5 to 10 ft	10 to 20 ft
DR1512	150 AMPS	#2	00	00
DR2412	240 AMPS	0000	0000	0000
DR1524	75 AMPS	#2	#2	00
DR2424	120 AMPS	#2	#2	00
DR3624	180 AMPS	00	00	0000

System Safety Wiring Requirements



Note: The above UL required safety parts are not supplied by Trace Engineering. High quality Trace Engineering DC disconnects, covered class T fuses, and battery cables are available from your Trace dealer. Other items may be obtained by calling or faxing:

INDUSTRIAL CONTROLS SUPPLY COMPANY
22410 70 AVE WEST, UNIT #6
MOUNTLAKE TERRACE, WASHINGTON, USA 98043
Phone: 1-800-756-2356 or 1-206-771-6344, FAX: 1-206-775-8901

Stacking Inverters

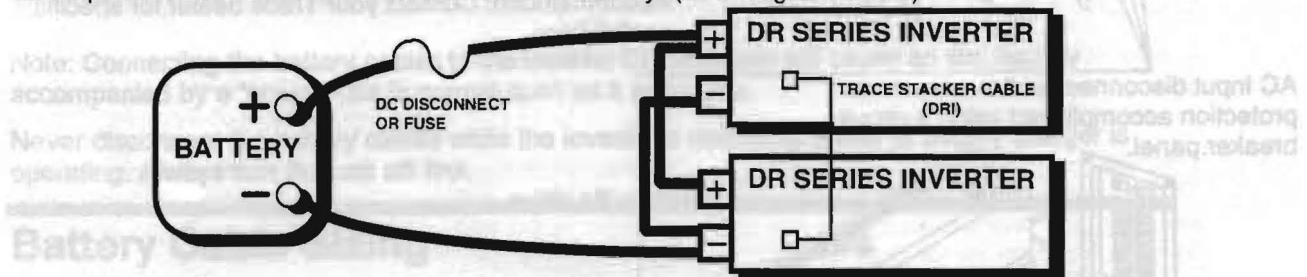
Note: Stacking allows twice the power output for operating 240VAC loads. "E" and "W" models of the DR series can not be stacked.

Precautions

- Only stack like models of the DR inverter. i.e. DR1512 with a DR1512
- Use only a Trace Engineering stacker cable(DRI). It is not a standard telephone cable.
- Connect neutrals together close to the inverters
- Connect the inverters negative terminals together according to this manual.
- Make and verify all AC and DC connections are made in accordance with NEC code and this manual. Make sure that all connections are tight. Connect the stacker cable to each inverter's **COMM** port. (Torque battery terminals 10-15 foot-pounds, AC terminals 10-12 inch-pounds)

Connections

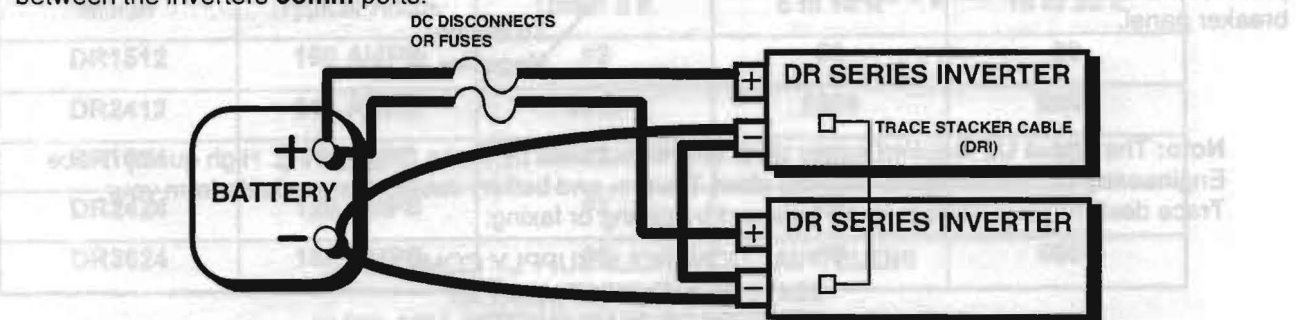
Connection with One DC Disconnect Device- When stacking two DR units with one DC disconnect device, connect the units and battery as follows. Connect the negative terminals of the inverters together, and then attach one of the negatives to the battery. Next connect the positive terminals of the inverters together, and attach one to the battery. Place the DC disconnect device in the positive line between the inverter and the battery. (See diagram below)



Stacking DR Inverters with One DC Disconnect or Fuse

Connection with Two DC Disconnects- If individual disconnects are to be used between the battery positive and each inverter, connect the stacked system as follows: Connect the negative terminals of the inverters together and connect each negative terminal to the battery also. Connect each positive terminal of the inverter to the battery through a DC disconnect in each positive line. Do not tie the positives together between inverters. (See diagram below)

Once the inverters are connected to the battery, connect the Trace Engineering stacker cable between the inverters **comm** ports.



Stacking DR Inverters with Two DC Disconnects or Fuses

Operation

The power switch of one unit turns both inverters on and off, this unit becomes the "master". The other unit is the "slave" and will follow the master throughout its modes of operation. Whichever unit is turned on first becomes the master inverter.

For example, the inverters will both charge when AC line power is available to the master unit. This will take place after the generator spin-up delay of approximately 40 seconds has passed. Accordingly, both units will transfer back to inverter mode when the master unit senses a loss of AC input power.

The only situation in which the slave may shut down the master inverter is with fault conditions such as hi/low battery, overcurrent, or overtemperature conditions. Both inverters will auto reset after a fault condition has been cleared. The exception is that an overcurrent condition will generate a shutdown for both inverters that will require a manual restart of the system.

NOTE: The DR series inverters, unlike the "U series", are **series stacking**, meaning the outputs are connected in series thus doubling the voltage to 240 VAC. The DR inverters **cannot** be paralleled to double power at 120VAC.

Theory of Operation

The stacked inverters are designed to accept power input from a split-phase, 3 wire 120/240 VAC system, 120 volts to each inverter. The **HOT IN** terminal of each inverter accepts one leg of 120 volts each and the **NEUTRAL IN** terminals of both inverters tie together and connect to the system power neutral leg.

Any AC loads being powered while AC input is present to the inverters will be in addition to the power being drawn for battery charging. Each unit of the pair can provide full pass through current of 30 amps for 120 volt systems, while simultaneously supporting full charging current of 35 amps each at 24 volts DC or 70 amps total, or 70 amps each at 12 volts DC or 140 amps total.

When AC input power is lost, the units switch from charger to inverter mode. Once this switch is made 120 VAC is available from each individual inverter, or 240 VAC is available across the **HOT OUT** terminals of the stacked pair.

Stacked inverters will typically support about twice the surge power of one stand-alone unit when powering 240VAC loads. For example, a DR1524 stacked pair will surge about 9000 watts of incandescent lights. Keep in mind that typical incandescent light bulbs require about five times normal run current at start up.

Search Mode Operation with Stacked Pairs

When two DR inverters are stacked, the search control on the master unit will determine how much load must be present to "wake-up" both inverters. As a result, loads that will be used to bring the inverters out of search mode must be wired to the master unit's 120 VAC output or across both units 240 VAC output. Refer to the section on **Search Mode Watts** on page 6 for operation of the search mode control.

RC4 Remote Control

The optional RC4 remote control unit duplicates the power On/Off Switch on The DR series inverter/charger, and gives several LED indications.

The on/off switch is a momentary switch. Pressing it alternately turns the unit on and off.

The LED indicator on the RC4 will show the following conditions:

- **On/Off-** When the inverter is off the light is off. A solid LED means the unit is on.
- **Search Mode-** When the inverter is in the search mode the LED will flash at a rate of two times per second.
- **Charge Mode-** When the unit is in the charge mode, the LED will flash at a rate of five to six times per second.
- **Error Mode-** When the inverter experiences high or low battery voltage, over temp, or overload conditions, the LED will flash rapidly.

In order for the inverter to recognize the RC4, the unit must be turned on with the RC4 connected.

Parts List

Before installing the RC4 remote, confirm that you received the following items:

- RC4 remote on/off switch with 50 feet of six conductor wire attached to a standard telephone plug.
- Black face plate (1.6" x 3.0")
- Two stainless steel Phillips head screws.

If any items are missing contact your Trace dealer for parts.

Installation

Using the face plate as a template, drill 1/16 inch holes for the mounting screws. The switch will require at least a 15/16 inch hole behind the face plate. Next route the cable through the face plate, then to the inverter. The last step is to attach the switch to the face plate by pressing it into place.

Plug the RC4's cable into the **COMM** port on the inverter and the unit is ready for use.

Note: The RC4 cannot be used with a stacked pair of inverters.



Installation Diagrams

A. Installation with Single AC Panel

In all installations it is important to ensure that AC power from any source (generator, public power) is never fed to the inverter's AC output. It is essential that the inverter's AC output is not fed to its AC input. The diagram below is simple and meets these requirements. However, there are two precautions to keep in mind:

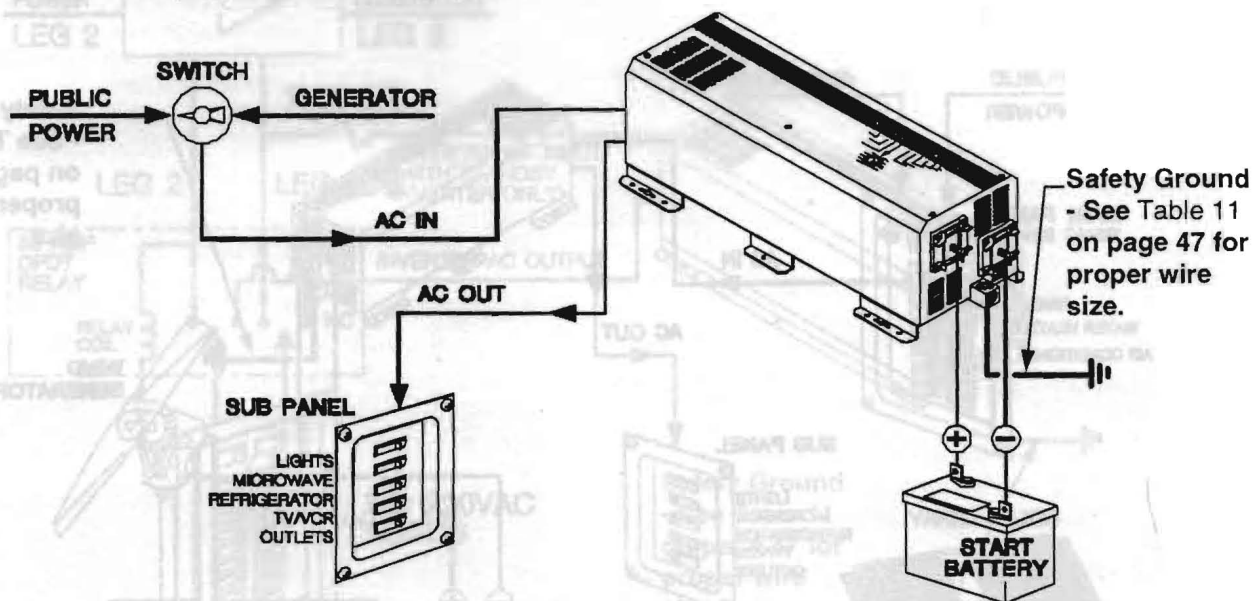


Figure 6, Installation with a Single AC Panel

- 1) With only one AC panel encompassing **all** loads, the inverter could be connected to loads which are greater than it can run.
- 2) The maximum system current is limited by the inverter's AC input breakers. One breaker provides 30 amps of pass through current, the other supplies the charger.

The above configuration is acceptable, but not recommended Diagram "B" is preferable because it isolates the inverter from inappropriate loads.

Caution!! Do not use this system if there are 220 VAC loads on the system.

B. Installation with AC Sub Panel

This is the recommended configuration for installing an inverter with the built-in battery charger. It operates in the following manner: When there is power available at the main panel, the inverter's automatic transfer relay closes, connecting the main panel to the sub-panel. When there is no AC present at the main panel, the relay opens and the sub-panel is fed AC power generated by the inverter.

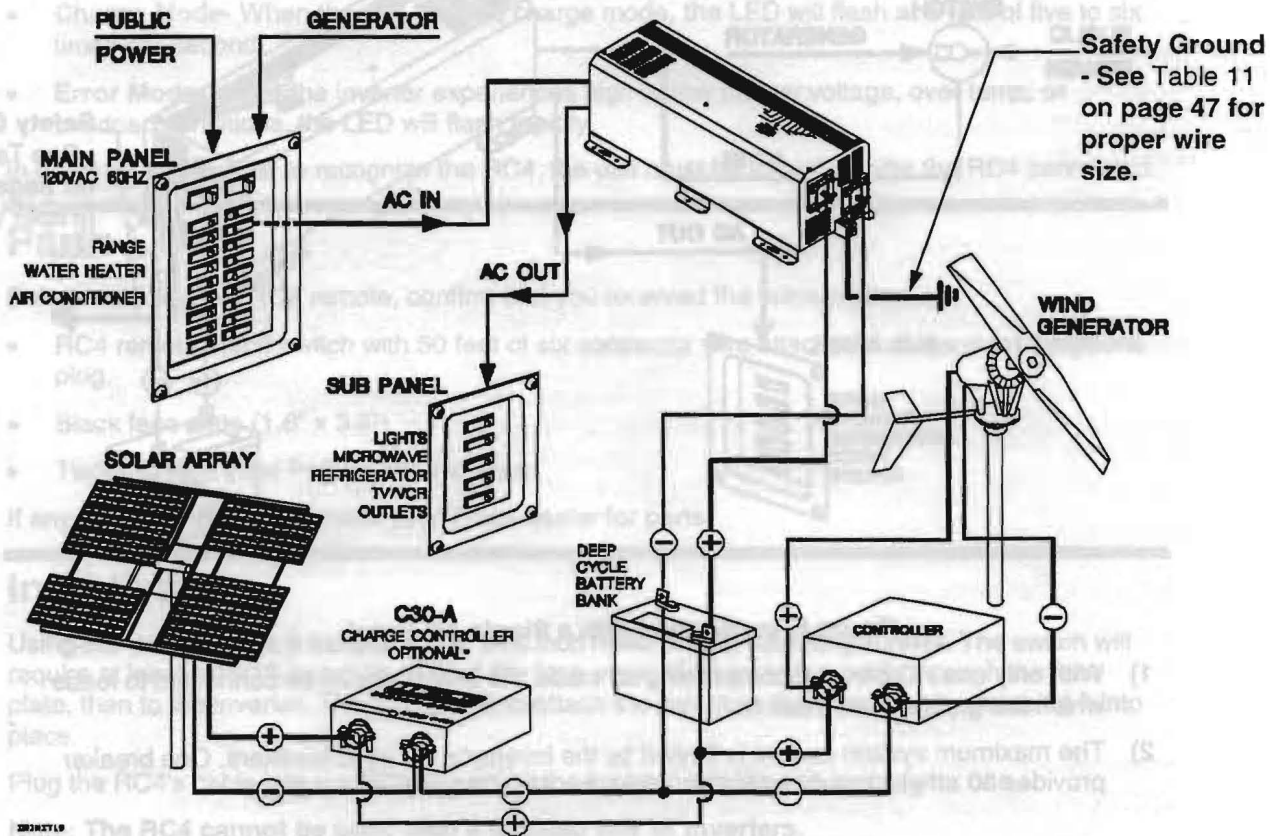


Figure 7, Installation with an AC Sub Panel

This installation automatically ensures that public or generator AC power is never routed to the output of the inverter. The inverter's AC output cannot be fed to its input. Additionally, the inverter will only be connected to appropriately sized loads that are dedicated to the sub-panel.

C. Installation with External Relay

This configuration may be desirable when the pass through current is greater than 30 amps.

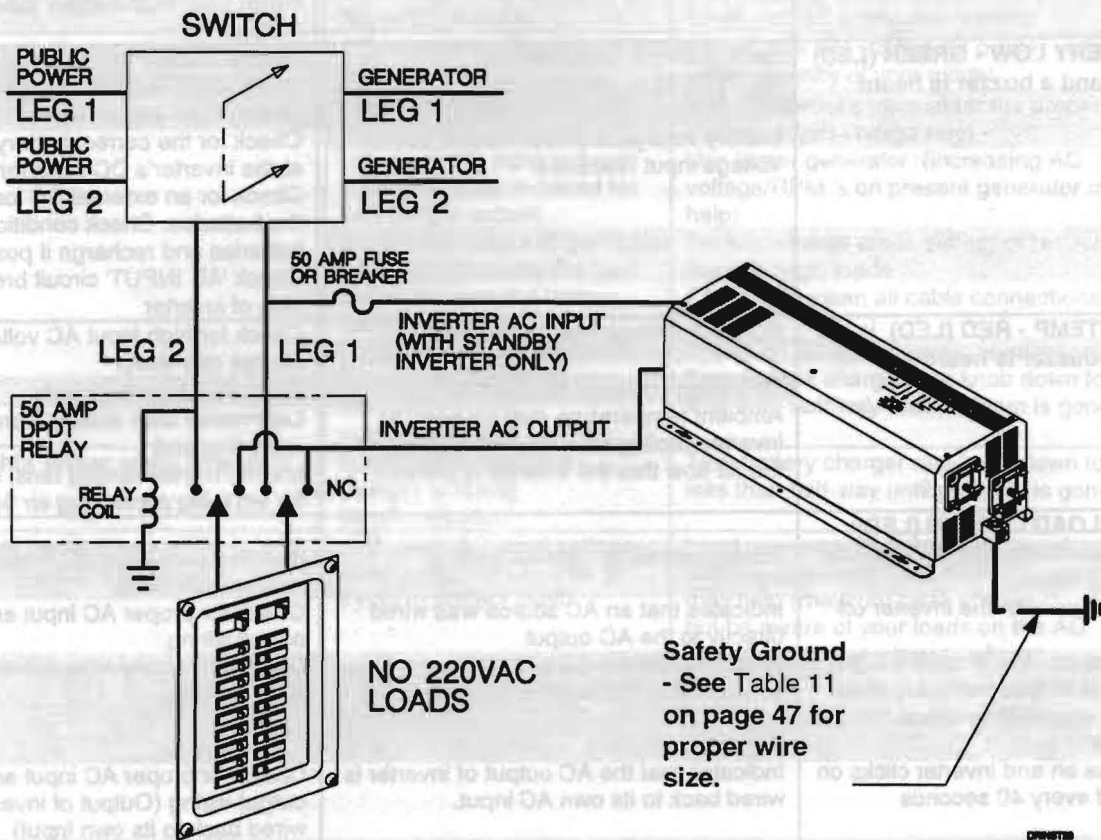


Figure 8, Installation with External Relay

When the AC panel is being run by the generator, leg 1 and leg 2 of the generator are connected independently to the two halves of the AC panel. When the inverter is operating, both sides of the AC panel are automatically connected together.

Caution!! Do not use this system if there are 220 VAC loads on the system.

Troubleshooting Guide

BATTERY HI - RED (LED) is on and a buzzer is heard	Battery voltage is above the high battery voltage input tolerance.	Check for the correct battery voltage at the inverter's DC input terminals. Ensure your DC source is regulated below your High battery cut-out voltage.
BATTERY LOW - GREEN (LED) is on and a buzzer is heard	Battery OVER-DISCHARGE PROTECTION circuit is on Battery voltage is below the low battery voltage input tolerance.	Charge battery or disable your OVER-DISCHARGE PROTECTION setting (turn adjustment to OFF). Check for the correct battery voltage at the inverter's DC input terminals. Check for an external DC load on the batteries. Check condition of batteries and recharge if possible. Check 'AC INPUT' circuit breaker on side of inverter
OVERTEMP - RED (LED) is on and a buzzer is heard	AC input voltage may be too high Operating too large of a load for too long. Ambient temperature may be high or inverter cooling fans may have failed or the air flow thru the inverter is blocked	Check for high input AC voltage, turn charge rate down Remove excessive loads. Let inverter cool down before restarting and check inverter cooling fans, or check for anything preventing air flow
OVERLOAD - GREEN (LED): - comes on after the inverter was running loads - comes on with the inverter off - comes on after flickering 5-10 seconds of loud humming when an AC source is connected to the inverter - comes on and inverter clicks on and off every 40 seconds - comes on while charging	Excessive load on the AC output Indicates that an AC source was wired directly to the AC output Indicates that the AC source was connected to the inverter AC output. Indicates that the AC output of inverter is wired back to its own AC input. Charger circuit may be damaged	Remove excessive AC loads and restart the inverter Check for proper AC input and output wiring. Check for proper AC input and output wiring. Check for proper AC input and output wiring (Output of inverter wired back to its own input) Have inverter/charger serviced
INVERTER MODE (LED): - is on and no power output. - is flashing and no power output.	Good AC voltage on inverter AC terminal block. No AC voltage on inverter AC terminal block. Load too small for the search mode circuit to detect	Check for open AC output breakers or fuses and AC wiring connections Have unit serviced Reduce search mode watts setting, increase your AC load or defeat search mode setting.
No power output and no warning LED's are on.	Battery voltage at the inverters terminals is too high or low	Check the battery voltage, fuses or breakers and cable connections
Power output is low and inverter turns loads on and off	Low battery	Check condition of batteries and recharge if possible.
Power output is low	Loose or corroded battery connections Loose AC output connections	Check and clean all connections Check all AC output connections
Surge power is low	Weak batteries, battery cables too small or too long	Refer to cable and battery recommendations in owner's manual
AC output voltage is low	Measuring AC output with the wrong type of voltmeter. Your meter displays 80 - 100VAC (USA units) with no loads running. AC voltage on the output measured with a True RMS voltmeter is low.	Must use a True RMS reading meter (most meters are <u>average reading</u> not <u>True RMS reading</u>) Have unit serviced

CHARGER LED: - indicates charging, but no charge is occurring to the batteries - is on, but no output power	Circuit breaker on side of inverter is open No AC voltage on inverter AC terminal block. Good AC voltage on inverter AC terminal block.	Engage 'AC INPUT' circuit breaker on side of unit Check 'AC PASS-THRU' circuit breaker on side of inverter Check for open AC output breakers or fuses and AC wiring connections
Charger is inoperative or giving a low charge rate	AC voltage has dropped out-of-tolerance Charger controls improperly set (check charge rate) Low peak AC input voltage (164 volts peak required for full charger output) AC current output of generator too small to handle the load Loose or corroded battery cable connections. Loose AC output connections Generator is unstable - charger is losing synchronization	Check your AC voltage for proper voltage and frequency of your model. Refer to owner's manual for the proper setting (adjust charge rate) Use larger generator (increasing AC voltage/RPM 's on present generator may help) Reduce charge amps setting or reduce pass through loads Check and clean all cable connections Check all AC output wiring connections Turn battery charger rate knob down to less than half-way until problem is gone
AC lights flicker while charging	Generator is unstable - charger is losing synchronization	Turn battery charger rate knob down to less than half-way until problem is gone
Charger turns down while charging from a generator	High peak AC input voltage from generator (inverter is trying to protect itself).	Load generator down with a heavy load. Turning generator output voltage down may help (may turn peak voltage down, but be aware of your loads on the AC output running at a lower voltage)

Applications

Resistive Loads

These are the loads that the inverter finds the simplest and most efficient to drive. Voltage and current are in phase, or in step with one another. Resistive loads usually generate heat in order to accomplish their tasks. Toasters, coffee pots and incandescent lights are typical resistive loads. Larger resistive loads—such as electric stoves and water heaters—are usually impractical to run from an inverter. Even if the inverter could accommodate the load, the size of battery bank required would be impractical.

Inductive Loads

Any device that has a coil of wire in it probably has an inductive load characteristic. Most electronics have transformers (TV's, stereos, etc.) and are therefore inductive. Typically, the most inductive loads are motors. The most difficult load for the inverter to drive will be the largest motor you manage to start. With inductive loads, the rise in voltage applied to the load is not accompanied by a simultaneous rise in current. The current is delayed. The length of the delay is a measure of inductance. The current makes up for its slow start by continuing to flow after the inverter stops delivering a voltage signal. How the inverter handles current that is delivered to it while it is essentially "turned off", affects its efficiency and "friendliness" with inductive loads. The best place for this out of phase current is in the load, and Trace's "impulse phase correction" circuitry routes it there.

Inductive loads, by their nature, require more current to operate than a resistive load of the same wattage rating, regardless of whether power is being supplied by an inverter, a generator or grid.

Induction motors (motors without brushes) require 2 to 6 times their running current on start-up. The most demanding are those that start under load, e.g., compressors and pumps. Of the capacitor start motors, typical in drill presses, band saws, etc., the largest you may expect to run is ½ to 1 hp. Universal motors are generally easier to start. Since motor characteristics vary, only testing will determine if a specific load can be started and how long it can be run.

If a motor fails to start within a few seconds, or it begins to lose power after running for a time, it should be turned off. When the inverter attempts to start a load that is greater than it can handle, it will turn itself off after about 10 seconds.

Submersible Well Pumps

The well pump is often the hardest load to start for inverter system. Submersible pump motors are particularly hard because the motor is very narrow (in order to fit down the well) and draws extremely high starting current.

When selecting a pump, check the **LOCKED ROTOR AMPS** in the motor specifications. This is usually the best guide to the maximum load the pump will place on the inverter. It must be less than the **Max. AC Current** listed in the specifications at the end of this manual. Pump suppliers and well drillers often oversize the pump considerably in order to reduce complaints of poor pressure, low flow, etc. Get several quotations and explain that you are very concerned about the inverter being able to power the pump. It makes sense to operate a smaller pump longer instead of a larger pump for a shorter period of time when you are powering it from batteries or a solar electric system.

When buying a pump, select a three wire type. This refers to the electrical configuration of the power and starting windings in the pump motor. A three wire pump requires a separate box at the top of the well for the starting circuit - a two wire pump has the start electronics built inside. The separate starting box is preferred. If possible, select a relay type starting box instead of an all electronic type - the relay types have been found to work better with inverters and generators.

The relay type also allow use of a larger or additional starting capacitor - it may help if the inverter has a hard time starting the pump. Consult your pump supplier for more information.

If a 220/240 vac motor is required, you must either use two 120 vac inverters in a stacked configuration or include a step-up transformer in the system. When used with a well pump, connect the step-up transformer after the pressure switch in order to reduce the load the transformer itself puts on the inverter. This requires that 120 vac instead of 240 vac be connected to the pressure switch.

As a last resort, consider powering the well pump directly from the generator instead of the inverter. Many systems do not have enough battery capacity or excess power to handle a load as heavy as a well pump. Using the generator with a storage tank with several days capacity may be more economical than oversizing the inverter, battery and solar array just to power the well pump.

Problem Loads

Trace Engineering's modified sine wave inverters can drive nearly every type of load. However, there are special situations in which loads may behave differently with the inverter than with public power (this may include not working at all). Keep in mind that any loads that Trace has tested and noted as working well, have been noted from our own experience or customer reports. Due to the wide variety of load types and internal changes made to these loads by the manufacturer, Trace cannot be responsible for any loads that fail in your application, including those loads Trace has had success with. We provide this list of experiences simply as a reference and not as a guarantee of a particular products performance.

Very small loads: - If the power consumed by a device is less than the threshold of the search mode circuitry, it will not run. See the section on search mode operation for ways to solve this problem.

Fluorescent lights & power supplies- Some devices when scanned by the load sensor cannot be detected. Small fluorescent lights are the most common example. (Try altering the plug polarity-turn the plug over). Some computers and sophisticated electronics have power supplies that do not present a load until line voltage is available. When this occurs, each unit waits for the other to begin. To drive these loads either a small companion load must be used to bring the inverter out of its search mode, or the inverter may be programmed to remain at full output voltage. See the section search mode operation.

Microwave ovens - Microwave ovens are sensitive to peak output voltage. The higher the voltage, the faster they cook. Inverter peak output voltage is dependent on battery voltage and load size. The high power demanded by a full sized microwave will drop the peak voltage several volts due to internal losses. Therefore, the time needed to cook food will be increased if battery voltage is low. Trace has had reports of some microwave models not operating at all from a modified square wave form. As a result we recommend you try before you buy!

Clocks - The inverter's crystal controlled oscillator keeps the frequency accurate to within a few seconds a day. However, external loads in the system may alter the inverter's output waveform causing clocks to run at different speeds. This may result in periods during which clocks keep time and then mysteriously do not. Most clocks do not draw enough power to trigger the load sensing circuit. In order to operate without other loads present, the load sensing will have to be defeated. (See section on Search Mode Control.)

Searching - If the amount of power a load draws decreases after it turns on, and if this "on" load is less than the load sensing threshold, it will be turned alternately on and off by the inverter.

Ceiling Fans - Most large diameter, slow turning fans run correctly, but generate more noise than they would connected to public power. The high speed type fans operate normally.

Dimmer Switches - Most dimmer switches lose their ability to dim the lights and operate either fully on or off. Trace has had excellent success with a Leviton slide dimmer switch p/n 6621

(600W 120Vac). It is microprocessor controlled and does not utilize switching methods incompatible with modified sinewave output inverters.

Rechargeable Devices - Sears "First Alert™" flashlights fail when charged by the inverter. "Skil™" rechargeable products are questionable. Makita™ products work well. A new (as of January 1997) Black and Decker™ Dustbuster™ and Spotlighter™ tested OK. When first using a rechargeable device, monitor its temperature for 10 minutes to ensure that it does not become abnormally hot. Excessive heat will be your indicator that it should not be used with the inverter.

Laser Printers - While many laser products are presently operating from TRACE ENGINEERING inverters, and we have personally run a Texas Instruments Microlaser™ and HP IIP™, we have had reports of an HP III™ and a Macintosh™ Laser Writer™ failing under inverter power. We, therefore, do not recommend the use of laser printers.

Computer Printers- Trace has found that Hewlett-Packard™ Inkjet printers work well from the modified square waveform.

Electronics- AM radios will pick up noise, especially on the lower half of their band. Inexpensive tape recorders are likely to pick up a buzz. Large loads should not be started while a computer is operating off the inverter. If a load is large enough to require “soft starting” it will “crash” the computer.

Cell Phones- Some cellular telephone users have reported interference from modified square wave inverters. This interference is sometimes in the form of a clicking sound.

Low Battery Dropout - The inverter will turn off to protect itself if your battery bank cannot deliver the necessary amperage to drive a particular load without falling below the low voltage protection point for three seconds. With the inverter off, the battery voltage will rise and then it will resume operation.

Technical Information

DR Series Specifications

MODEL	DR1512	DR2412	DR1524	DR2424	DR3624
Continuous Power @ 20°C	1500 VA	2400 VA	1500 VA	2400 VA	3600 VA
Efficiency	94% max	94% max	94% max	95% max	95% max
Input Current					
Search Mode	0.045 amps	0.055 amps	0.030 amps	0.030 amps	0.030 amps
Full Voltage	0.700 amps	0.900 amps	0.350 amps	0.450 amps	0.500 amps
Rated Power	165 amps	280 amps	80 amps	140 amps	210 amps
Short Circuit	400 amps	800 amps	280 amps	560 amps	720 amps
Nominal Input Voltage	12 vdc	12 vdc	24 vdc	24 vdc	24 vdc
Input Voltage Range	10.8-15.5 vdc	10.8-15.5 vdc	21.6-31 vdc	21.6-31 vdc	21.6-31 vdc
Auto Low Battery Protection	11v or defeated	11v or defeated	22v or defeated	22v or defeated	22v or defeated
Voltage Regulation-Maximum			±5%		
Voltage Regulation- Typical			±2.5%		
Waveform			Modified sine		
Power Factor allowed			0 to 1		
Frequency Regulation			60Hz ± .04%		
"E" models			50Hz ± .04%		
"J" models			50Hz ± .04%		
"K" models			50Hz ± .04%		
Standard Output Voltage			120 vac		
"E" models			230 vac		
"W" models			220 vac		
"J" models			105 vac		
"K" models			105 vac		
Adjustable Load Sensing			5 to 100 Watts		
Series Operation for 240 vac			yes		
"E,W" models			no		
Forced Air Cooling			Variable Speed		
Automatic Transfer Relay			30 amps		
"E" models			20 amps		
"W" models			20 amps		
Adjustable Charge Rate	0-70 amps	0-120 amps	0-35 amps	0-70 amps	0-70
Number of Charging Profiles			10		
Three Stage Charging			yes		
Temperature Comp Probe			Optional		
Remote Control			Optional		
Environmental Characteristics					
Operating Ambient Temp			0°C to +60°C		
Non-operating Temp			-55°C to +75°C		
Altitude Operating			15,000 feet		
Altitude Non-operating			50,000 feet		
Unit Weight	35lbs (16kg)	45lbs (21kg)	35lbs (16kg)	40lbs (19kg)	45lbs
(21kg)					
"E" models	39lbs (18kg)	NA	39lbs (18kg)	45lbs (21kg)	NA
Dimensions			8.5" x 7.25" x 21" / 21.6cm x 18.4cm x 54.6cm		
Mounting			Wall with 16" mounting centers or shelf		

*Specifications subject to change without notice.

Max Regulated Power vs. Battery Voltage

As the battery voltage is reduced, the maximum regulated power the inverter can produce decreases. The inverter regulates RMS voltage by changing the width of its output waveform. The graph below defines the points at which the combination of power and battery voltage results in square wave output. The area above the line represents combinations of voltage and power at which the inverter's output is in regulation. The area below the line shows unregulated operating conditions.

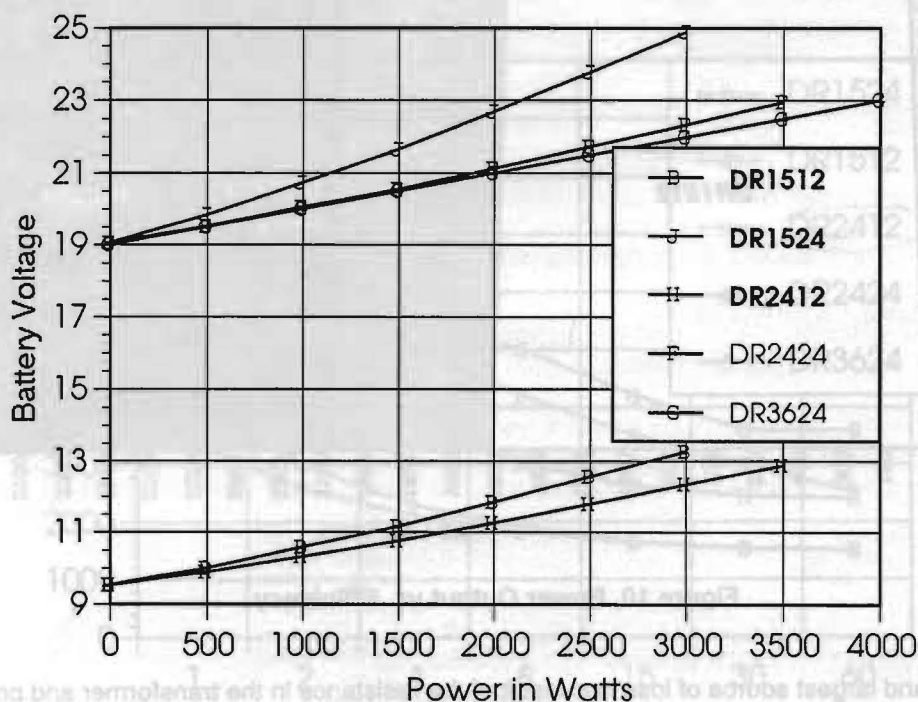


Figure 11, Maximum Regulated Power Output vs. Battery Voltage

AC APPLIANCES OR RHAPSODY		DC AMPS	
HOT WATER	1500 W	12.5 AMPS	140
FREEZER			30
FRIDGE		2.4 "	27
ICE MAKER		2.5 "	28
ALL LAMPS			
COFFEE	900	7.5 "	85
TOASTER	900	7.5 "	85

IN 24 HOURS WITH FRIDGE, FREEZER & ICE RUNNING 1/3 OF TIME

$$DC AMPS = \frac{24(30+27+28)}{3} = \frac{85 \times 24}{3} = 680 \text{ AMP HRS}$$

WITH COFFEE, TOAST, VACUUM, LIGHTS USED AS WELL DC AMPS USED > 700

" 800 AMP TOTAL CAPACITY, SHOULD RECHARGE AFTER APPROX 400 AMP USED

- SAY EVERY 12 HOURS MAX

Typical Battery Draw of Common Appliances

Table 8, Typical Battery Draw of Common Appliances (For 12 Volt Inverters)

APPLIANCE	WATTS	TIME IN MINUTES					
		5	15	30	60	120	240
Single PL Light	10	.1	.3	.7	1.3	2.7	5.3
B & W TV	50	.4	1	2	4	8	17
Computer	100	1	2	4	8	17	34
Color TV	200	2	4	8	17	34	67
Blender	400	3	8	17	34	67	133
Skil Saw	800	6	17	34	67	133	266
Toaster	1000	8	23	46	93	185	370
Microwave	1200	10	28	57	114	227	455
Hot Plate	1800	15	44	88	176	353	706
		AMP HOURS					

If the current draw at 120 VAC is known, then the battery amperage at 12VDC will be 10 times the AC amperage divided by the efficiency (90% in this table).

Motors are normally marked with their running rather than their starting current. Starting current can be 2-6 times running current.

Refrigerators and ice makers typically run about 1/3 of the time. Therefore, their average battery current draw is 1/3 what their amp rating would indicate.

Table 9, Typical Battery Draw of Common Appliances (For 24 Volt Inverters)

APPLIANCE	WATTS	TIME IN MINUTES					
		5	15	30	60	120	240
Single PL Light	10	.06	.2	.3	.7	1.3	2.7
B & W TV	50	.2	.6	1	2	4	8
Computer	100	.4	1	2	4	8	17
Color TV	200	1	2	4	8	17	34
Blender	400	2	4	8	17	34	67
Skil Saw	800	3	8	17	34	67	133
Toaster	1000	4	11	23	46	93	185
Microwave	1200	5	14	28	57	114	227
Hot Plate	1800	8	22	44	88	177	353
		AMP HOURS					

If the current draw at 120 VAC is known, then the battery amperage at 24VDC will be 5 times the AC amperage divided by the efficiency (90% in this table).

Motors are normally marked with their running rather than their starting current. Starting current can be 2-6 times running current.

Refrigerators and ice makers typically run about 1/3 of the time. Therefore, their average battery current draw is 1/3 what their amp rating would indicate.

IN 24 HOURS WITH FRIDGE, TOASTER, TV, LIGHTS, ETC. RUNNING 1/3 OF TIME

$$DC \text{ AMPS} = \frac{24 \times (34 \times 27 + 38) + 25 \times 24}{3} = 880 \text{ AMP HRS}$$

WITH CHARGE, TOAST, TV, LIGHTS, ETC. AS WELL AS AMPS USED 27

200 AMP TOTAL CAPACITY, SHOULD RECHARGE AFTER APPROX 40% USED

- SAY EVERY 12 HOURS MAX

USED

Table 10, English to Metric Wire Conversion Table

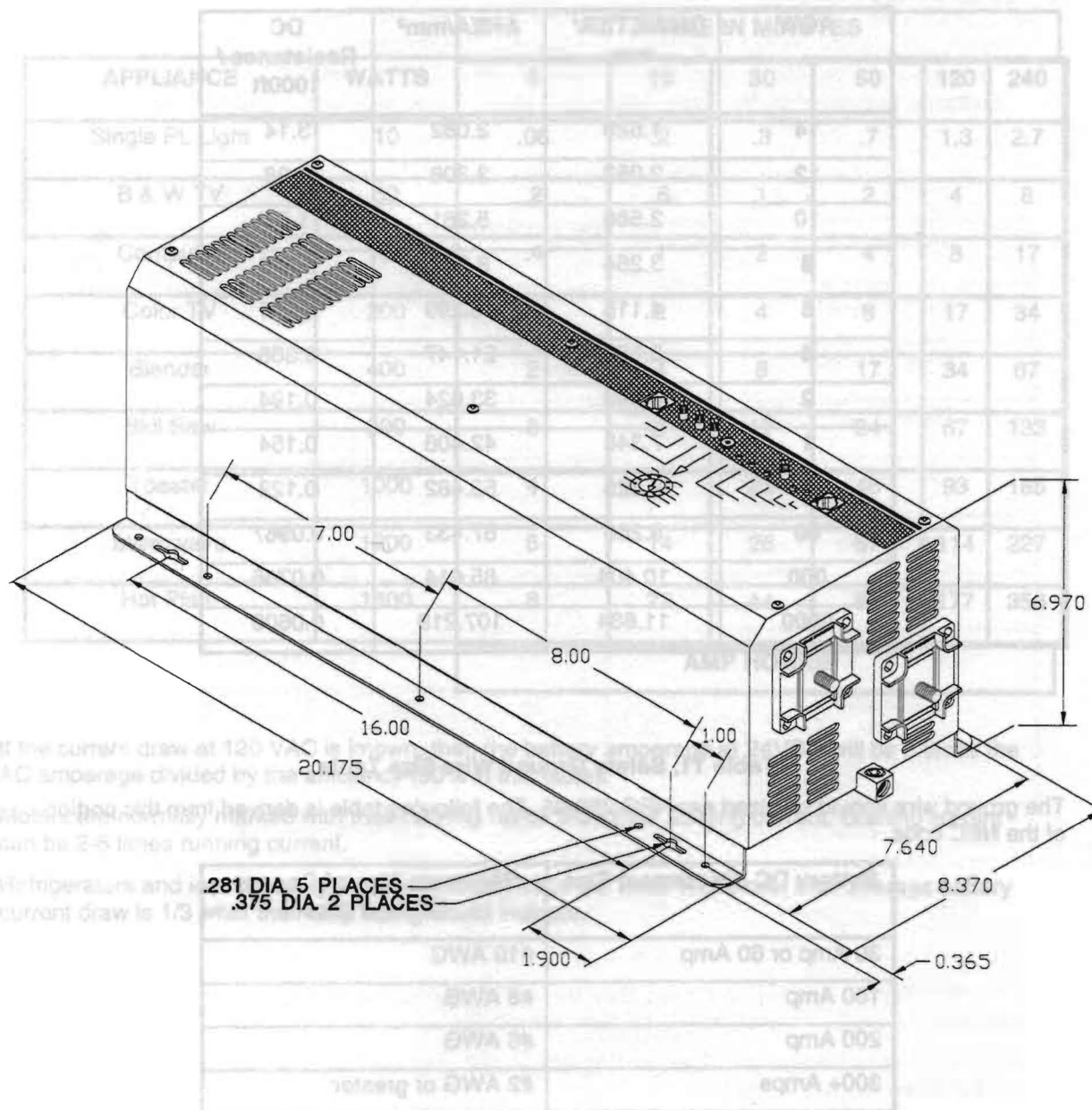
AGW	DIAMETER/ mm	AREA/mm ²	DC Resistance / 1000ft
14	1.628	2.082	3.14
12	2.052	3.308	1.98
10	2.588	5.261	1.24
8	3.264	8.367	0.778
6	4.115	13.299	0.491
4	5.189	21.147	0.308
2	6.543	33.624	0.194
1	7.348	42.406	0.154
0	8.525	53.482	0.122
00	9.266	67.433	0.0967
000	10.404	85.014	0.0766
0000	11.684	107.219	0.0608

Table 11, Safety Ground Wire Size Table

The ground wire should be sized per NEC 250-95. The following table is derived from this portion of the NEC code.

Battery DC Disconnect Size	Minimum Size of Copper Ground Wire
30 Amp or 60 Amp	#10 AWG
100 Amp	#8 AWG
200 Amp	#6 AWG
300+ Amps	#2 AWG or greater

Figure 12, Dimensioned DR Series Installation Drawing



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Tech Note

02/04/97

SUBJECT: RMS Values, Meters, and Measurement

The following is to help alleviate confusion about measurement of RMS (Root Mean Square) values of AC voltage.

RMS, or Root Mean Square, is the measurement used for any time varying signal's effective value: It is not an "Average" voltage and its mathematical relationship to peak voltage varies depending on the type of waveform. By definition **RMS Value**, also called the effective or heating value of AC, is equivalent to a DC voltage that would provide the same amount of heat generation in a resistor as the AC voltage would if applied to that same resistor.

Since an AC signal's voltage rises and falls with time, it takes more AC voltage to produce a given RMS voltage. In other words the grid must produce about 169 volts peak AC which turns out to be 120 volts RMS (.707 x 169). The heating value of the voltage available is equivalent to a 120 volt DC source. (this is for example only! This does not mean DC and AC are interchangeable.).

The typical multi-meter is not a **True RMS** reading meter. As a result it will only produce misleading voltage readings when trying to measure anything other than a DC signal or sine wave. Several types of multi-meters exist, and the owner's manual or the manufacturer should tell you which type you have. Each handles AC signals differently, here are the three basic types.

A **rectifier type** multi-meter indicates RMS values for sinewaves only. It does this by measuring average voltage and multiplying by 1.11 to find RMS. Trying to use this type of meter with any waveform other than a sine wave will result in erroneous RMS readings.

Average reading digital volt meters are just that, they measure average voltage for an AC signal. Using the equations in the next column for a sinewave, average voltage (V_{avg}) can be converted to Volts RMS (V_{rms}), and doing this allows the meter to display an RMS reading for a sinewave.

A **True RMS** meter uses a complex RMS converter to read RMS for any type of AC waveform.

When taking readings with a **non True RMS** reading meter, a 120 Volt RMS sinewave will still measure about 120 volts RMS. This is because the meter uses the mathematical relationships shown below to give a proper RMS reading for a sinewave. However if used with a modified sinewave or square wave these meters will only read about 90-105 volts. Don't be misled, there is nothing wrong with the inverter or the meter, and to prove this try the following test. plug in a normal light bulb and check its brightness. If there is only 90-105 volts RMS available it will look orange as it would during a brown out. If it appears to have normal brightness the voltage is approximately 120VAC RMS.

You can see that improper measurement can easily lead someone to believe that a modified sinewave or square wave inverter is not putting out its rated power. For example, remembering that Power = Volts(90-105) x Amps (33) a 4000 watt inverter (24VDC input) would measure out at about 3000-3500 watts if a proper true RMS reading is not taken.

Normally True RMS reading meters are very expensive, such as the Fluke 87 series meters. However, Radio Shack now offers two models priced under \$90.00. Check with Radio Shack for details and features.

A few handy things to keep in mind about RMS values that apply when dealing with a sine wave, are as follows:

- Peak Volts AC x .707 = V_{rms}
- $V_{rms} = 1.11 \times V_{avg}$
- $1.414 \times V_{rms} = \text{Peak Volts AC}$
- $V_{avg} = .637 \times \text{Peak Volts AC}$

For a modified sinewave or square wave these equations do not apply, and the easiest way to deal with this is to invest in a True RMS reading meter. (For a square wave V_{avg} , V_{rms} , and V_{peak} are all equal.)

Tech Note

02/04/97

Making Sense of Search Sense Mode

Several of Trace Engineering's inverter's incorporate a power saving "Search Sense Mode". The purpose of this is so that the inverter does not have to idle at full output voltage when there are no loads to run.

How does Search Sense Work?

While idling in the search sense mode, the inverter sends out a pulse about once per second. This electrical pulse travel through the AC wiring "looking" for loads that are connected to the system.

When a load is detected, the inverter then has to make a decision as to whether or not the load is large enough to bother with. This decision point is user adjustable via the Search Sensitivity control on the inverter. The sensitivity is given in watts. The lowest setting is usually 5 watts and the highest setting is 100 watts.

For example, if the search sensitivity is set at 40 watts, and no loads are present that are 40 watts or greater the inverter will "ignore" these smaller loads and remain in idle mode. When a load that is greater than 40 watts appears, the inverter recognizes this as time to go to work, and applies power to the load.

The search sense mode is defeatable by setting it to "off" or defeat. In this case the inverter remains at full output voltage at all times, while waiting for loads.

Why do I need search sense?

Search sense allows you to selectively power only items that draw more than a certain amount of power, but the bigger reason lies in power savings. Imagine an inverter that has a no load idle power of 8 watts. This means the inverter needs 8 watts to power itself even if no loads are present.

In example if a water pump is driven by the inverter for only one hour total per day then the other twenty-three hours out of the day the inverter is using 8 watts per hour just to sit there and do nothing. That power comes from the batteries.

You then set the search sense so that the inverter sleeps until the pump wants to run, and the situation we just looked at greatly improves. Now instead of the inverter idling at 8 watts, only ½ watt is drawn while in search mode. This is a savings of 7½ watts per hour or 172.5 watt-hours. This converts directly to 14 amp-hours for a 12 volt battery system.

In systems with small batteries or limited charging capability, this could be a substantial savings.

Why does the search sense act unusually with certain loads?

Unfortunately, not all things in life are perfect and search sense is no exception. Several types of loads can cause problems with search sense mode, either causing the unit to turn on and then off, or not to turn on at all.

Incandescent Lights: These have a higher starting wattage when the filament is cold than the continuous rating of the bulb. For example, if the inverter is set to sense a 40 watt load, and a 30 watt bulb is turned on the inverter will initially sense this since the bulbs cold starting wattage is higher. The bulb will then go off and after a cool down period will come back on, and so on.

Fluorescent Bulbs: These work the opposite of incandescent light bulbs. If the inverter is set to detect a 30 watt load and a 40 watt fluorescent is switched on, the inverter will not detect it. This is because the fluorescent tube is less than 30 watts until the gas in the tube ionizes.

Other loads: There are some appliances which draw power even though they are turned off. TV's with instant on circuits, microwaves with digital clocks, VCR's, and clocks. If the search sensitivity is set higher than the combined loads, then an auxiliary load must be used to bring the inverter out of search mode before the appliances can be turned on. If the sensitivity is set lower than the combination of the loads, the loads will remain on and excess battery drain will occur since the inverter won't ever go to sleep. (3 such 15 watt loads would amount to an additional 90 amp-hours per 24 hours in a

12VDC system). One solution is to turn the item off at the wall, use an extension cord with a rocker switch, a switch at the outlet, or an appropriate circuit breaker.

How to confirm that search sense does work!

A neon-type night light may be used as a remote indicator to show whether the inverter is searching or not. Plug the night light into the wall and if the inverter is in search mode the light will blink, showing the search pulses sent out by the inverter. If the inverter is running a load the light will be solid since continuous power is being delivered to a load. A normal incandescent type night light may also work to show the pulses, however it will use more power.

How do I set up the search mode feature on the inverter?

The search sense feature on the inverter is only valuable if the inverter can spend a fair amount of time "sleeping" each day. Therefore, if search sense is to be utilized it must be adjusted properly. The initial adjustment should be made so that the inverter comes on only when needed.

The sensitivity control should be adjusted so that the smallest load being run can "wake" the inverter up and cause it to deliver power to the load.

If loads change significantly, then re-tuning of the search sensitivity will be required. It may take several adjustments to tweak the sensitivity to just the right point.

If problem loads are in the system such as discussed previously, follow the suggestions given to eliminate the problem. Some TV's with instant on circuits have a menu or control to disable it. If clocks are the problem load, consider using battery powered units.

If the problem loads just can't be eliminated in one of the suggested manners the only choice is to disable the search sense feature, causing the inverter to always remain at full output voltage.



Battery Voltage and Current

Why does the voltage on a discharged battery measure the same as a fully charged battery, until loads are applied?

The simple answer to this might go as follows: A battery creates electrical power by converting energy from a chemical reaction into electrical energy. As this reaction slows down the battery voltage will drop. In a lead acid battery the electrolytes conductivity (how well electrical current can flow through it) changes. The same current may be available but the rate of the reaction decreases, causing a voltage drop.

It is interesting to note that a charged 12 volt lead acid battery at rest (not powering loads and unused for a least 3 hours) will read about 12.6 volts. Hook up a load and the voltage will drop to about 11.9 volts.

Another way of looking at this is to use an analogy of a water pump (a battery is an electric pump). The pressure in PSI a pump delivers is like a battery's voltage. The volume of water in gallons/minute (GPM) is like electrical current. Let's look at a 12 PSI pump with no loads (the pump is running but the outflow valve is turned off). The pump will run and the internal pressure of the pump will build up to some point higher than 12 PSI. Once the valve is opened and the water is free to flow into the loads, the pressure will drop to the rated output pressure of 12 PSI, but only if the load is not too big. If the pump is designed to maintain 12 PSI at 15 GPM, and a load demanding 20 GPM is connected, the pump will not be able to keep up and the pressure will get sucked down to some lower PSI. If the load is then reduced or removed, the pump will catch up and return to it's rated 12 PSI pressure. If the pump has an infinite source of water such as a lake or the water utility (this is like the grid, no battery) the pump will never run out of pressure, and as long as the pump is operated at or below it's 15GPM level it will hold 12 PSI.

However, a pump that is connected to a water tank with a finite capacity, will start to lose the ability to hold pressure as the level of water in the tank drops. Think of siphoning water from a

bucket, as the level of the water drops the volume of water exiting the siphon slows down.

When the tank is full it is capable of feeding more "pressure" to the pump inlet due to gravity, and the pump always has enough water available to maintain its rated pressure and volume. However, if the water tank gets low the pump will not have enough water volume coming in to maintain 12 PSI at 15 GPM. If the loads are taken away from the pump by closing the valve on the outflow, even with low pressure in the tank the pump will eventually pump up to 12 PSI, it will just take it longer to get there. Then when the valve is opened the pump will sustain 12 PSI for a brief while, but since the tank is no longer feeding the pump as fast as needed the pressure will eventually drop. This analogy can be restated by replacing the pump with a battery, pressure with voltage, volume with amps, outflow valve with a switch, water with electricity, and the water tank with the battery electrolyte.

The level of the tank, could be thought of as the rate of the reaction taking place in the electrolyte. When the battery is fully charged the electrolyte has an excess of reactions taking place to feed the battery terminals. This tapers off with time as the electrolyte is spent, so maintaining voltage becomes near impossible. With no loads, the spent electrolyte will be capable of producing near rated voltage but only after a period of time has elapsed for enough reactions to take place to bring the voltage back up. Hopefully this scenario will help make clear why a battery measured at rest can show near its rated voltage but will not run a load.

Measuring battery condition with the battery at rest.

A good estimate of a battery's state of charge can be made by measuring the voltage across the battery terminals with the battery at rest (No

energy input, no energy output) for at least three hours. These readings are best taken in the early morning, at or before sunrise, or in late evening. Take the reading while almost all loads

are off and no charging sources are producing power. Connect a voltmeter across the positive and negative outputs of the battery or battery bank.

The following table will allow conversion of the readings obtained to an estimate of state of

charge. The table is good for batteries at 77°F that have been at rest for 3 hours or more. If the batteries are at a lower temperature you can expect lower voltage readings.

Battery State of Charge Voltage Table

Percent of Full Charge	12 Volt DC System	24 Volt DC System	48 Volts DC System
100%	12.7	25.4	50.8
90%	12.6	25.2	50.4
80%	12.5	25	50
70%	12.3	24.6	49.2
60%	12.2	24.4	48.8
50%	12.1	24.2	48.4
40%	12.0	24	48
30%	11.8	23.6	47.2
20%	11.7	23.4	46.8
10%	11.6	23.2	46.4
0%	<=11.6	<=23.2	<=46.4



Tech Note

02/04/97

Grounding Vs. Lightning

This technote is intended to provide information on basic grounding techniques that will help prevent inverter damage due to lightning. It is not intended to be a complete course on grounding or a guarantee against protection during a lightning strike situation. The NEC is the ultimate authority as to legitimate grounding techniques for your electrical system.

If an electrical system has components grounded at different points in the earth, large voltage differences will exist between these points during a lightning strike (Figure 1). If this voltage appears between the AC and DC side of the inverter it will fail. All Trace inverters are designed to withstand a minimum of 1750 volts between AC and ground, and 500 volts between DC and ground.

One Ground For All Equipment (Figure 2)

The first step in inverter protection is to make sure that all equipment in the system is physically grounded at the same location. This assures that there is no voltage potential between grounds in the system (Fig.1). No voltage means no current flow through the system. Practically speaking, this would mean connecting the generator and battery grounds together, as well as the case or "safety" grounds in the system, and then attaching all to the same earth grounding rod (See the NEC for specific information on grounding requirements, and hardware).

In severe conditions, the generator frame should physically be isolated from the earth by a wood frame or some other insulating means. This assures that the single point ground system is maintained.

Keep Equipment Close Together

All equipment involved in a system should physically be located as close as possible to one another. This reduces the potential that is developed between the ground site and the individual components of the system during a lightning strike. This single point grounding greatly reduces the potential for lightning damage to electrical equipment.

If you are unable to achieve single-point grounding due to large distances between equipment or other variables, other means of lightning protection must be considered. Consult a reputable lightning protection company.

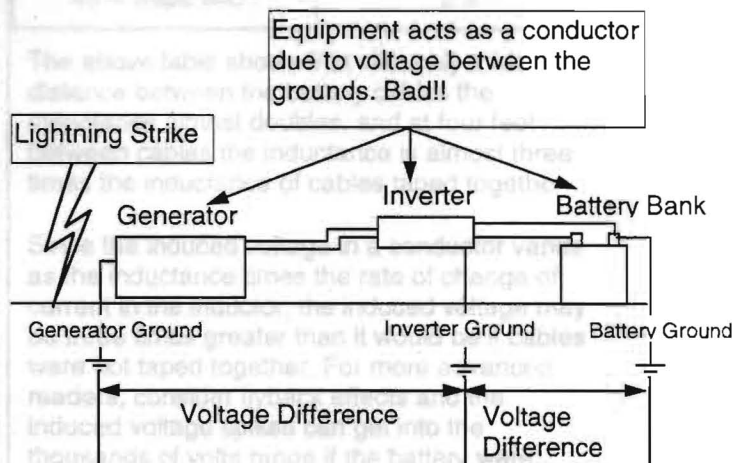


Figure 1- Multiple Point Ground System

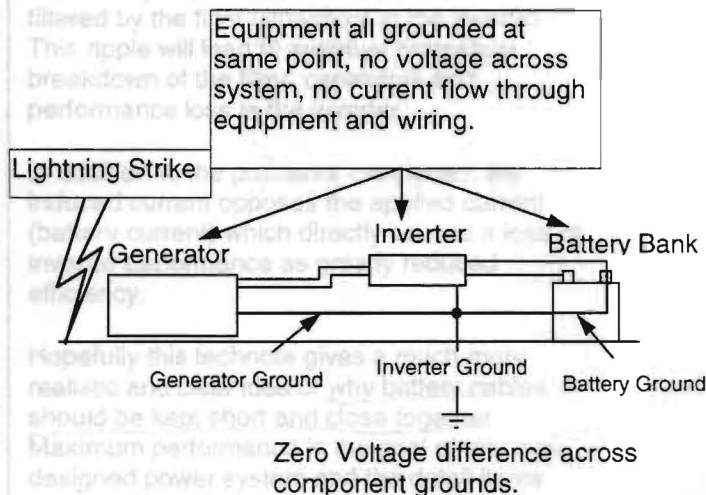


Figure 2- Single Point Ground System

Tech Note

02/04/97

Battery Cable Inductance

What is Inductance?

When current passes through a conductor a magnetic field is set up around the conductor. As this magnetic field builds, it induces voltage in any conductor which is close by, and it induces a voltage in the original conductor. The voltage induced into the original conductor is called self-inductance, and tends to oppose the current which produced it.

The magnitude of the self-induced voltage is proportional to the size of the loop formed by a wire. The larger the loop, the larger the self-induced voltage. The positive and negative battery cables in a system are in reality only a single circuit (wire), and so the inductance of the battery circuit depends on how the cables are physically positioned or arranged with respect to one another.

Tape Battery Cables Together to Reduce Inductance

If battery cables are separated by a distance, they have much more inductance than if they are close together. If the two battery cables were coaxial there would be virtually no induced current flow since the magnetic fields would cancel one another. However, we don't have coaxial battery cables, but we can approximate them by taping the cables together every four to six inches. When the cables are taped together the magnetic fields around each battery cable tend to cancel each other. When cables are separated the magnetic fields add together and increase the inductance of the battery cables. If you aren't convinced that taping battery cables together helps reduce inductance, consider the following table of information collected by Trace Engineering. We tested two sixteen foot long #4/0 AWG battery cables connected together at one end and parallel to one another.

Battery Cables	micro-Henries
Taped Together	3.3
12" Separation	6.0
48"+ Separation	8-9

The above table shows that with only a foot of distance between the battery cables the inductance almost doubles, and at four feet between cables the inductance is almost three times the inductance of cables taped together.

Since the induced voltage in a conductor varies as the inductance times the rate of change of current in the inductor, the induced voltage may be three times greater than it would be if cables were not taped together. For more advanced readers, consider flyback effects and the induced voltage spikes can get into the thousands of volts range if the battery were suddenly removed from the circuit (worst case).

These induced voltage changes cause ripple in the battery cables and must be absorbed or filtered by the filter capacitors in the inverter. This ripple will lead to eventual premature breakdown of the filter capacitors and performance loss in the inverter.

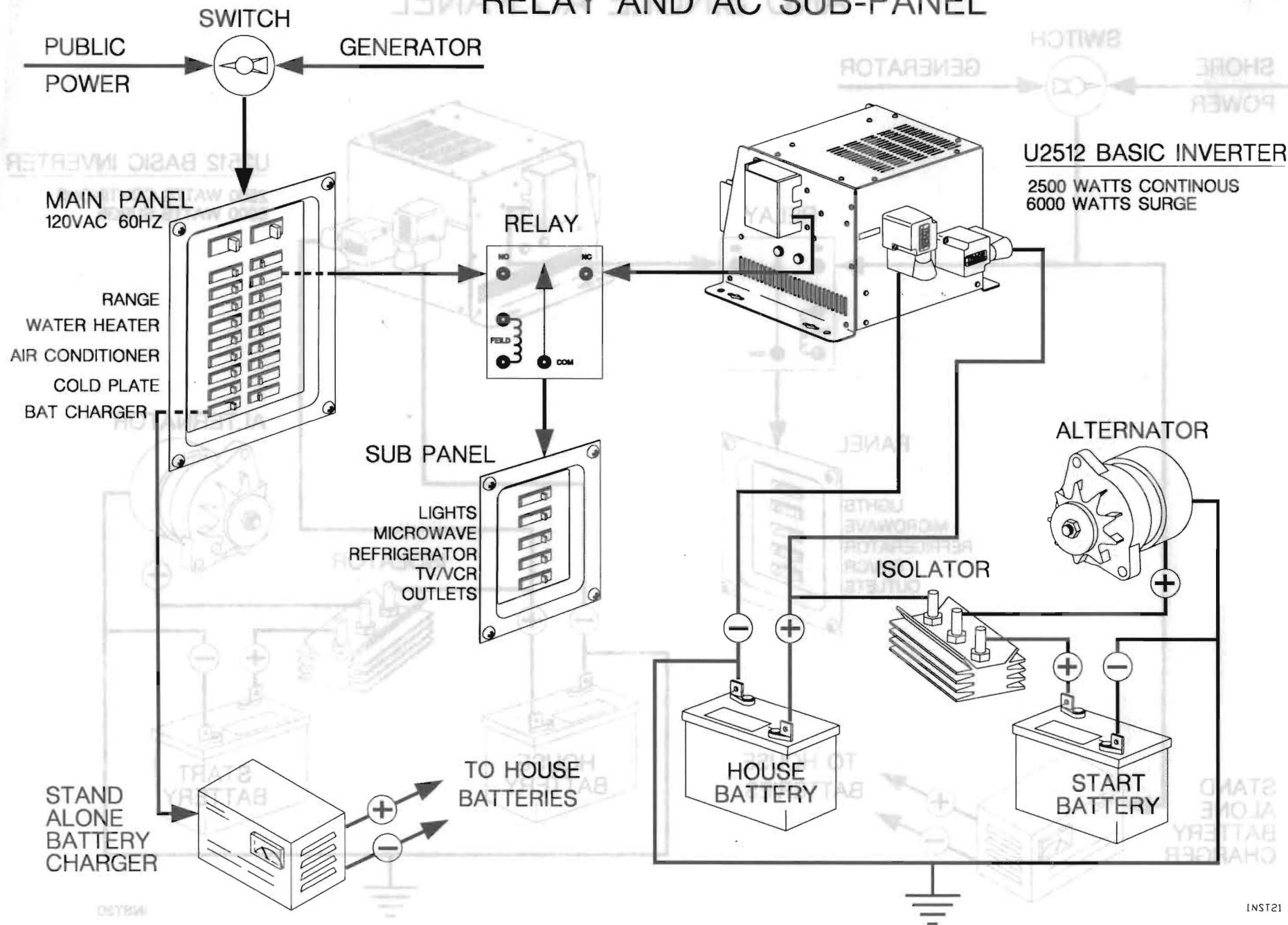
In addition to the problems mentioned, the induced current opposes the applied current (battery current) which directly causes a loss of inverter performance as greatly reduced efficiency.

Hopefully this technote gives a much more realistic and clear idea of why battery cables should be kept short and close together. Maximum performance is the goal of any well designed power system and the detail items such as this will help achieve the goal.

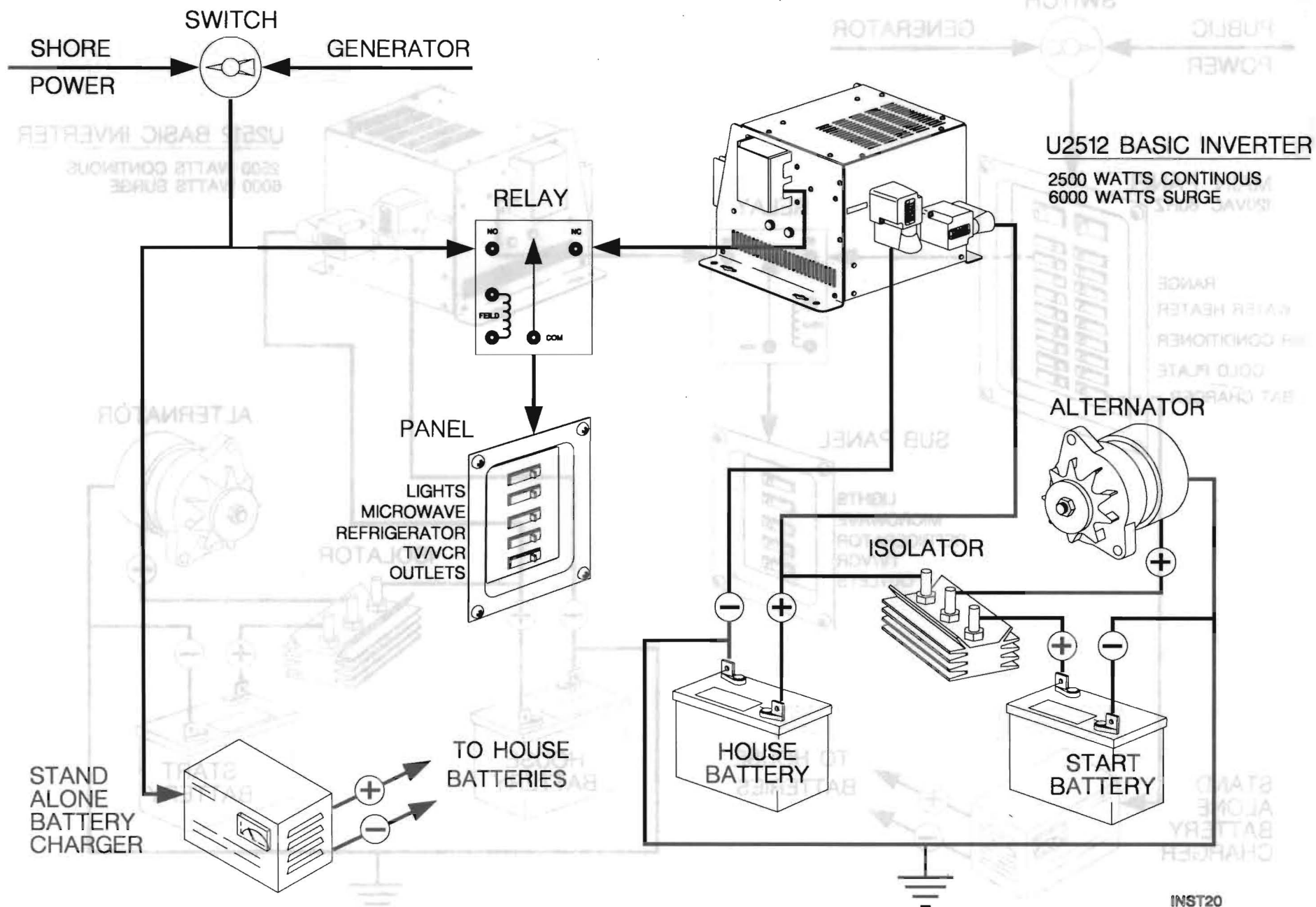
Distance Between	Inductance in
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MARINE/RV INSTALLATION- BASIC INVERTER WITH EXTERNAL RELAY AND AC SUB-PANEL

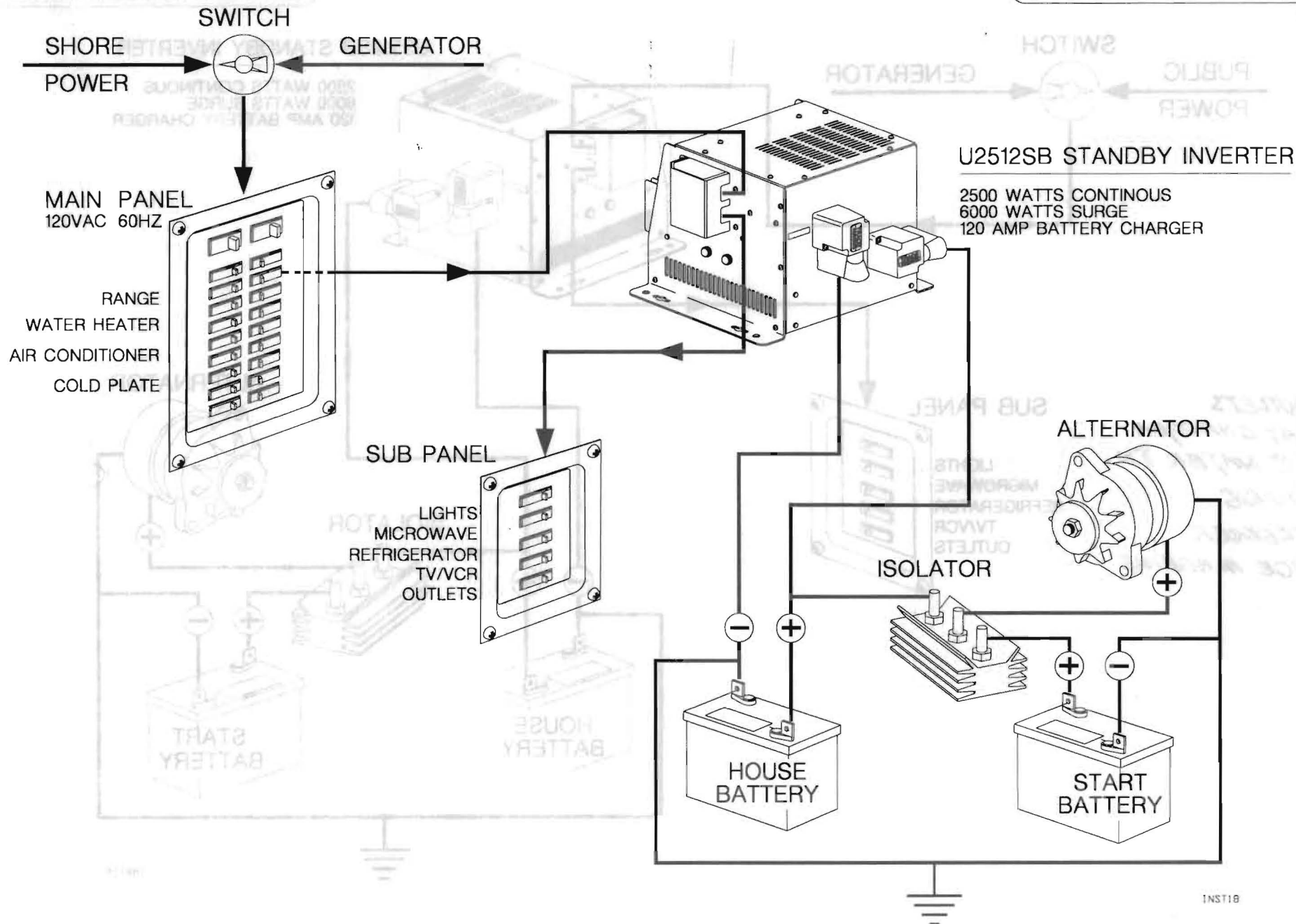
Trace
ENGINEERING



MARINE/RV INSTALLATION- BASIC INVERTER WITH EXTERNAL RELAY AND SINGLE AC PANEL



MARINE/RV INSTALLATION- STANDBY INVERTER WITH AC SUB-PANEL



MARINE/RV INSTALLATION- STANDBY INVERTER WITH SINGLE AC PANEL

