

# ELECTRONIC DESIGN

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## OPERATION MANUAL FOR THE Intelli-Cell Model 112 PRE-PRODUCTION AND EVALUATION UNITS

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The Intelli-Cell model 112 (ICU) is a universal rechargeable battery tester, charger, rejuvenator and analyzer for any Lithium-ion (LiIon), Lithium Phosphate (LiPo), sealed lead-acid (LA), Nickel-Cadmium/Nickel Metal Hydride (NiCd/NiMH) single battery or battery pack, from 1.25 volts to 12 volts. It can process batteries from cell phones, toys, cordless phones, media players, Uninterruptable Power Supplies (UPS), alarm backup batteries, notebook batteries and so on, from 400 milliamp hours to 5 Amp Hours, from 1.2 volts to 12 volts.

When not processing batteries, it makes a handy general-purpose bench DVM (0 to 15VDC) and a short/continuity tester with beeper, with the included test cable.

This is an intelligent machine that already has all the information stored for the types of batteries as described, so all parameters such as safe current charge and discharge, temperature, charge voltage, discharge voltage, reform voltage/current and so on, are already in memory. The ICU will even attempt to guess at the type and voltage of the battery as the battery is set up. As new battery technology comes on line, your ICU can be flashed with new parameters. As long as the battery selection is correct and the operator follows proper procedures, no damage can be done to any battery being processed. The ICU will even reverse polarity if the operator installs the battery backwards. The ICU has been designed for very easy use by even untrained personnel and buttons on the keypad will only work as the ICU expects, so pushing an incorrect function will be ignored, or a poor selection will be processed as the ICU decides to be a safer choice.

There are many features that make the ICU not only easy to use, but also quite versatile. An illuminated LCD display will always prompt the operator on the next step, as well as display voltages, currents, amp hours, time left of analyzing or restoration, etc. A nine-button keypad selects the type, voltage and amp hour rating of the battery being processed, and there are five functions that can be performed on the battery. Each selection, as well as the start or completion of a task is indicated by a beep and will display on the LCD.

**These are the functions, which will be described briefly, and later in detail:**

**CHARGE      FAST CHARGE      RESTORE      FAST TEST      ANALYZE**

The battery can be placed on the slanted **plate** of the ICU and the gold-plated spring probes can be slid left and right, and adjusted in height with the screw knob to match the contacts of the battery. The battery holder bracket can be lowered and locked into place with the side screw knob. Alternatively, the **cable** connection can be used for larger batteries using the included universal adapter, or with special adapters like the Apple battery adapter (adapters are sold separately). The plate has a built-in thermistor that will need to feel the battery so always make sure the battery is lying flat in the center of the plate. If you use the cable, note that there is a thermistor at the end of the cable that must be in contact with the battery. A piece of tape can be used to stick the thermistor to the battery. Note that if you fail to have either the plate or the cable thermistor feeling the battery, the ICU may stop and warn you after 15 minutes during charging cycles. If you decide to ignore warnings and continue the charge, the ICU will automatically go to a safer and lower charge/discharge rate that will take the battery longer to process. In the case of Lithium batteries, it is mandatory to have a thermistor contact the battery so the ICU can shut down the battery in the case of an overheated and possibly dangerous condition that can cause an explosion or fire.

## **BRIEF DESCRIPTION OF ALL FUNCTIONS**

**POWER:** This powers up, or puts the ICU in standby mode and shuts off the fan and LCD. However, even in standby mode, the LED polarity indicators will remain lit and if a battery is installed, the auto-polarity circuit will still function to protect the ICU and the battery against reverse polarity.

**CHARGE:** After battery selection is made, the CHARGE function will simply charge the battery (up to 2.5 Amps) at accepted regulated voltages while monitoring current and temperature. When fully charged, the ICU will beep and keep the battery trickle-charged until analyzed, tested or removed. Most batteries will take less than 2 hours, except large LA batteries, which take longer.

**FAST CHARGE:** After battery selection is made, the FAST CHARGE function will charge the battery using a highly regulated current at the battery's selected AmpHour rating (up to 2.5AmpHours) for a time determined by the type and size of the battery, while monitoring voltage and temperature. This works better on all batteries *except* Lithium batteries. For Lithium batteries, voltages are carefully monitored to keep within safe voltages. When a battery warms up, the ICU automatically switches to the conventional CHARGE function. Note that in the case of all LA batteries, or very large Lithium batteries, the FAST CHARGE function actually activates the CHARGE function as required by these batteries. The FAST CHARGE function is important to correctly size the crystals in NiCd/NiMH batteries and will obviously charge them faster than normal. Note that many Lithium Ion batteries have an electronic charging circuit built in that will not allow FAST CHARGE to work properly; the ICU will pick this up by intermittently cycling, showing no charge current for a few seconds. The ICU will think that the battery is fully charged in just a few minutes when it senses no charging current and stop the charging cycle. These types of batteries should be charged using the normal CHARGE function. In some cases, mostly on batteries larger than 1500mAh, the circuit in the battery won't allow charging beyond a certain current and won't allow the ICU to charge them at the normal 1/2C (50%) charging current and will cycle, turning charging on and off. The ICU will pickup the off as a fully charged battery even though the battery is not fully charged. If this seems to be happening, simply set the battery amp hours on the ICU for half the current. Obviously, this will take the battery longer to charge fully but at least will keep the battery circuit from cycling. If you want to analyze the battery using either the Analyze or Fast Test, reset the ICU after charging and now set the amp hours correctly so that calculations are done correctly. These smart batteries don't usually complain on discharging, only charging. The assumption is that they are trying to protect a cheap charger from overloading and don't realize that the ICU can supply this current. Batteries without this limiter circuit pose no problems for the ICU.

**RESTORE:** The RESTORE function is usually used for NiCd/NiMH batteries, but will function as a simple discharge/charge cycle for other types.

The ICU will discharge all batteries at their rated AmpHours (or maximum 2.5 Amps) until their universally accepted "discharged" voltage is reached. After that, the ICU automatically switches to the CHARGE function with Lithium and LA batteries. However, with NiCd/NiMH batteries, after discharging, the function will switch to the actual restore/recovery function that resizes and realigns the crystals, eliminating the memory effect these batteries have when their crystals become enlarged and corrupted. The restore function slows discharge rates while monitoring and maintaining established reforming voltages for two hours where the crystals will dissolve. Afterwards, the ICU switches mode to CHARGE which aligns the chemicals and crystals for the most power. Note that the growth of the size of the crystals on NiCd batteries can cause the batteries to short if not periodically restored. When a NiCd battery is shorted, the short can be removed by a large power surge which will remove the shorted crystal. But since the membrane is now ruptured, the battery will simply become shorted after only one charge cycle when small crystals fill the rupture, so all NiCd batteries that show shorted should not be repaired or restored.

**ANALYZE:** This function is offered to allow the accurate test of a fully charged battery by actually measuring the Amp Hours directly, and it can take up to two hours. All times, voltages and currents are displayed during the test.

The ICU will discharge the battery dynamically at a highly regulated current of precisely one/half the AmpHour rating of the battery, and measure the time it takes for the battery to reach its official “discharged” voltage. A good battery will take two hours, while a weak battery will take less time. When the official “discharged” voltage is reached, the ICU will calculate the actual AmpHour rating of the battery. Note that most manufacturers today lie about their ratings. Look for batteries that are seriously off spec before condemning them.

**FAST TEST:** This function is fast, only a minute or two. It will record the starting voltage of the battery, then put the battery in full discharge to its rated AmpHours (up to 2.5 Amps) for one (or two) minutes, then measure the voltage afterwards under load, and calculate the quality of the battery in percent. All voltages and currents are displayed during the test.

**RESET:** This can be used even with a battery still set up, and will simply start the setup process as if a new battery has been installed. The ICU will also call for RESET itself if it senses a problem or malfunction.

### **OPERATION OF THE ICU112**

*Note that the function buttons might take a few seconds to be acknowledged if the ICU112 is busy doing something. If a button doesn't immediately function, just hold it for a short time until that function is processed.*

Power up the ICU by pressing the POWER button. The LCD will indicate a test calibration by showing the model and EDS version number, then display **NO BATTERY. PLACE IN TRAY OR USE CABLE.**

*Note that the gold battery contacts of the battery plate of the ICU and the cable are actually the same connection. Also, both thermistors are monitored so you could conceivably use the thermistor on the cable while the battery is on the plate, and vice-versa. Therefore, only one battery can be processed at one time.*

Normally, there is a weak 0.5VDC signal at the positive terminal that is used to sense for shorts. A working battery of any voltage or polarity negates this weak voltage. A totally dead, non-shortened or open battery will not be sensed automatically.

*Note that the battery polarity RED LEDs above the plate correctly show the positive terminal of the battery on the plate, but also monitor the cable. Therefore, it is possible that the red and black alligator clips of the cable may not necessarily be red for positive and black for negative! This is usually not an issue since the ICU switches polarity anyway, but on a totally dead battery you may want to make sure the polarity matches the colors. Simply switch the main AC power switch off in the rear, and when powered back on, the cable polarity will default to red for positive and the **NORM POLARITY LED** will be lit.*

As you mount the battery on the plate, or connect with the cable, the ICU will indicate the positive terminal by lighting the red LED above the plate. At first, the ICU will act as a simple DVM or continuity tester and display the voltage, or alternatively, display **SHORT ACROSS INPUTS**. After ten seconds, if still connected, the ICU will switch to its main intended function and analyze the battery, then will display the suggested type and voltage of the battery. This suggestion may be wrong, since the battery voltage may be out of normal range. However, the ICU will display **ACCEPT OR SELECT** and allow you to use the up and down arrows to select the correct battery, then press the **ENTER** button. Then the ICU will ask you to

**SET AMP HOUR RATING** which is also done using the up and down arrows and pressing the **ENTER** button. You should set the rating for the amount as listed on the side of the battery. Ratings from 400 milliAmpHours to 5.0 AmpHours are available.

*Note that a totally dead (non-shorted) battery with zero volts will be ignored by the ICU. Therefore, you can set the ICU for the type of battery before installing it on the plate or with the cable. While the ICU is displaying **NO BATTERY**, simply use the up and down arrows and the **ENTER** button to select type, voltage and amp hours. Make sure that the battery is installed with the correct polarity since the ICU could not sense the correct polarity.*

After the settings are in place, the ICU will display **SELECT FUNCTION..... RESTORE-CHARGE-ANALZ** at which time any of the five functions can be chosen.

Note that during the FAST CHARGE functions, if the ICU doesn't feel the expected warmth of the battery (100 degrees F) within 15 minutes, it may stop work on the battery and beep continuously, displaying **CHECK BATTERY TEMP! IF OK PRESS CHARGE** and wait for your response. If the thermistor is correctly attached and the battery is indeed cool to the touch, you may press CHARGE as directed, and the ICU will continue. After 45 minutes, the ICU will automatically lower all currents in half and update timings to reflect corrections in calculations if warmth is still not sensed. You normally won't get the warning during the normal CHARGE function.

As a safety, the ICU is calibrated to stop all functions and display **WARNING! HOT BATTERY** if temperatures beyond 125 degrees F are sensed. Batteries can be harmed by excessive heat, and Lithium batteries in particular can explode and catch fire, so it is mandatory that one of the thermistors is touching a lithium battery at all times while the ICU is functioning.

### **BATTERY TYPES AND STATISTICS**

These are the 15 most popular configurations of batteries and battery packs that the ICU112 has statistics in memory for. The ID#, TYPE is the chemical makeup, the VOLT is the voltage of the cell or pack, the CHGV is the established safe charge voltage, the DISV is the established discharge voltage per cell or pack, and the TRICV is the trickle charge current or voltage.

ID#	TYPE	VOLT	CHGV	DISV	TRICV
1	Nix1	1.2	1.75	1.00	20mA/~1.3V
2	LAx1	2.0	2.40	1.80	5% or 2.2V
3	Nix2	2.4	3.25	2.00	20mA/~2.6V
4	LiPx1	3.3	3.45	2.00	3% or 3.5V
5	Nix3	3.6	5.25	3.00	20mA/~4.0V
6	Lix1	3.6	5.00	3.00	5% or 4.0V
7	LAx2	4.0	4.70	3.50	5% or 4.5V
8	Nix4	4.8	6.50	4.00	20mA/~5.5V
9	LAx3	6.0	7.00	5.30	5% or 6.7V
10	Nix6	7.2	10.5	6.00	20mA/~8.2V
11	LiPx2	6.6	6.90	5.00	3% or 6.9V
12	Lix2	7.2	10.0	6.00	5% or 8.0V
13	LiPx3	9.9	10.5	7.50	3% or 10.5V
14	Lix3	10.8	13.0	9.00	5% or 12.0V
15	LAx6	12.0	13.5	10.5	5% or 13.2V

#### CHARGE details:

The ICU charges the battery from a fixed voltage source CHGV displaying the amount of current, until the charging current is under 100mA or 4 hours (whichever is first), then switches to the trickle TRICV voltage, at which time the ICU will display CHARGING COMPLETE, ANALYZE OR REMOVE. You may leave the battery in this function for as long as you wish, or run a QUICK TEST or ANALYZE the battery, or just remove it.

#### FAST CHARGE details:

The ICU will attempt to charge the battery at its highest current rating (maximum 2.5 Amps) while carefully monitoring voltage and temperature. This function is best for NiCd and NiMH batteries and need not be used for any other types. After 20 minutes, if the expected temperature is not reached, the ICU will stop charging and continuously beep until the operator checks battery temperature and placement of the thermistors, and may confirm that all is well by pressing CHARGE. After 45 minutes, the FAST CHARGE is switched to the lower CHARGE function automatically. Note that although you can select FAST CHARGE for lithium batteries, many lithium battery packs are “smart batteries” and will automatically stop accepting the charge on their own if they have their own charging circuit. Use the conventional CHARGE function on these types. All LA batteries will actually use the CHARGE function even if FAST CHARGE is selected. As in the CHARGE function, charging stops until the charging current is under 100mA or 4 hours (whichever is first), then switches to trickle charge.

#### RESTORE details:

This function is either two steps or three steps, depending on the type of battery. The ICU will display DISCHARGE CYCLE ON during the first step. You can cycle lithium and LA batteries as well if you feel the need, but these will simply be cycled from discharging until DISV is attained and then switched directly to charging (or waiting to cool if warm).

The RESTORE function is mostly used for NiCd and NiMH batteries to reverse the memory effect caused by the crystal formations of the electrolyte becoming corrupted and oversized. It is absolutely required for all NiCd batteries that do not have enough deep discharge cycles to keep them healthy. Trickle-charging these without heavy use until dead causes them to become shorted by the growth of oversized crystals in their chemical composition, and cannot be restored with any degree of success after they have shorted.

In the case of NiCd and NiMH batteries, the ICU will discharge these batteries quickly until their DISV voltage is reached.

Next, the ICU will display COOLING & REFORMING and will slow down the discharge rate while maintaining the battery or battery pack at ½ DISV voltage for two hours. During the wait, the ICU will alternately display the time left of the restoration process and the voltage.

The last step is to CHARGE the battery or battery pack until the battery is fully charged, then to remain on trickle-charge until removed or tested.

#### ANALYZE details:

This is a very accurate analysis of the battery where the battery is discharged at ½ the rated AmpHour setting for a period of time, not exceeding two hours. In this mode, the ICU will display ANALYZING, WAIT....., and alternatively display the current discharge rate, the voltage under load, and the possible maximum remaining time in minutes. When the battery reaches the established DISV discharge voltage, the ICU will beep, then calculate the exact AmpHour rating of the battery. This test can take from a few minutes to a maximum of two hours, depending on the quality of the battery.

#### FAST TEST details:

This is a fast, under two minutes, test of the battery or battery pack measuring the initial voltage  $V_i$ , discharging the battery at its rated AmpHour load (up to 2.5 Amps) and measuring its ending voltage under load  $V_e$  after one or two minutes. The quality factor formula is  $V_e/V_i$  and is shown as a percentage. A general rule of thumb is any rating above 90% is excellent, above 80% is good, above 70% is fair, and anything less indicates a weak, or partially discharged battery. This test is most accurate after a battery is fully charged and left unused for a few hours. If tested immediately after charging, the quality factor may show a few points lower, since many batteries show an unusually high voltage immediately after being fully charged and this tilts the formula slightly lower.

In the FAST TEST function, the ICU will display ANALYZING, WAIT....., display the initial voltage, run the test, then beep and display the ending voltage under load, then calculate and display the quality factor as a percentage.