ON Semiconductor

Design Note – DN06044/D

Switching Charger for Rechargeable NiCd and NiMH Batteries

Device	Application	Input Voltage	Current	Topology	I/O Isolation
NCP3066 MC33340(2)	Nixx Battery Charger	1-8 Cells (5-25 V)	>1.2A	BUCK	NONE

Circuit Description

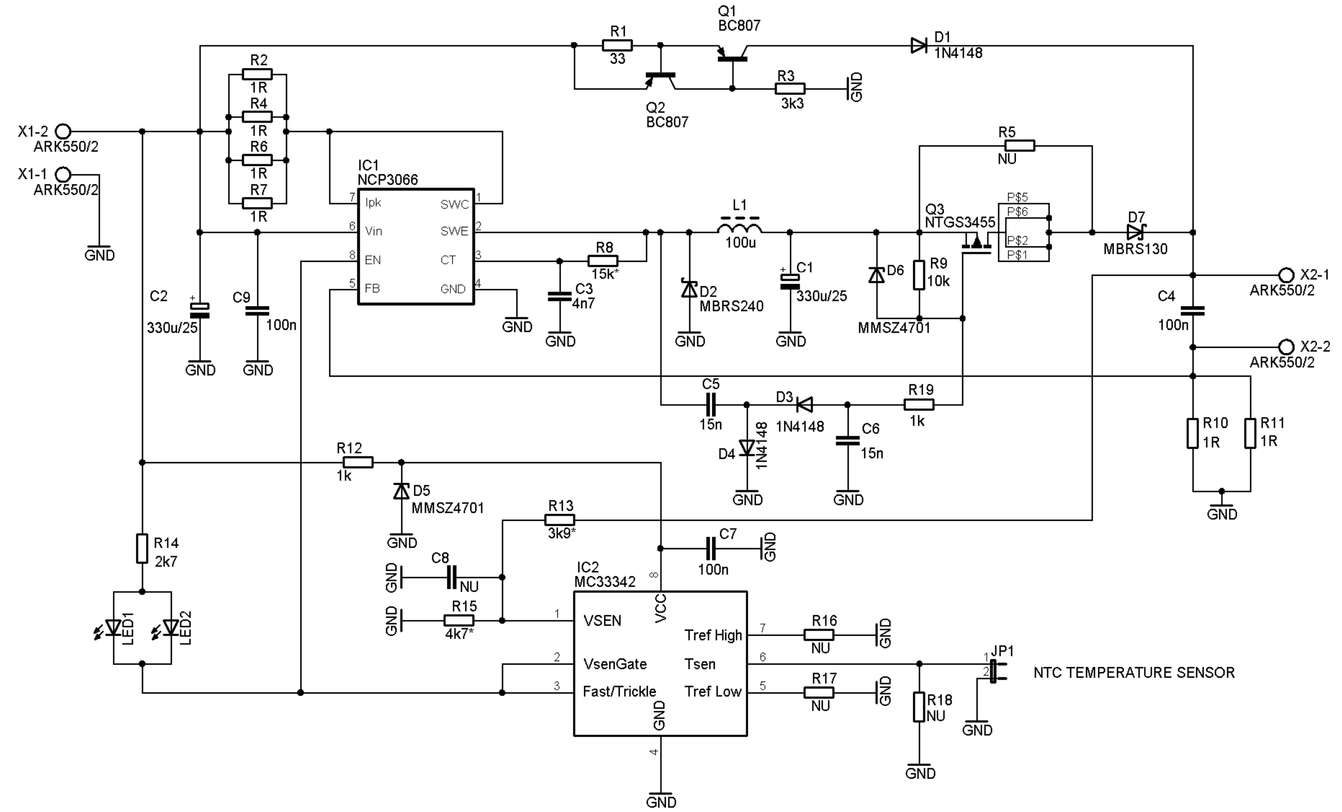
This circuit is intended for charging NiCd and NiMH batteries with 1-8 cells in series. Power circuit is based on the NCP3066 in the constant current mode oriented buck converter. It operates around 135 kHz switching frequency in continuous conduction mode.

Charging is controlled by the MC33340(2) that is searching negative voltage slope to detect a fully charged battery. The MC33340(2) has battery undervoltage and overvoltage protection, charge time or temperature protection.

Key Features

- Switching operation
- Wide input and output operation voltage
- Regulated output current
- High frequency operation
- Minimal output current ripple
- Reverse battery protection
- Output short circuit protection
- Time or temperature protection
- Small components size
- Single layer PCB

Schematic



**) These components should be changed for cell count other than 2 cells (see Table 1).*

Figure 1 – Nixx battery charger schematic

Design Notes

The charger is separated into a power and a logic part. The power part is controlled by the NCP3066 and the logic part by the MC33340(2). The power part is used to control constant charging current, the logic part is used to control charging circuit and manage protection. There is also a trickle charging circuit (Q1, Q2, R1, R3 and D1) that charges batteries with a small constant current to keep the battery in a charged state after fast charging is completed.

Power part

Output current is set by resistors R10 and R11. Thanks to the low feedback voltage there is also a small power loss. Output current and power loss can be calculated using equations (1) and (2).

$$I_{OUT} = \frac{V_{FB} \cdot (R10 + R11)}{R10 \cdot R11} = \frac{0.235 \cdot (1+1)}{1 \cdot 1} = 0.47A \qquad (1)$$

$$P_{R10R11} = V_{FB} \cdot I_{OUT} = 0.235 \cdot 0.47 = 110mW \qquad (2)$$

Inductor is selected according to equation (3).

$$L_{\min} = \left(\frac{V_{OUT}}{f \cdot \Delta I_{L\max}}\right)\left(1 - \frac{V_{OUT}}{V_{IN\max}}\right) = \left(\frac{6}{135 \cdot 10^3 \cdot 0.75 \cdot 0.47}\right)\left(1 - \frac{6}{25}\right) = 95.8\mu H \Rightarrow 100\mu H \qquad (3)$$

Operation frequency is set by capacitor C3 and pulse feedback resistor R8 that is used to stabilize convertor operation. Its value is around 135 kHz. Pulse feedback resistor value is experimentally founded for different battery cell count.

Peak current is limited by R2, R4, R6 and R7 to 740 mA.

Battery reverse polarity protection is composed by Q3, D3, D4, D6, C5, C6, R9 and R19. A charge pump is used to get enough gate voltage to open the protection P-MOSFET if the NCP3066 is switching. When the battery is connected wrong then the NCP3066 is blocked by the MC33340(2), the charge pump does not allow voltage to open the P-MOSFET and the battery is disconnected. Zener diode D6 protects Q3 gate against high V_{GS}. If this protection is not needed then all protection components should be not used and R5 (0 Ω) will cross MOSFET. But if battery is connected with reverse polarity then short current will flow through R10, R11, D2, L1 and R5.

Trickle charging current is set by resistor R1. Charging current value can be calculated by equation (4)

$$I_{TRICKLE} = \frac{V_{BEQ2}}{R1} = \frac{0.6}{33} = 18mA \quad (4)$$

Control part

Charging is controlled by the MC33340 or the MC33342. The difference is fast charge hold off time only. For the MC33340 it is 177 s and for the MC33342 it is 708 s. Power supply voltage for the control IC is limited by the shunt regulator (D5 and R12). This IC controls power by utilizing the NCP3066's ENABLE pin which is used to switch on and off fast charging. The MC33340(2) has a voltage sensor input with under and overvoltage protection. This protection is set by the resistor divider R13 and R15 so that the voltage on the V_{SEN} pin will be between 1 – 2 V.

$$V_{SEN\,\min} = CellCount \cdot 0.9 \cdot \frac{R15}{R13 + R15} \quad (5)$$

$$V_{SEN\,\max} = CellCount \cdot 1.5 \cdot \frac{R15}{R13 + R15} \quad (6)$$

Suitable resistor divider, pulse feedback resistor value and minimum input voltage are in Table 1.

Table 1. Components depended on cells count

Cells count	R13 [kΩ]	R15 [kΩ]	C3 [nF]	R8 [kΩ]	V_{INmin} [V]
1	3.9	NU	4.7	22	4.5
2	3.9	4.7	4.7	22	6.5
3	6.8	4.7	4.7	22	8.5
4	12	4.7	4.7	22	11.5
5	15	4.7	5.6	27	13
6	18	4.7	8.2	22	16
7	22	4.8	8.2	27	18
8	27	4.9	8.2	33	19.5

Resistors R16, R17 and R18 set the charge time limit or under/over temperature limit. Time setting is made by resistors for R16 – R18 (0 Ω to disable). Temperature sensor (NTC) can be connected to JP1 and by R16 a R17 can be set under and over temperature limit. Time setting is in Table 2 for temperature setting see MC33340(2) datasheet.

Table 2. Temperature and time limit configuration

Backup Termination Mode	Programming Inputs			Time Limit Fast Charge (Minutes)
	$t3/T_{ref}$ Low (Pin 5)	$t2/T_{sen}$ (Pin 6)	$t1/T_{ref}$ High (Pin 7)	
Time	Open	Open	Open	283
Time	Open	Open	GND	247
Time	Open	GND	Open	212
Time	Open	GND	GND	177
Time	GND	Open	Open	141
Time	GND	Open	GND	106
Time	GND	GND	Open	71
Temperature	0 V to V_{CC} − 0.7 V	0 V to V_{CC} − 0.7 V	0 V to V_{CC} − 0.7 V	Timer Disabled

Function monitoring

Charger indicates state of charging by one LED diode. There are two states, permanent lighting that indicates end of fast charging and all of errors like under/over voltage, overtime and under/over temperature. Second state is indicated by short LED blink with around 1 s period that indicates fast charging. There is possible to use SMT or thru hole LED on the PCB.

Higher charging current

Higher charging current is limited by the maximum peak current of the NCP3066 internal switch, but if an external switch is used the current can be higher.

Conclusion

This circuit is ideal to use for low cost high efficiency charging circuits for example for cameras, portable players and other devices power by NiCd or NiMH batteries. Its feature is small size, low power dissipation (no heatsink is needed) and single layer PCB. All components are the same size and are a standard value (in some cases there are additional footprints for one component to achieve required value).

PC Board

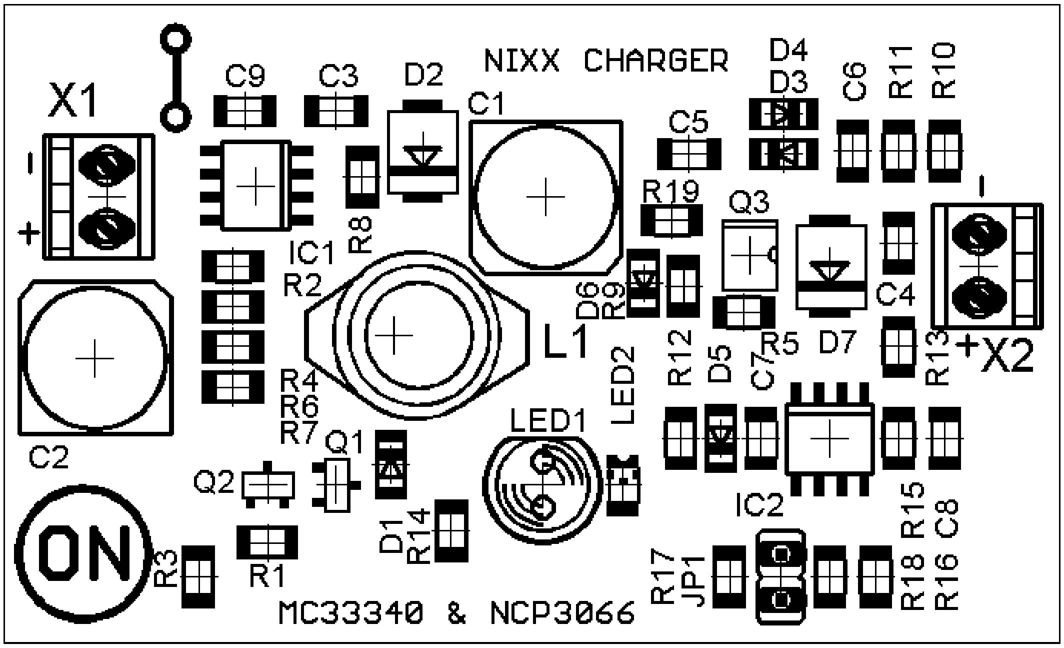


Figure 2 – components position on PCB

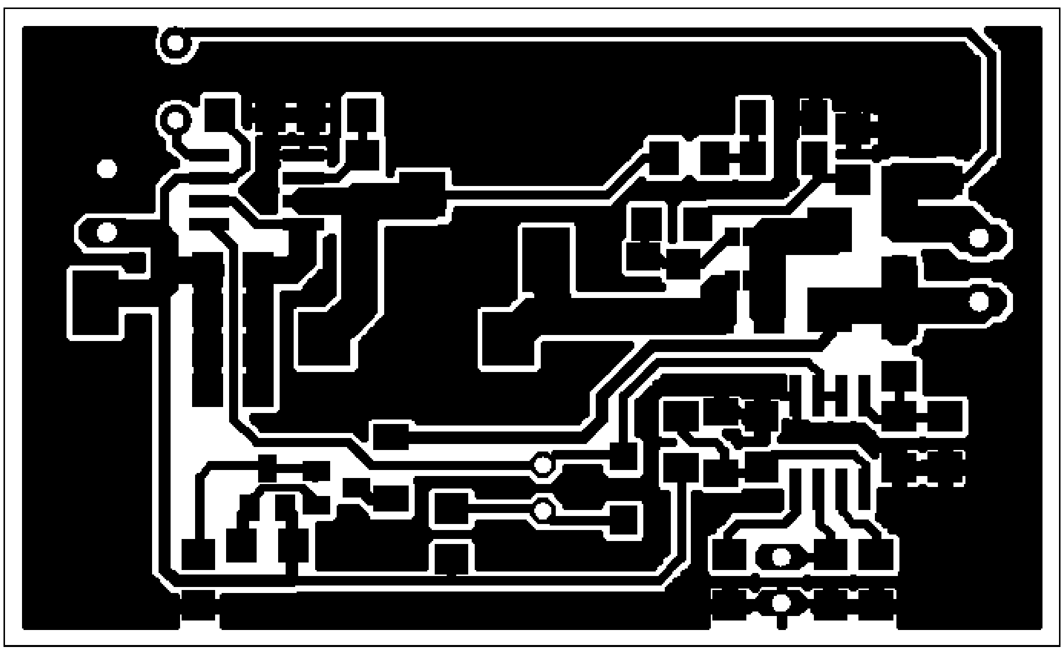


Figure 3 – PCB's top side (58 x 36 mm)

Measurements

Light blue – SWE pin
Dark blue – Output voltage
Pink – LED cathode
Green – Output current

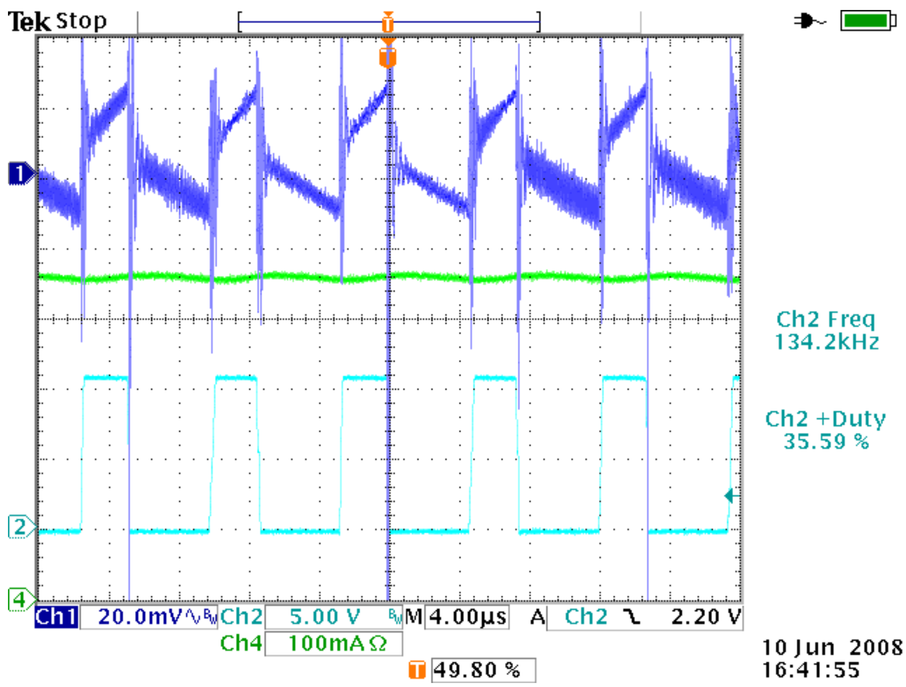


Figure 4 – V_{IN} = 12 V, 2x NiMH AA cell

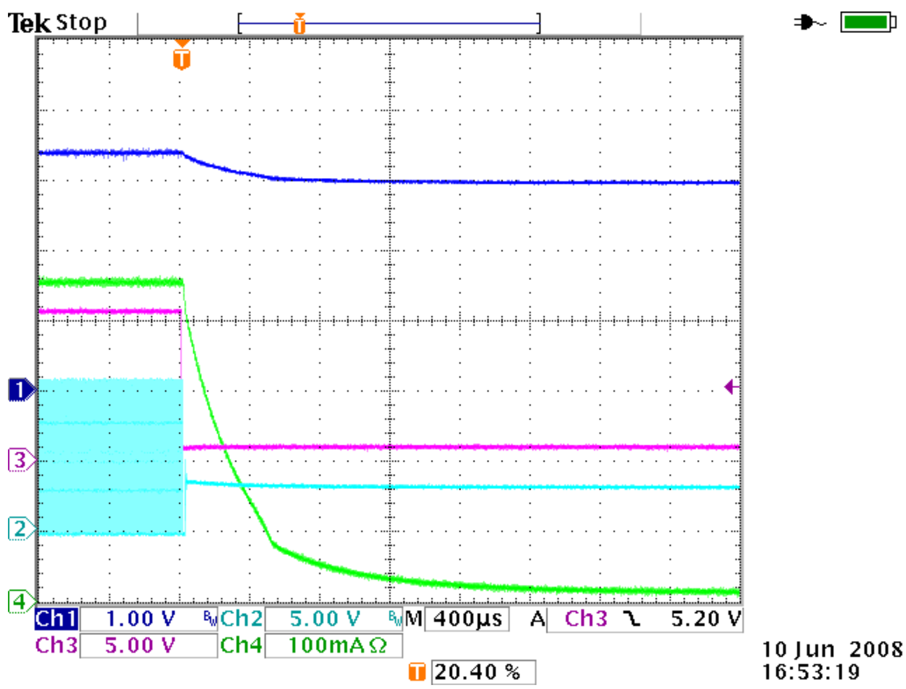


Figure 5 – V_{IN} = 12 V, 2x NiMH AA cell, charging switch off for measure

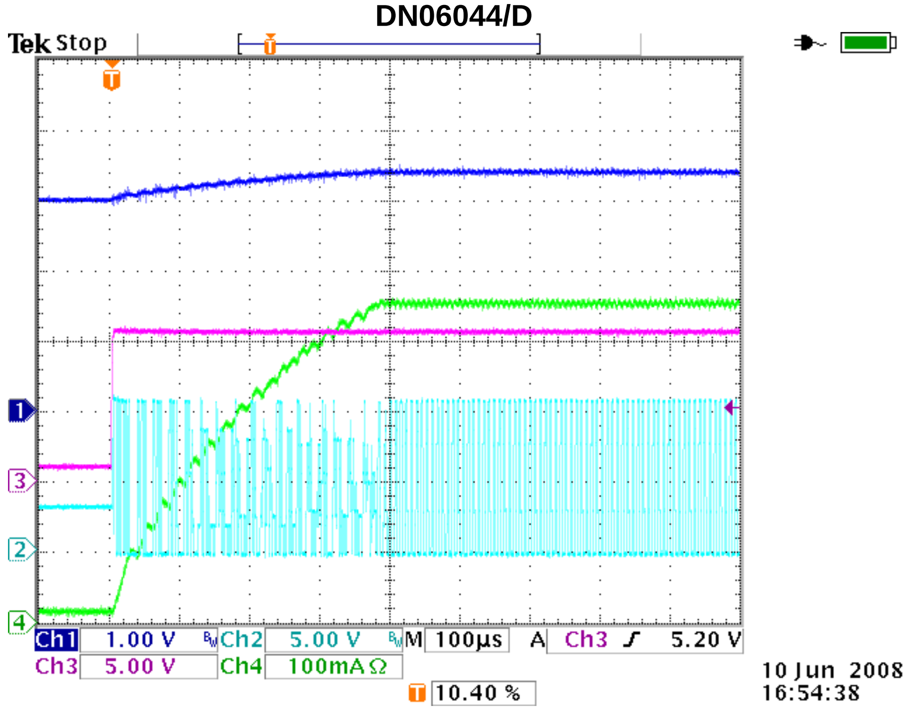


Figure 6 – V_{IN} = 12 V, 2x NiMH AA cell, charging switch on after measure

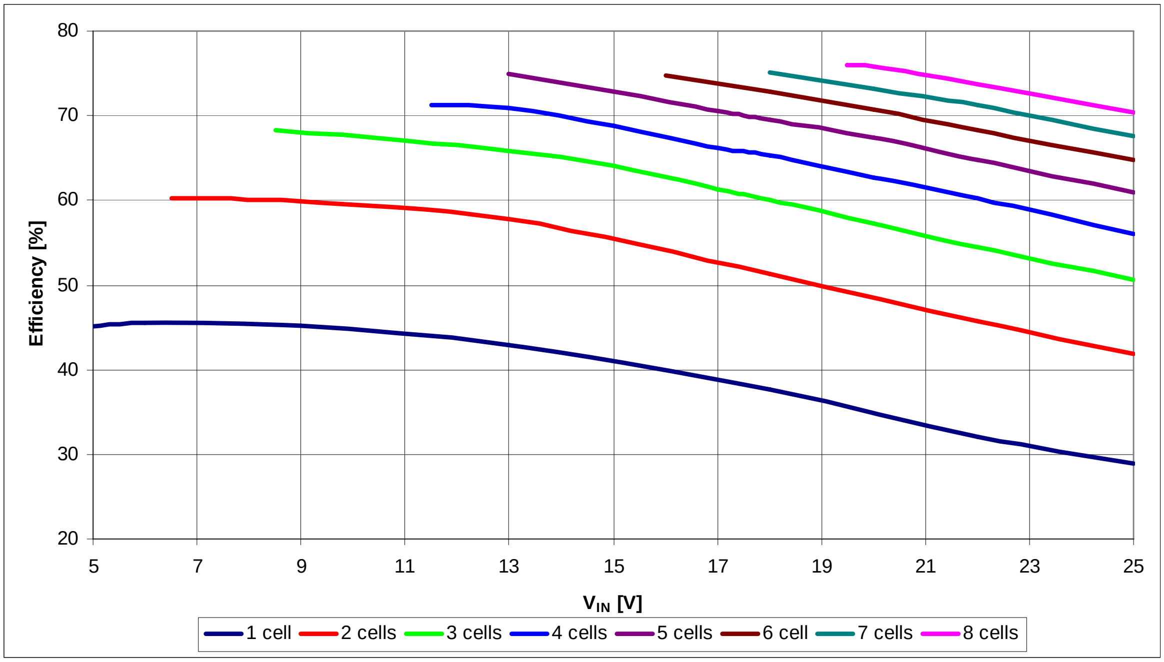


Figure 7 – Charger efficiency

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