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Application Note #: AN0020

Device: ICS1708

Description: Sequential Battery Charger for NiCd/NiMH Battery Packs with Thermistors

Theory Of Operation for a 5 Cell, 2.7A-Hr NiMH /NiCd Battery Pack with Thermistors

1.0 Purpose

The schematic provided shows a sequential charger configuration using two ICS1708 NiMH/NiCd charge control ICs with low cost through-hole and surface mount components available from many sources. Component count, size, and cost reductions may be realized by implementing through-hole or surface mount transistors that include integral resistors available from semiconductor manufacturers such as On Semiconductor, ROHM, and Panasonic. These sources also provide surface mount ICs consisting of multiple diodes, resistors, or capacitors

2.0 Charger Operation

One low cost 14 pin quad LM339 comparator and two low cost 8 pin ICS1708 charge control ICs provide the control for charging one battery pack alone in either slot or for charging two battery packs sequentially. Interfacing is shown utilizing through-hole bipolar transistors, 2N3905 PNP and MPSA14 NPN darlington, and 1N4148 diodes. Under normal conditions fast charge begins automatically on the first battery pack detected. Once fast charge starts on that battery pack, it normally continues until it is fully charged (“ready”). Then the charger proceeds to fast charge the other battery pack. Once fast charge starts on a battery pack, insertion or removal of the other battery pack has no effect on the battery fast charging. Similarly a fully charged battery pack that is “ready” in either slot is not affected by the insertion into or removal of the battery pack of any condition in the other slot.

2.1 Normal Priority Fast Charge Control Operation

Two sections of an LM339 quad comparator per slot are used for detecting battery insertion or removal and determining the temperature status of the battery pack. Under normal conditions once fast charge begins, the other slot is disabled. The ICS1708 that starts fast charge on the battery in its slot immediately removes the 5V supply from the other ICS1708 using its CMN pin 3 via transistor interfacing. This action is bi-directional between the two ICS1708s. So there is no specified priority slot. Priority is determined by the ICS1708 that starts fast charge first. When fast charge completes, the ICS1708 indicates “ready” and keeps its own 5V supply on using its MMN pin 2 and releases the 5V supply to other ICS1708 as its CMN pin 3 turns off via transistor interfacing.

2.2 Normal Two Battery Fast Charge to Topping/ Maintenance Charge Stage Sequencing

Fast charge starts on the first battery detected when two normal condition battery packs are in the charger at power up, or when one battery pack is inserted right after the other. The other slot is disabled until fast charge completes on the first battery pack. Then fast charge begins immediately on the second battery pack. The ICS1708 controlling the slot with the second battery pack disables the topping charge to the first battery pack until fast charge completes on the second battery pack. This method provides full power availability to fast charge the uncharged battery pack and also insures that no interfering affects can occur as the uncharged battery pack fast charges. When fast charge completes on the second battery pack, topping and maintenance charging commences on both battery packs. Once fast charge begins, the topping charge capability to the other slot is disabled. The ICS1708 that is controlling fast charge on the battery in its slot, immediately overrides the CHG pin 1 function of the other ICS1708 using its CMN pin 3 via diode interfacing. This action is bi-directional between the two ICS1708s.

2.3 Topping and Maintenance Charge Control Operation

Once an ICS1708 completes fast charge on the battery in its slot, the battery is ready for use. If the battery remains in the slot, the ICS1708 controlling that slot is available to apply the topping and maintenance charge stages. If there is no battery in the other slot or if the battery in the other slot too cold to fast charge (near 5 °C or colder), or has an internal open, an activated PTC protector being most likely, topping charge proceeds on the "ready" battery. Other opens to or in the other battery pack such as a plus to minus open or an open to or in the thermistor circuit allows topping to continue on the charged battery that is "ready" and remains in the charging slot.

2.4 Hot Battery Management

The best remedy for a hot battery pack (50 °C or hotter) is to instruct the user to rest the battery pack until it is cool to the touch. If a hot battery pack is installed or it gets hot during fast charge and the other battery pack is installed waiting to be fast charged, fast charge stops on the hot battery pack and fast charge begins on the other battery. If there is no other battery pack or if it has already completed fast charge (i.e. it is "ready"), the fast charge fast stage remains active for the hot battery pack, but no charge current is applied. The hot battery indicator goes on. If the battery cools down a few degrees, the hot battery indicator goes off and charging continues. Charge current is applied and removed appropriately into the topping/maintenance charge stages. The output of the lower LM339 comparator for each slot goes low when the battery in its slot is hot or gets hot. The comparator overrides the CHG pin 1 function of the ICS1708 and activates the 5V supply to the other ICS1708 via diode interfacing. This action is bi-directional between the two ICS1708s. The hot battery indicator remains on whenever the battery pack temperature is above 50 °C.

2.5 Cold Battery Management

The best remedy for a cold battery pack (near 5 °C or colder) is for the user to allow the battery pack to warm above 5 °C. Cell manufacturers are emphatic about not fast charging very cold battery packs. Fast charging stops if the battery pack drops below 5 °C in this application. If a cold battery pack is installed or gets cold during the charging process, and the other battery pack is installed waiting to be fast charged, fast charge begins on the other battery. If there is no other battery pack or if it has already completed fast charge i.e. is "ready", the cold battery must warm above 5 °C before fast charge begins. The charger slot with the cold battery remains off until the battery warms above 5 °C. The output of the upper LM339 comparator for each slot goes high when the battery in its slot is or gets cold. The comparator removes the 5V supply to the ICS1708 controlling fast charge to the cold battery via transistor interfacing. In the unlikely but possible event a battery gets cold while in the topping and maintenance charge stages, the comparator output high mentioned above is bypassed via diode interfacing to MMN pin 2, so the 5V supply to the ICS1708 remains on and the topping/maintenance charges continue.

2.6 Defective Battery Management

The most common failure mode of battery packs besides eventually losing their ability to store charge is shorted cells. Each of these occurrences is manifested to users by the abrupt performance decline they observe and knowledge they have about the age, use pattern, and sometimes appearance of the battery pack. Galaxy Power provides methods for detecting and indicating shorted cells, so this feature could also be included as part of an enhanced version of this application.

An open PTC due overload in use, or any open cell, interconnect, etc. in the plus to minus path in the battery pack prevents charging of that battery as the ICS1708 begins its polling mode. If the other battery is installed and it has not already been fast charged (i.e. not "ready"), the charger will fast charge that battery pack. An open in the thermistor or connection to it, results in the same function as an open in the plus to minus power path as mentioned above, except the ICS1708 does not begin its polling mode as it has no 5V supplied to it with for the missing thermistor condition.

3.0 Power Management

The application shown uses Power Integration's "top switch" converter typology to create input power for the dual sequential charger. The input voltage provided by the top switch converter is held to 1.3V above the voltage of the battery fast charging. This approach allows use of a low drop, low cost linear current source configuration, minimizing heat generation. One of two 2N3905 PNP transistors connects the top switch voltage sense circuit to the appropriate battery; i.e. the battery pack being fast charged. Using a transistor interface one of the two ICS1708s switches on and off an IRF7321D2 FETKY which is also controlled by the single current source control. The P channel transistor in the FETKY is both a switch and a low drop linear current regulator pass element.

The current source control consists of a single 2N3905 transistor sensing the voltage drop across a .27Ω, 5W resistor with its base emitter junction. The 2N3905 collector controls the gate of the FETKY transistor providing a regulated 2.5A current source. Keeping the charge current at about 2.5A keeps the charger's input power consumption just below 25Watts allowing use of Power Integration's low cost 8 pin TOP243 IC in the converter for providing the input power to the sequential charger. With a 2.5A charging source battery packs charge from completely empty to completely full well within the ICS1708 1C (1Hour) 75 minute fast charge timer limit.

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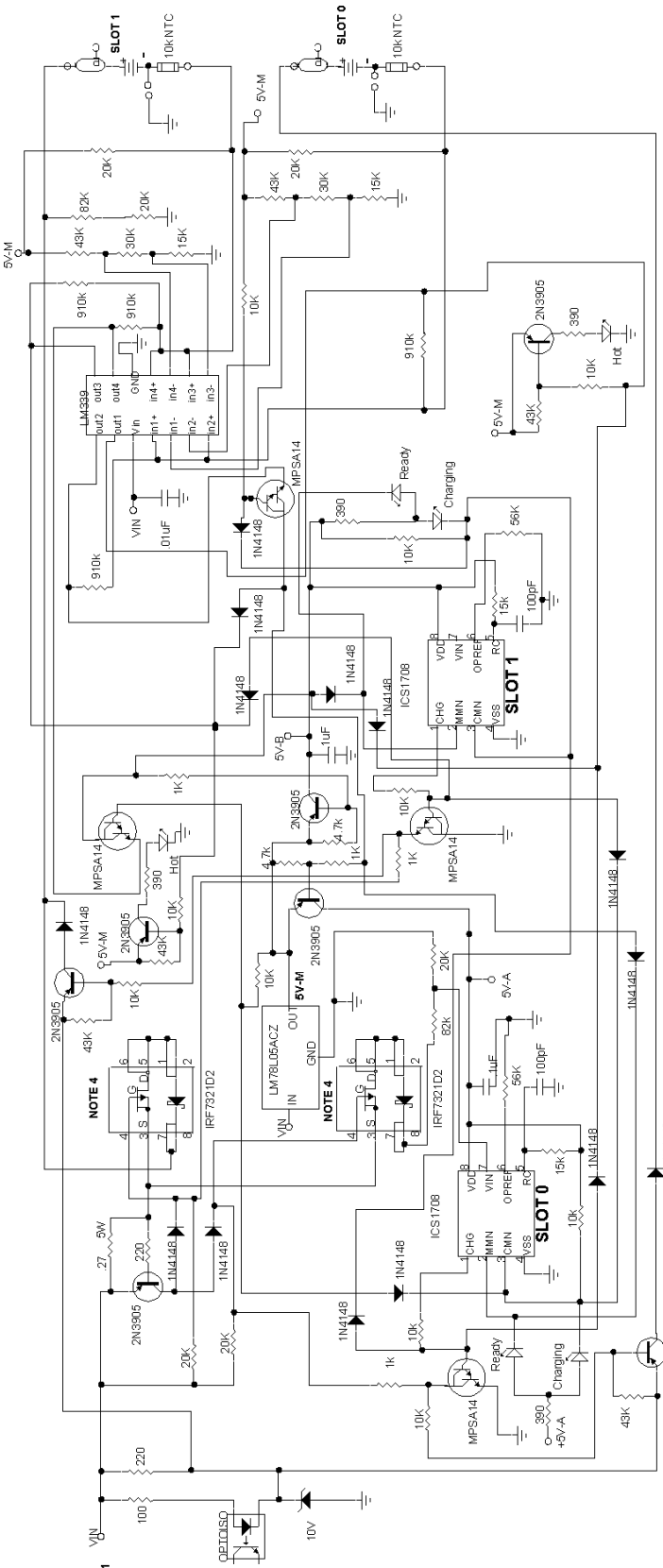
SLOT 1
SLOT 0
10kNTC
5V-M
LM339
ICS1708
MPSA14
2N3905
IRF7321D2
LM78L05ACZ
TOPSWITCH CONTROL
OPTOISO
Ready
Charging
Hot
Notes:
1. Input provided by Power Integration TOP243 based top switch converter.
2. Schematic is for costing and breadboarding purposes.
3. All resistors ar .25W, 5% unless otherwise specified.
4. IRF7321D2 are surface mount on large foil (greater than 1.5 sq.in. per device)
5. Quad comparator is LM339.

Sequential Charger Electronic Component Costing

P/N	QTY		UNIT PRICE (1Kpcs)		TOTAL
100	1		$0.01		$0.01
220	2		$0.01		$0.02
390	4		$0.01		$0.04
1K	4		$0.01		$0.04
4.7K	2		$0.01		$0.02
10K	10		$0.01		$0.10
15K	4		$0.01		$0.04
20K	6		$0.01		$0.06
30K	2		$0.01		$0.02
43K	6		$0.01		$0.06
56K	2		$0.01		$0.02
82K	2		$0.01		$0.02
910K	4		$0.01		$0.04
.27 5W	1		$0.13		$0.13
1N4148	14		$0.04		$0.56
2N3905	7		$0.04		$0.28
MPSA14	4		$0.06		$0.24
IRF7321D2	2		$0.79		$1.58
LM7805ACZ	1		$0.14		$0.14
LM339	1		$0.18		$0.18
ICS1708	2		$0.73		$1.46
LED	6		$0.08		$0.48
10 V Zener	1		$0.10		$0.10
100pF	2	5% NPO	$0.04		$0.07
.01uF	1		$0.03		$0.03
.1uF	2		$0.03		$0.06
Total					$5.80

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1. Component count & cost reductions will be realized as surface mount ICs (multiple transistors with integral resistors; multiple diode & resistor networks) are incorporated into the approach.
2. Contact Power Integrations for TopSwitch control input and pricing.