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## ICS1702 Evaluation Board

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### General Description

Galaxy Power, Inc.'s **ICS1702 Evaluation Board** allows quick evaluation of the ICS1702 Charge Controller for Nickel-Cadmium and Nickel-Metal Hydride Batteries. The evaluation board provides the designer an opportunity to both test the ICS1702 and a fast charge battery charger. The board is self-contained and can provide a constant current to charge a battery when optional components are installed.

The board includes resistors that are user-installed to customize operation for the desired charge rate, discharge pulse current, and number of cells in the battery pack. The board has a 5V regulator that provides power to the ICS1702 and the LED display. The board also has a breadboarding area consisting of a matrix of holes for user added components.

Before using Galaxy Power, Inc.'s **ICS1702 Evaluation Board**, ICS recommends the user review the ICS1702 data sheet to become familiar with the operation of the controller.

The **ICS1702EB** can be purchased two ways: **ICS1702EB** or **ICS1702EB/CR**. The difference between these boards is a constant current linear supply as shown in the board schematic. The **ICS1702EB** has an area on the board reserved for these components. The **ICS1702EB/CR** contains a kit which includes an LM317 and associated parts needed to build a current regulator

### Setting-up the Board for your Application

Refer to the evaluation board schematic diagram. The ICS1702 requires that the battery voltage is normalized to the voltage of one cell, or about 1.2V. To do this, resistors must be installed in the locations marked R6 and R8. The appropriate values can be selected from Table 1. An assortment of resistors is provided with the board.

**Table 1**

Cells	R6	R8
1	Open	Short
2	2.0k	2.0k
3	1.0k	2.0k
4	1.0k	3.0k
5	3.0k	12k
6	2.0k	10k
7	2.0k	12k
8	1.3k	9.1k

If the evaluation board is used with battery packs containing more than eight cells, the resistors can be determined by counting the number of cells to be charged in series. Then choose either R6 or R8 and solve for the other resistor using:

$$R8 = R6 * (\# \text{ of cells} - 1) \text{ or } R6 = \frac{R8}{(\# \text{ of cells} - 1)}$$

R7 sets the open circuit (no battery) reference voltage at the OPREF pin voltage. The purpose of this voltage reference is to detect the removal of the battery from the charging system. The voltage at this pin is compared to the voltage at the VIN pin when the current source is turned on. If the voltage at VIN is greater than the voltage at OPREF, the ICS1702 assumes the battery has been removed and the ICS1702 enters the polling detect mode. For proper operation, the voltage at OPREF must be set between the (divided down) open circuit voltage produced by the current source and the maximum normalized battery. As a guide, set the voltage at OPREF (TP1) to be 200mV to 300mV higher than the maximum normalized battery voltage. For most batteries, the maximum normalized battery voltage at full charge is 1.7 to 1.8V, so OPREF (TP1) should be set at about 2V.

When power is applied to the board, the controller will start a charge sequence unless a logic low is applied to the RESET terminal. When RESET is removed by a logic high or open, a charge sequence will begin.



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The board provides several low value resistors that may be used to set the amplitude of the discharge pulse. The resistors can be installed in any or all of the locations labeled R1, R2, or R3. The resistor value is calculated by setting the amplitude of the discharge pulse. The discharge pulse amplitude is typically 2.5 times the charge current based on 1.4V/cell. The required power rating of the resistor is highest when the Discharge-to-Charge and Discharge-Only Auxiliary Modes are used. See the ICS1702 data sheet for additional information. The resistor locations R1, R2, and R3 are connected in series. The unused locations must have a jumper to complete the circuit. Not using the discharge pulse feature will not affect the performance of the ICS1702.

The ICS1702 is capable of operating at nine different charge rates between 4C (15 minutes) and C/4 (four hours). The charge rate is selected by installing jumpers in the appropriate locations. Table 2 shows the proper settings to use for the desired charge rate.

**Table 2: Charge Rate List**

Charge Rate	Jumper S0	Jumper S1	Topping Charge pulse Rate	Maintenance Charge Pulse Rate	Fast Charge Timer Duration (after reset)
4C (15 min)	1 & 2	1 & 2	one every 40 sec	one every 160 sec	21 min
2C (30 min)	1 & 2	2 & 3	one every 20 sec	one every 80 sec	39 min
1.3C (45 min)	1 & 2	None	one every 13 sec	one every 53 sec	57 min
1C (60 min)	2 & 3	1 & 2	one every 10 sec	one every 40 sec	75 min
C/1.5 (90 min)	2 & 3	None	one every 7 sec	one every 27 sec	110 min
C/2 (120 min)	2 & 3	2 & 3	one every 5 sec	one every 20 sec	144 min
C/2.5 (150 min)	None	1 & 2	one every 4 sec	one every 16 sec	212 min
C/3 (180 min)	None	None	one every 3 sec	one every 13 sec	244 min
C/4 (240 min)	None	2 & 3	one every 2 sec	one every 10 sec	275 min

The ICS1702 has several auxiliary modes available. Table 3 shows the jumper configurations for the auxiliary modes.

**Table 3: Mode Select List**

Mode Selected	Jumper AUX0	Jumper AUX1	Mode Operation
Direct Maintenance	2 & 3	1 & 2	Indefinite C/40 maintenance charge
Charging System Test	2 & 3	2 & 3	Charging system test for embedded applications
Ten Hour Timer	1 & 2	1 & 2	Limits total charge including the maintenance charge to 10 hours
Discharge-to-Charge	1 & 2	2 & 3	Battery discharge to 1V/cell followed by the selected charge mode
Condition	1 & 2	None	Timed C/10 topping charge followed by a C/40 maintenance charge
Fast Charge	None	None	Normal fast charge
Discharge-Only	None	2 & 3	Battery discharge to 1V/cell



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The ICS1702 has the capability to use either temperature slope termination, voltage slope termination or both methods simultaneously. Table 4 shows the termination method and the jumper settings. Refer to the ICS1702 data sheet for more information on charge termination methods.

**Table 4: Termination Select List**

Termination Method	Jumper DTSEL
Voltage slope termination only	None
Voltage slope and temperature slope termination	1 & 2
Temperature slope termination only	2 & 3

### Power Requirements

The evaluation board uses a regulator to provide +5 volts for the controller. The regulator allows operation from a DC supply of 8 to 32 volts when the supply is connected to the +V terminal. The board may also be operated from an external 5 volt supply by removing the regulator (U2), wiring a jumper between regulator pins 1 and 3, and by connecting 5 volts directly to the +5V terminal.

### Connections To External Circuitry

A normally closed thermal switch or a thermistor should be connected to the TS terminal. If a thermal protection device is not used, the TS terminal must be grounded.

Connect the battery between the +BAT and GND terminals. If using an external current source, connect the charging current source and its return between the +CUR and GND terminals. If the on board current source is used, no connection to the +CUR terminal is required.

Two charge signals are provided to control external charging circuitry. CHG is high when the charging current is on. The other signal CHG is low when the charging current is on.

The charging circuitry should provide a current at an amplitude that is equal to the product of the battery capacity and the desired charge rate. For example, to charge a 1.2 ampere hour battery in 30 minutes, the current required would be 2.4 amps or 2C where 'C' is the battery capacity.

It is important to note that the ICS1702 does not control the current flowing into the battery in any way other than turning it on and off. The charging current should be constant when using voltage slope termination. The current may vary when using temperature slope termination.

### Current Regulator (CR option)

The ICS1702EB/CR contains an LM317 regulator. The LM317 is configured as a constant current source. The amplitude of the current is determined by the value of R15 and the setting of R16. As an example, with a 2 ohm resistor for R15, the current can be adjusted with R16 from 0.625A to 1.25A. The LM317 will regulate a voltage difference of 1.25 volts between the OUT and ADJ pins.

### Operation

Before applying power to the board, ensure that the board is properly initialized.

- Set the AUX0 and AUX1 jumpers for the desired mode of operation.
- Set the S0 and S1 jumpers for the correct charge rate.
- If needed, set the DTSEL jumper for the desired termination method.
- Check to make sure the divider resistors R6 and R8 are of the correct value to normalize the battery pack voltage to one cell.
- If applicable, choose a value for R15 (see the section on Current Source).
- If applicable, choose resistors R1, R2 and R3 to obtain the required discharge current.

After applying power to the board, set the following:

- Adjust the potentiometer R7 for the desired open circuit reference voltage at the OPREF pin.
- If applicable, set the LM317 charging current by adjusting the potentiometer R16.
- Push and hold the reset switch SW1 for at least 700ms. All LEDs should turn off while the switch is depressed. If fast charge is selected, the green CHG LED will light. The LED will remain lit until full charge is detected by the ICS1702. At that moment, the CHG LED will turn off and the MAINT LED will light, indicating that the topping charge stage has begun. The MAINT LED will remain on until a reset is issued either by interrupting the power, removing the batteries or depressing the reset switch SW1.

If the ten hour timer mode is selected, the LED sequence is the same as the fast charge sequence explained above. After a maximum of 10 hours has elapsed (from the time the ICS1702 was reset), the controller will shut down and the MAINT LED will turn off.

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If either direct maintenance or the condition mode is selected, the MAINT LED will turn on. The LED will remain on until a reset is issued either by interrupting the power, removing the batteries or depressing the reset switch SW1.

If the discharge-only mode is selected, the MAINT LED will flash at a one second rate until the battery has been discharged. When the battery is discharged, the controller will shut down and the MAINT LED will turn off.

If the discharge-to-charge mode is selected, the MAINT LED will flash at a one second rate until the battery has been discharged. When the battery is discharged, the appropriate charge indicator will turn on. See the data sheet for more detailed information on this auxiliary mode of operation.

## Polling for a Battery

Upon power-up or after a reset is issued, any excess charge from filter capacitors at the +BAT and +CUR terminals is removed with a series of discharge pulses. After the discharge pulse series is complete, the voltage at VIN must be greater than 0.5V when a battery is present. If the voltage at the pin is less than 0.5V, the ICS1702 assumes no battery is attached, and the polling detect mode is initiated.

The ICS1702 then applies a 100ms charge pulse. During the pulse, the ICS1702 monitors the VIN pin to determine if the divided down terminal voltage is above OPREF. If the battery is present, the voltage will be clamped below the reference on OPREF when the current pulse is applied. If a battery is not present, the voltage at VIN will rise above the reference at OPREF. The POLL LED lights immediately.

Charge pulses will repeat at one second intervals until the battery is reinstalled. The POLL LED is active as long as the ICS1702 is in the polling detect mode. Once a battery is installed, the ICS1702 will turn off the POLL LED and enter the soft start stage. The ICS1702 will automatically re-enter the polling detect mode if the battery is removed during the fast charge, topping charge, or maintenance charge stages. Any open circuit in the current path to the battery will initiate the polling detect mode.

When in the topping charge or maintenance charge stages, a charge pulse may not occur for several seconds. During the period between charge pulses, the voltage at VIN should be greater than 0.5V if a battery is attached. If the voltage at VIN is less than 0.5V, the ICS1702 assumes the battery has been removed, and the polling detect mode is initiated.

## Out-of-Temperature Range

The TEMP LED activates if the battery is either too hot or too cold to fast charge. If a thermistor is used, the ICS1702 employs internal voltage references to determine if a battery is hot or cold. *Note: Remove R9 and replace with a jumper when using a thermistor.* A 10k $\Omega$  @ 25°C thermistor with an external pull-up resistor is typically used. See the ICS1702 data sheet for additional information.

If a thermal switch is used, choose a switch that opens at 45°C or lower. If a thermal protection device is not used, the TS terminal must be grounded.

GPI strongly recommends the use of a thermal safety device in the battery pack. One source of thermal switches is Portage Electric Products, Inc., in North Canton, Ohio; (216) 499-2727. A source of thermistors is Semetic USA (Ishizuka Electronics Corp.), Babylon, NY; (516) 587-4086.

## Design Considerations

When designing external current source circuitry for use with the ICS1702, there are several important considerations to make before starting the design and the PC board layout.

For fast charge rates (1C through 4C), consideration has to be given to the use of a pulse-width modulated switch mode current source in order to reduce size and power dissipation.

Switch mode current sources can provide the ability to charge battery packs that require voltages higher than the primary supply. For instance, to charge a 24 volt battery from a 12 volt vehicle battery, a switch mode boost converter could be used.

In general, linear chargers are less complex and more cost effective, but less efficient than switch mode chargers. For lower charge rates (C/1.5 through C/4), consideration should be given to using a linear charger unless the size and ability to dissipate heat are not available.

It is very important that care be taken to minimize noise coupling and ground bounce. In addition, wires and connectors can add significant resistance and inductance to the charge and discharge circuits.



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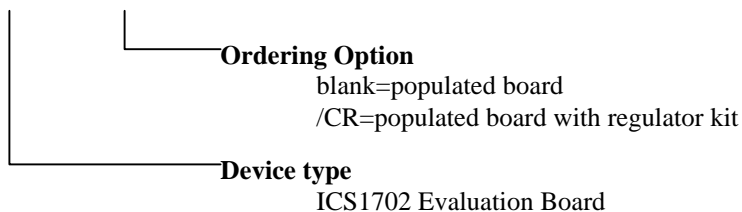
When designing the printed circuit board, make sure ground and power traces are wide and bypass capacitors are used right at the controller pins. Use separate grounds for the signal, charge, and discharge circuits. Separate ground planes on the component side of the PC board are recommended. Be sure to connect these grounds together at the negative lead of the battery only.

For the discharge circuit, keep the physical separation between power and return (ground) to a minimum to minimize field radiation effects. This precaution is also applicable to the constant current source, particularly if it is a switch mode type. Keep the ICS1702 and the constant current source control circuits outside the power and return loops described above. These precautions prevent high circulating currents and coupled noise from disturbing proper operation.

Galaxy Power Incorporated wants to help create a successful battery charging solution using the ICS1702. If you need technical advice or applications information, call the Intelligent Charging Solutions hotline at (610) 676-0188 x-277.

### Ordering Information

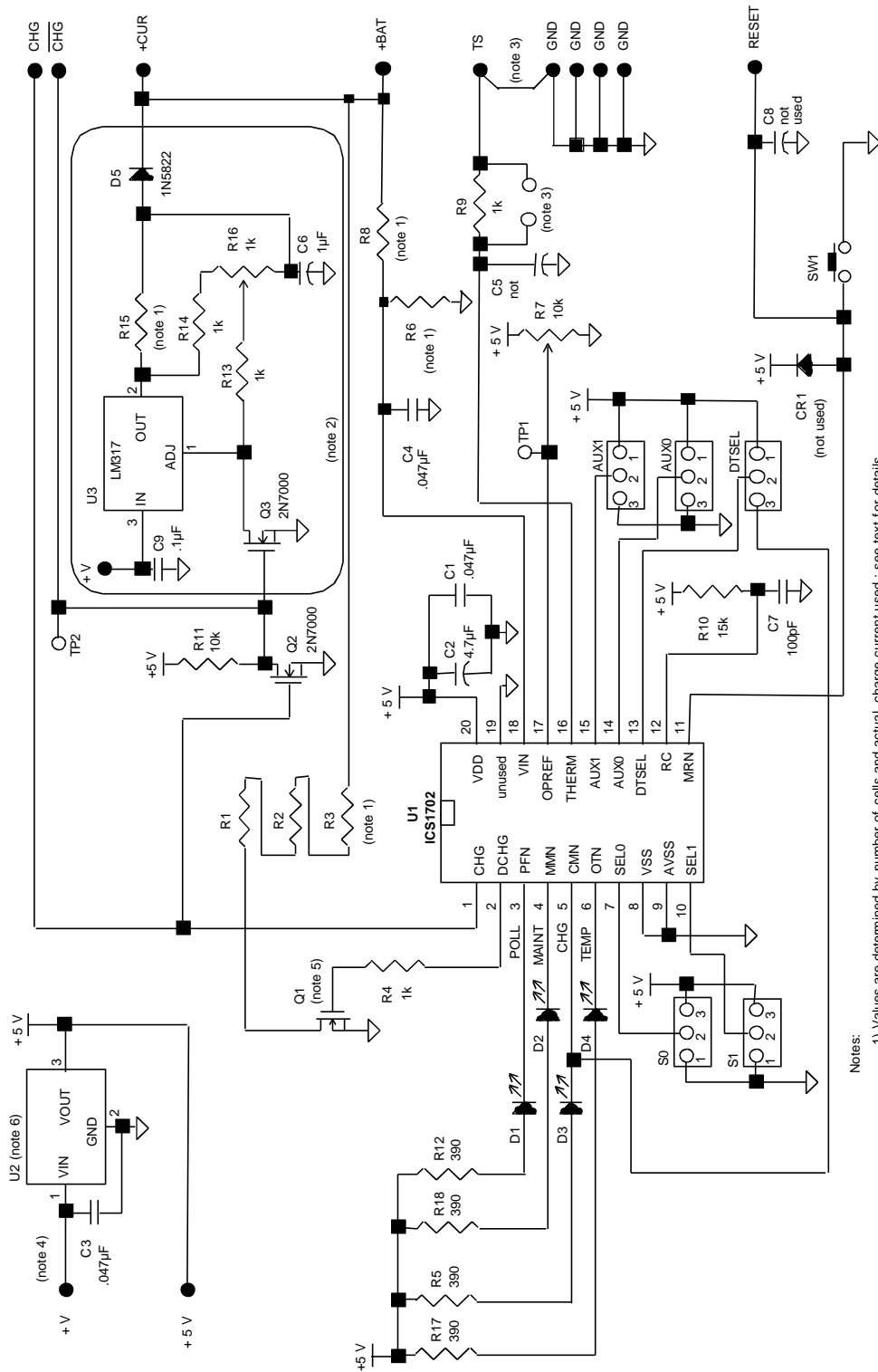
#### ICS1702EB /CR





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Notes:

- 1) Values are determined by number of cells and actual charge current used ; see text for details.
- 2) Components within dotted lines can be supplied as a kit for user-installation when ordered; see ordering information.
- 3) Remove TS to GND zero ohm resistor and replace R9 with a jumper when using a thermistor requires an external pull-up resistor to +5V (see ICS1702 data sheet for details).
- 4) 8 Vdc minimum input
- 5) Logic level compatible FET
- 6) LM340, AN7805 or equivalent

**ICS1702 EVALUATION BOARD REVISION C SCHEMATIC**