Model DP10 and DP20 Series
Low Voltage Disconnects

Application Notes

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INTRODUCTION

The **DP10** and **DP20** Low Voltage Disconnects (LVD) are designed to extend the life of your battery by preventing damaging over-discharge. They can also protect valuable instruments and equipment from potentially damaging low voltage conditions. They work with lead-acid, nickel-cadmium, and nickel-metal-hydride type batteries. They can be configured to work with other types of batteries as well. The LVD is installed electrically between the battery and the load and it disconnects the negative load lead from the battery when the customer specified disconnect voltage is reached. The LVD incorporates a three second delay before disconnecting the load to prevent unintentional disconnects caused by transient high current pulses that may occur. The LVD can withstand onetime surge currents up to twice the current rating of the unit for five seconds. After disconnecting a load, and while still connected to a discharged battery, the LVD will draw a small quiescent current to maintain operation. If connected in a system with a battery charger hooked up in parallel, as the battery is recharged the LVD will reconnect the load after the battery is about 50% charged.

The **DP10** and **DP20** are also available in alarm versions. The alarm can be visual (flashing LED), audible (Beeper), or both. The alarms can be mounted on the PCB or to remote headers. The alarm will indicate for sixty seconds before the load is disconnected. If the battery voltage is restored before the sixty seconds is up, the alarm will cease and reset. There is a three second delay that operates in both directions to prevent nuisance tripping and resetting of the alarm circuit. If the LVD disconnects the load, the beeper will cease, but the LED will continue to flash at a lower rate.

The **DP10** and **DP20** feature easy installation. The LVD has a single mounting hole through the center. Two-sided tape may also be used to easily mount it to almost any surface. The LVD uses 0.250" PCB tabs for use with 0.250" quick-disconnect connectors. The electronics are potted for rugged industrial applications. Rather than using mechanical relays that can wear out and draw large currents, these LVD's use semiconductor devices for a lifetime of worry free use. Model DP10 shown below.

BENEFITS

- Saves battery replacement costs
- Improved battery performance and reliability
- Increased battery life
- Prevents reverse polarity charging of cells
- Minimizes battery pack temperature rise
- Improved equipment performance
- Allows safe, unattended discharge of battery

FEATURES

- Mounting hole for permanent installation using hardware
- Easily mounted using 2-sided tape
- Maximum surge current of twice rating for five seconds
- Works with sealed lead-acid and nickel-cadmium type batteries
- Customer specified and adjustable disconnect voltage
- Audible and visual alarms available
- Circuit is potted for strength and reliability

ACCESSORIES

- LVD-REDLED — Red Super-Bright LED with 12” long leads - comes with clear panel mount lens *
- LVD-BEEPER — Remote Beeper provided on 12” long leads *

* You must have an alarm version of an LVD to use this accessory

SPECIFICATIONS

General Conditions: Ambient Temperature = 25 ºC (77 ºF)

Model Number	DP10	DP20
Maximum Continuous Current	10 A	20 A
Maximum Surge Current (5 sec.)	20 A	40 A
Quiescent Current	~2.5 mA	
Maximum Voltage (breakdown)	40 V peak	
Disconnect Delay	3 sec.	
Operating Temperature	0 to 60 ºC (32 to 140 ºF)	
Storage Temperature	-40 to 80 ºC (-40 to 176 ºF)	
Dimensions	L 2.05” x W 2.05” x H 1.0”	
Weight	Approx. 2 oz.	
Terminals	0.250” x 0.032” PCB tab	

Battery Type	Lead-Acid	NiCd & NiMH
Standard Disconnect Voltage	1.75 V/cell	1 V/cell
Custom Disconnect Voltage	1.3 to 2 V/cell	0.6 to 1.2 V/cell
Reset Voltage	2.1 V/cell	1.3 V/cell
Battery	6 to 24 V (3-12 cells)	6 to 24 V (5-20 cells)

Alarm Cycle	2 Hz.
Alarm Duty Cycle	50%
Alarm Duration	60 sec.
Alarm Delays	3 sec.
LED Lens Mounting Hole	9/32” (0.281”)
LED Lens Panel Thickness	1/8” (0.125”) maximum

PART NUMBERING SYSTEM

Model No.

DP10	10 A maximum continuous load current
DP20	10 A maximum continuous load current

Voltage Code

Lead-Acid		NiCd & NiMH	
06L	6.0 V, 3 cells	060	6.0 V, 5 cells
08L	8.0 V, 4 cells	072	7.2 V, 6 cells
10L	10.0 V, 5 cells	084	8.4 V, 7 cells
12L	12.0 V, 6 cells	096	9.6 V, 8 cells
14L	14.0 V, 7 cells	108	10.8 V, 9 cells
16L	16.0 V, 8 cells	120	12.0 V, 10 cells
18L	18.0 V, 9 cells	132	13.2 V, 11 cells
20L	20.0 V, 10 cells	144	14.4 V, 12 cells
22L	22.0 V, 11 cells	156	15.6 V, 13 cells
24L	24.0 V, 12 cells	168	16.8 V. 14 cells
		180	18.0 V, 15 cells
		192	19.2 V, 16 cells
		204	20.4 V, 17 cells
		216	21.6 V, 18 cells
		228	22.8 V, 19 cells
		240	24.0 V, 20 cells

Disconnect Voltage Code (three digit number with the decimal point understood to be one number from the right). Examples:

105	10.5 V
064	6.4 V

Option Letter Code (combine as necessary)

Alarm Circuit w/onboard beeper & header for remote LED	/A
Alarm Circuit w/headers for remote beeper & LED	/B
Extended Temperature Range (-20 to 80 ºC / -4 to 176 ºF)	/E

Example 1: DP10-12L105
Model DP10 Low Voltage Disconnect rated for a continuous 10 A load on a 12-volt sealed lead-acid battery. The disconnect voltage is set for 10.5 volts. No options.

Example 2: DP10-12L105/AE
Same as example 1 but with onboard beeper, header for remote LED, and with an extended operating temperature range.

SELECTING THE CORRECT LOW VOLTAGE DISCONNECT

Select the Model Number

The current drain of your load will determine the current rating of your Low Voltage Disconnect (LVD). Model **DP10** is conservatively rated for 10 A continuous load current with a one time surge current rating of 20 A for up to 5 seconds. Model **DP20** is conservatively rated for 20 A continuous load current with a one time surge current rating of 40 A for up to 5 seconds. These ratings are based on the unit operating in free air.

Select the Nominal Voltage Code

Low Voltage Disconnects for sealed lead-acid and nickel-based batteries are basically the same. The main difference is in the reset voltage for different types of batteries. The standard reset voltage for sealed lead-acid batteries is 2.1 volts-per-cell and the standard reset voltage for nickel-cadmium and nickel-metal-hydride batteries is 1.3 volts-per-cell. The nominal voltage code for LVD's that operate with sealed lead-acid batteries is two numbers with the suffix "L". The nominal voltage code for LVD's that operate with NiCd and NiMH batteries is three numbers with the decimal point understood to be one digit from the right with preceding zeros as necessary (1.2 volts-per-cell nominal).

Ex.	For a 12 volt SLA battery use:	**12L**
	For a 9.6 volt NiCd battery use:	**096**

Select the Disconnect Voltage Code

The disconnect voltage is actually the voltage the LVD detects at which point it starts a 3-second delay timer before it disconnects the load. The delay is to prevent nuisance disconnects due to transient high current pulses that may occur. The battery voltage will continue to lower during the delay but the amount is negligible. The standard disconnect voltage for SLA batteries is 1.75 volts-per-cell. This voltage can normally be lowered when discharging the battery at a high rate (refer to your battery's documentation). The disconnect voltage for SLA batteries can be set between 1.3 and 2 volts-per-cell. The standard disconnect voltage for NiCd and NiMH batteries is 1 volt-per-cell. A lower disconnect voltage may be required when exercising or restoring a NiCd or NiMH battery. To prevent cell reversal with long strings, 1.1 or 1.2 volts-per-cell may be appropriate. The disconnect voltage for NiCd and NiMH batteries can be set between 0.6 and 1.2 volts-per-cell. Under any condition the minimum disconnect voltage is 4.5 volts. For lower disconnect voltages, please consult the factory. The disconnect voltage code is three numbers with the decimal point understood to be one digit from the right.

Ex.	For a 10.5 volt disconnect use:	**105**
	For a 6.4 volt disconnect use:	**064**

Option Codes

The model DP10 and DP20 Low Voltage Disconnects also come in alarm versions. The alarm can be visual (flashing red LED), audible (beeper), or both. The LED will always be remote mounted using leads, but the beeper can be mounted on the PCB or on leads. The alarm will indicate for sixty seconds before the load is automatically cut off. If the battery voltage is restored before the sixty seconds is up, the alarm will cease and the circuit will reset. There is a three second delay that operates in both directions to prevent nuisance tripping and resetting of the alarm circuit. If the LVD disconnects the load, the Beeper will cease, but the LED will continue to flash at a slower rate. There is also an option for an extended operating temperature range version. There are three option codes:

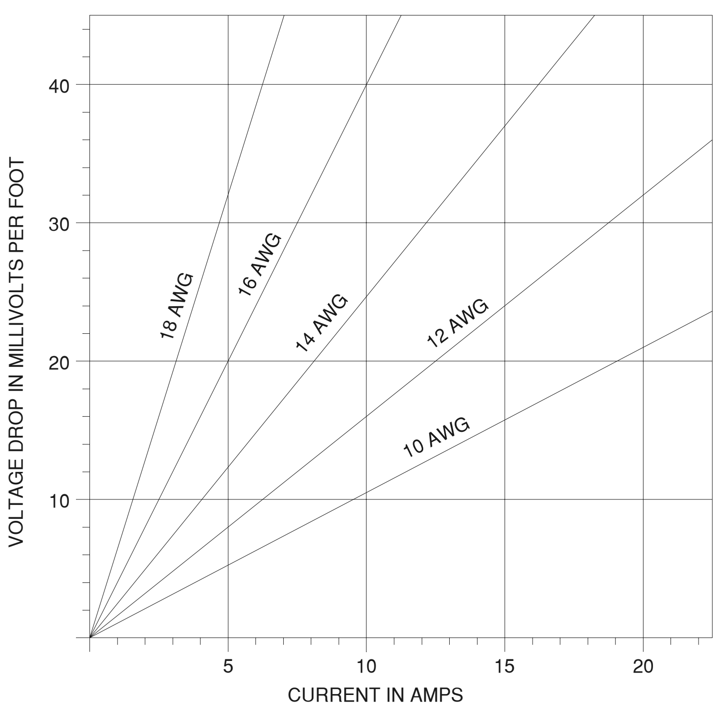
/A is used for a PCB mounted beeper and a header for an optional remote LED
/B is used for two headers for an optional remote beeper and optional remote LED.
/E is used for an extended temperature range (-20 to 80 ºC / -4 to 176 ºF)

APPLICATION INFORMATION

Recommended Wire Sizes
The size of the wires used to interconnect the load to the battery, with the low voltage disconnect in between, makes a difference in performance. Wire manufactures normally rate their wire for current carrying capacity based on a safe temperature rise for the insulation; however, these ratings do not take into account the voltage drop caused by the high currents and the resistance of the wire (IR loss).

For example:
Size 18 AWG wire has a recommended current rating of 15 A, but at 15 A size 18 AWG wire has a voltage drop of 96 mV/foot. If three foot long leads were used to connect the battery to the LVD and the LVD to the load, the voltage at the load would be 1.15 V less than at the battery (12 x .096). If size 12 AWG wire were used, the total voltage drop would only be 0.28 V (12 x .024).

For the best performance, the shortest length and largest size of hook-up wires should be used to interconnect the battery, load, and LVD. The following graph shows the approximate voltage drop, or IR loss, across leads as a function of wire size and load current. The table lists the recommended wire sizes for different loads.



TO SELECT WIRE SIZE FOR KNOWN OPERATING CURRENT AND KNOWN MAXIMUM TOLERABLE VOLTAGE DROP ACROSS LEADS:

1. TO FIND MILLIVOLTS PER FOOT, DIVIDE THE MAXIMUM TOLERABLE VOLTAGE DROP BY THE SUM OF POSITIVE AND NEGATIVE LEAD LENGTHS IN FEET.
2. DRAW A LINE ACROSS THE GRAPH AT THIS VOLTAGE.
3. DRAW A LINE UP THE GRAPH AT YOUR KNOWN CURRENT.
4. SELECT THE SMALLEST WIRE SIZE THAT CROSSES THE CURRENT LINE AT OR BELOW THE VOLTAGE LINE.

RECOMMENDED WIRE SIZES					
CURRENT	0-4 A	4-7 A	7-11 A	11-15 A	15-20 A
WIRE SIZE	18 AWG	16 AWG	14 AWG	12 AWG	10 AWG

Installation Location
Location plays a roll in how to best implement the Low Voltage Disconnect in your application – particularly in high current applications. This is because with high currents the resistance of the hook up wires and connectors will cause two voltage drops. The first voltage drop is between the battery and the LVD and the second voltage drop is between the LVD and the load.

If the main purpose of using the LVD is to protect the battery while obtaining the maximum discharge, locate the LVD as close to the battery as practical. This will minimize the effects of the voltage drop in the leads between the battery and the LVD so the voltage the LVD sees will be closer to the actual battery voltage.

If the main purpose of using the LVD is to protect sensitive equipment from potentially damaging low voltage conditions, locate the LVD as close to the equipment as possible. This will minimize the effects of the voltage drop in the leads between the LVD and the load so the voltage the LVD sees will be closer to the voltage that the load sees.

In both of the above cases, because the potential voltage drops occur downstream from the battery, the battery will be protected from a damaging over discharge condition.

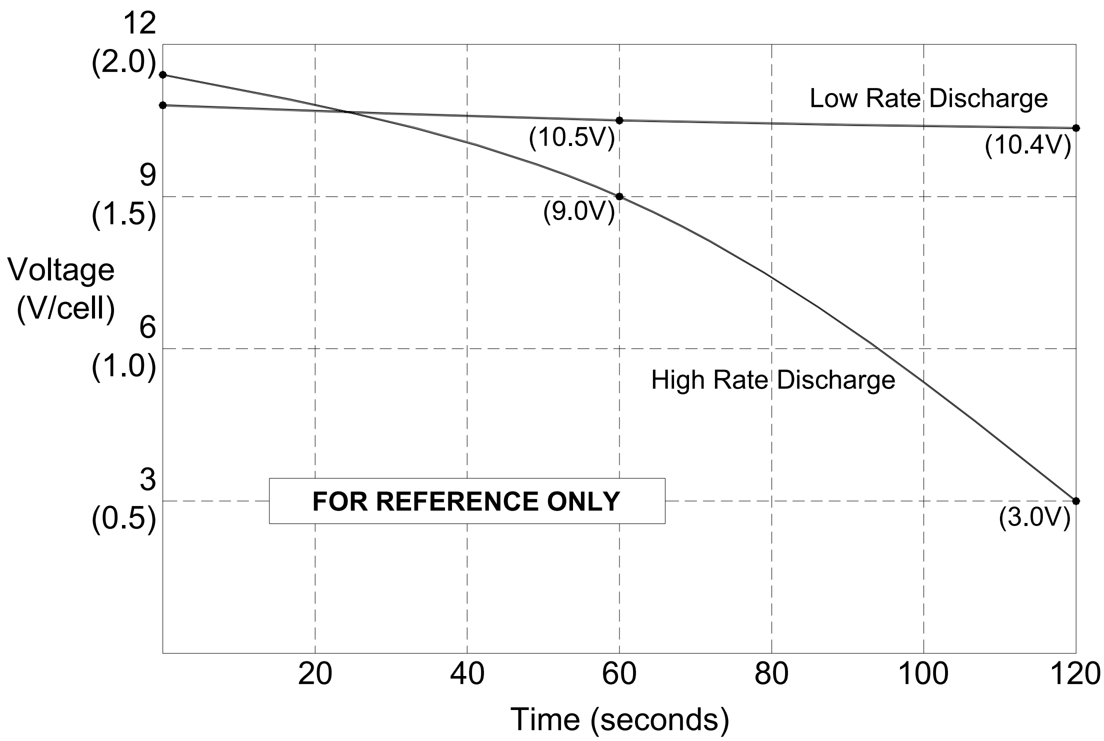
Connection Note
The –BATT and +BATT terminals on the LVD must be connected to the battery for operating power. The negative load lead must be attached to the –LOAD terminal on the LVD. Only the negative circuit is connected and disconnected by the operation of the LVD. The positive load lead may be connected to either the positive battery terminal (preferred for high current applications to minimize the voltage drop), or the +LOAD terminal on the LVD if it is more convenient.

Warning about Over-Discharge with Alarm Version Low Voltage Disconnects
There is a danger of over-discharging the battery when using the alarm version of the LVD. This is because the alarm will operate for a complete sixty seconds before the load is disconnected. With low rate discharge currents, this should not be a problem because the battery will be discharged only slightly during this time (see example 1 on next page); however, with high rate discharge currents, the battery may continue to be discharged to a potentially damaging voltage (see example 2 on next page). Increasing the voltage where the alarm starts can compensate for this. This is done by experimenting to determining the battery voltage sixty seconds before the desired disconnect voltage under actual load conditions. This higher voltage point is then used instead of the actual desired disconnect voltage when specifying the disconnect voltage code. If the load is to be manually shut off as soon as the alarm indicates, then the possible over discharge condition may not be a problem – it all depends on the application. It is the user's responsibility to perform discharge tests on their application to determine the proper "disconnect" voltage before placing an order for an LVD with or without an alarm.

Note: the curves in the graph are for reference only. They are meant to show examples of possible discharge curves and do not represent actual discharge curves.

Example 1: Low Rate Discharge
In this example, the battery is a 12 volt sealed lead-acid battery. The disconnect voltage is set for 1.75 V/cell or 10.5 volts. The battery is being discharged at a low rate current. In the sixty seconds preceding the battery reaching 10.5 volts, the voltage has dropped only a slight amount. In the sixty seconds between the LVD detecting the 10.5 volts and it actually disconnecting the load, the battery also dropped a negligible amount. There is no need to specify a special "high-offset" disconnect voltage.

Example 2: High Rate Discharge
In this example, the battery is a 12 volt sealed lead-acid battery. The disconnect voltage is set for 1.50 V/cell or 9 volts. The battery is being discharged at a high rate current. In the sixty seconds preceding the battery reaching 9 volts, the voltage has dropped a significant amount and is continuing to quickly drop. In the sixty seconds between the LVD detecting the 9 volts and it actually disconnecting the load, the battery has dropped to a potentially damaging level. If the disconnect voltage was instead specified at 1.9 V/cell or 11.4 volts, the LVD would have safely disconnected the load when the battery reached approximately 1.5 V/cell or 9 volts.

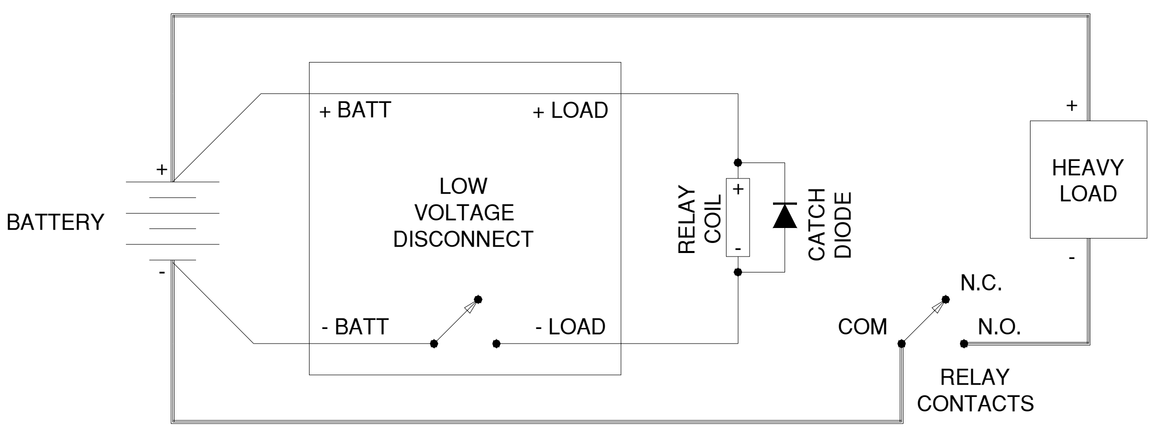


Full Discharge vs. Partial Discharge and Battery Life
If the LVD is meant to only occasionally operate then there is no concern about a full discharge. However, if your application calls for the LVD to always disconnect the load when the battery is discharged, rather than just as an emergency disconnect, then a higher disconnect voltage may be more appropriate. Continually discharging a battery 100% will severely reduce cycle life. To improve battery cycle life, batteries should only receive a shallow discharge. This applies to both lead-acid and nickel based batteries. Even deep

cycle lead-acid batteries should not be repeatedly discharged more than 80%. Consider using a higher disconnect voltage in these applications unless battery runtime is the primary consideration, in which case a larger capacity battery is called for.

To determine the most appropriate disconnect voltage for your application, many factors such as battery type & size, discharge current, required runtime, and desired cycle life must be considered and balanced. Consult your battery manufacturer or documentation or contact Xenotronix/TLI, Inc. for more information.

Using a Relay to Control the Load
When using the LVD in a system with a relay, as the relay coil magnetic field collapses, it can generate a voltage spike of several hundred volts. This voltage spike will damage the LVD. If the relay does not already have a catch diode added to prevent this voltage spike from occurring, it must be added. You will need a very-fast acting diode rated to handle the relay coil operating current. Since the diode will prevent the voltage spike, a 50V diode will work fine. Install the diode across the relay coil contacts with the cathode wired to the positive side and the anode wired to the negative side. The following diagram shows how to wire the LVD for controlling a relay:



In this application, the load is wired through the relay to the battery and the LVD is only used to monitor the battery voltage and control the relay. The full load current does not pass through the LVD. Most relay coils only draw in the hundreds of milliamps so there will be very little stress on the LVD and the voltage reads will not be affected by the voltage drop in the hook-up wires. The LVD can be used to control high power relays that can handle loads of several hundreds of amps (with coil currents up to 10A or 20A). Relay contacts are shown breaking the negative lead but can also be wired to break the positive lead.

Using with a Battery Charger in a Standby Application
If using a battery charger along with an LVD in a standby application, it should be hooked-up directly to the battery. This is best for the battery and the charger may be rated for higher current than the LVD or load terminals and wiring. The battery charger will not adversely affect the operation of the LVD. If the load is continuous, the battery charger should be rated at least twice the current rating of the load. This will allow the

battery charger to maintain the battery voltage during normal operation while supplying the load with current. If power is lost, the load will begin to discharge the battery until it is disconnected. Once power is restored, the battery charger will begin to recharge the battery. When the battery voltage reaches the LVD reset voltage, the LVD will reconnect the load. The extra current of the battery charger will eventually recharge the battery.

If the battery charger does not have enough current to both supply the load and recharge the battery, the battery will not be charged. To maximize the life of the battery, the load should be disabled and the battery fully recharged before the load is allowed to resume.

Using the LVD in some Motor Applications

In some types of motor load applications, disconnecting the battery while the motor is operating may cause the motor to act as an unregulated generator. This could allow the voltage to fly up causing current to flow in the reverse direction. In most applications, the battery will filter the voltage spike and protect the LVD and other connected equipment. In some applications, where the motor has a lot of stored energy, the reverse current may be significant enough to damage the LVD or other equipment. To prevent a damaging reverse current flow, a diode must be installed near the motor. The diode must be adequately rated to handle the motor operating current as well as the voltage spike.

ADJUSTING THE DISCONNECT VOLTAGE

WARNING: Improperly adjusting the disconnect voltage can lead to seriously over-discharging the battery and equipment damage caused by a low battery voltage.

If testing indicates that the disconnect voltage requires adjustment (possibly to compensate for a voltage drop in the wiring), it can be adjusted using the trimming potentiometer (note: the reset voltage is factory set and cannot be adjusted by the user).

Adjusting Out-of-Circuit:

To increase the disconnect voltage, adjust the trimming potentiometer to the right (clockwise). To decrease the disconnect voltage, adjust turn the trimming potentiometer to the left (counterclockwise). Make very small adjustments and then try it out.

Adjusting In-Circuit:

When increasing the disconnect voltage, remember that there is a 3-second delay before the LVD will operate (or the alarm will begin). When the battery is at the desired disconnect voltage, slowly make a small adjustment (CW) and wait 3-seconds before making another small adjustment until the LVD disconnects.

When decreasing the disconnect voltage, make a small adjustment (CCW) and wait to see where the LVD disconnects. Repeat until the desired disconnect voltage is reached (you will need to disconnect power from the LVD to reset it between attempts).

Advanced Adjustment Instructions:
To bypass the effects of the time delay, use a connector to connect a voltmeter to the test header pins identified on the hook-up diagram as –SIG and +SIG. The voltmeter will read ~5V in a connected condition and ~0V in a disconnected condition (except during delays and alarms when the voltages are reversed). If lowering the disconnect voltage, first turn the trimming potentiometer to the left (counterclockwise) – this step is not required when increasing the disconnect voltage. Connect a power supply, preset to the desired disconnect voltage, to the +BATT and –BATT terminals. The LVD should be in a connected condition and the signal voltage at ~5V. Slowly turn the trimming potentiometer to the right (clockwise) until the signal voltage goes low (from ~5V to ~0V). The load will be disconnected or the alarm will begin after the 3-seconds delay. You can check the reset voltage by increasing the power supply voltage until the signal voltage goes high. The load will be reconnected after the 3-seconds delay.

EXERCISING AND RECONDITIONING NICD AND NIMH BATTERY PACKS

When exercising or reconditioning a battery, a low voltage disconnect should be used to prevent over-discharging the battery and reversing the cells. Different models of the DP10 and DP20 LVD's can be used on 5 cell to 20 cell battery packs for exercising, and 8 cell to 20 cell battery packs for reconditioning. The minimum disconnect voltage is 4.5 volts. For disconnect voltages less than 4.5 volts please consult technical sales.

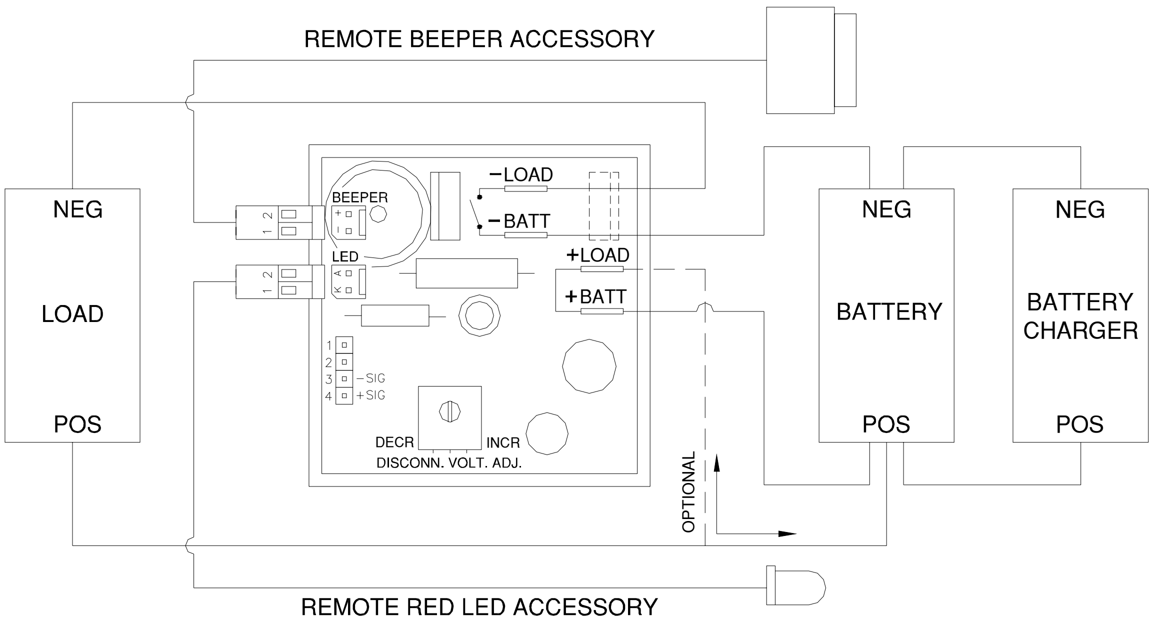
Exercising

The effects of dendritic growths, or crystalline formation, are most pronounced if a NiCd battery is left in the charger for days, or is repeatedly recharged without a periodic full discharge. Since most applications do not use up all the energy before recharge, a periodic discharge to one volt per cell is essential for the NiCd battery to prevent the buildup of dendritic growths on the cell plates. All NiCd batteries in regular use and on standby mode (attached to the charger for operational readiness) should be exercised once per month. Between these monthly exercise cycles, no further attention is needed and the battery can be used with any desired user pattern. NiMH batteries are also affected by dendritic growths, but to a lesser degree – they only need to be exercised once every three months. Because of their shorter cycle life, it is not recommended to over exercise NiMH batteries. Accept for some applications, it is neither necessary, nor advisable, to discharge a NiCd battery before each charge as excessive cycling puts extra strain on the battery.

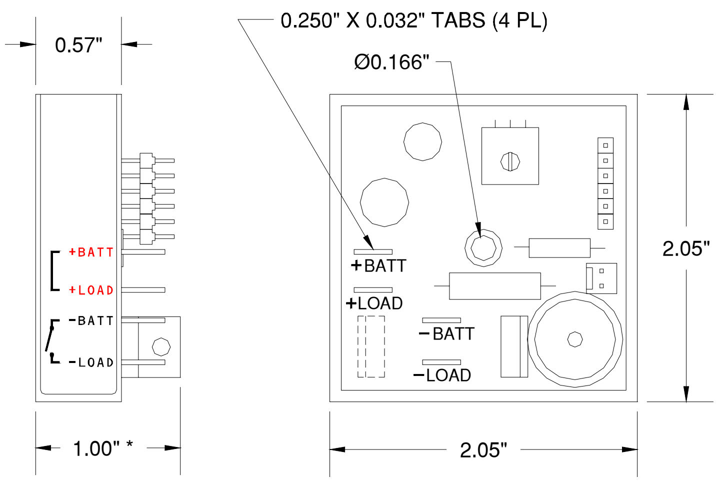
Reconditioning

If no exercise is applied for several months, the crystals ingrain themselves, making them more difficult to break up. In such a case, exercise is no longer effective in restoring a battery and reconditioning is required. Recondition is a slow, deep discharge that removes the remaining battery energy by draining the cells to a voltage to below one volt per cell. Tests performed by the US Army Lab have shown that a NiCd cell needs to be discharged to at least 0.6 volts to effectively break up the more resistant crystalline formation. During reconditioning, the current and voltage must be carefully controlled to prevent cell reversal.

HOOK-UP DIAGRAM



DIMENSIONS



WEIGHT: APPROX. 2 OZ.

*ALLOW AN ADDITIONAL 0.5 - 1 INCH IN HEIGHT FOR QUICK DISCONNECTS AND WIRING CLEARANCE.