Lithium-Ion Charger I

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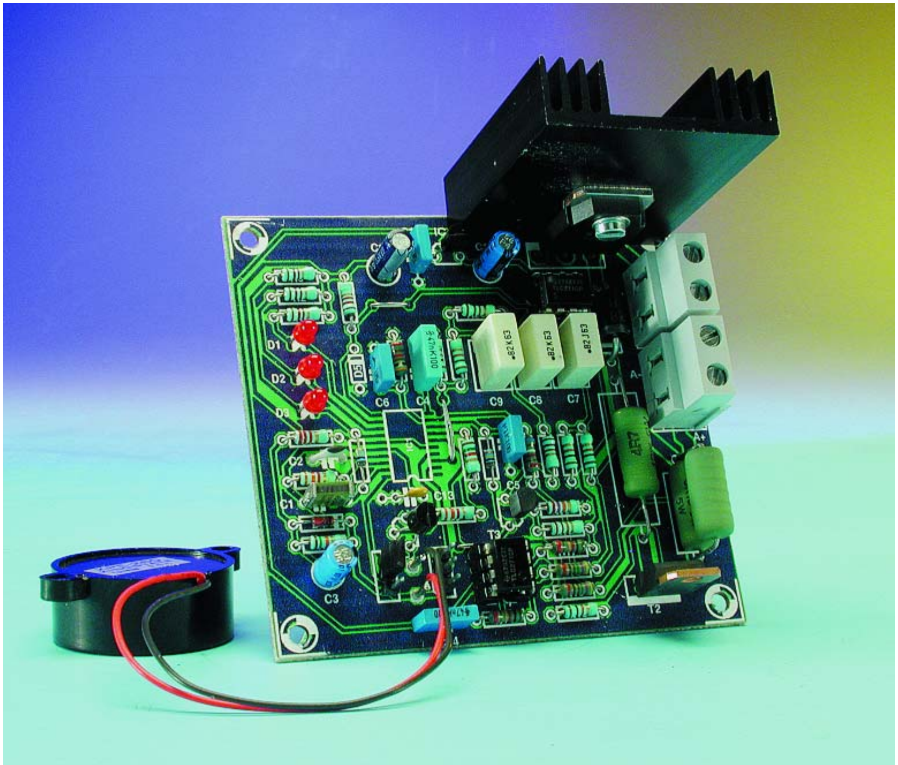


There are several ICs on the market that are specially designed for charging Lithium-Ion batteries. The LM3647 from National Semiconductor is one of those. The manufacturer describes this clever, 20-pins integrated electronics as a universal charge controller for Ni-Cd, Ni-MH and Li-Ion batteries. The IC can use a pulsed or constant charge current and can also be set up to discharge the battery before the charging process starts. During this process the LM3647 monitors the battery voltage, the time and (if required) the temperature. As soon as anything appears to go wrong, the charge current is stopped.

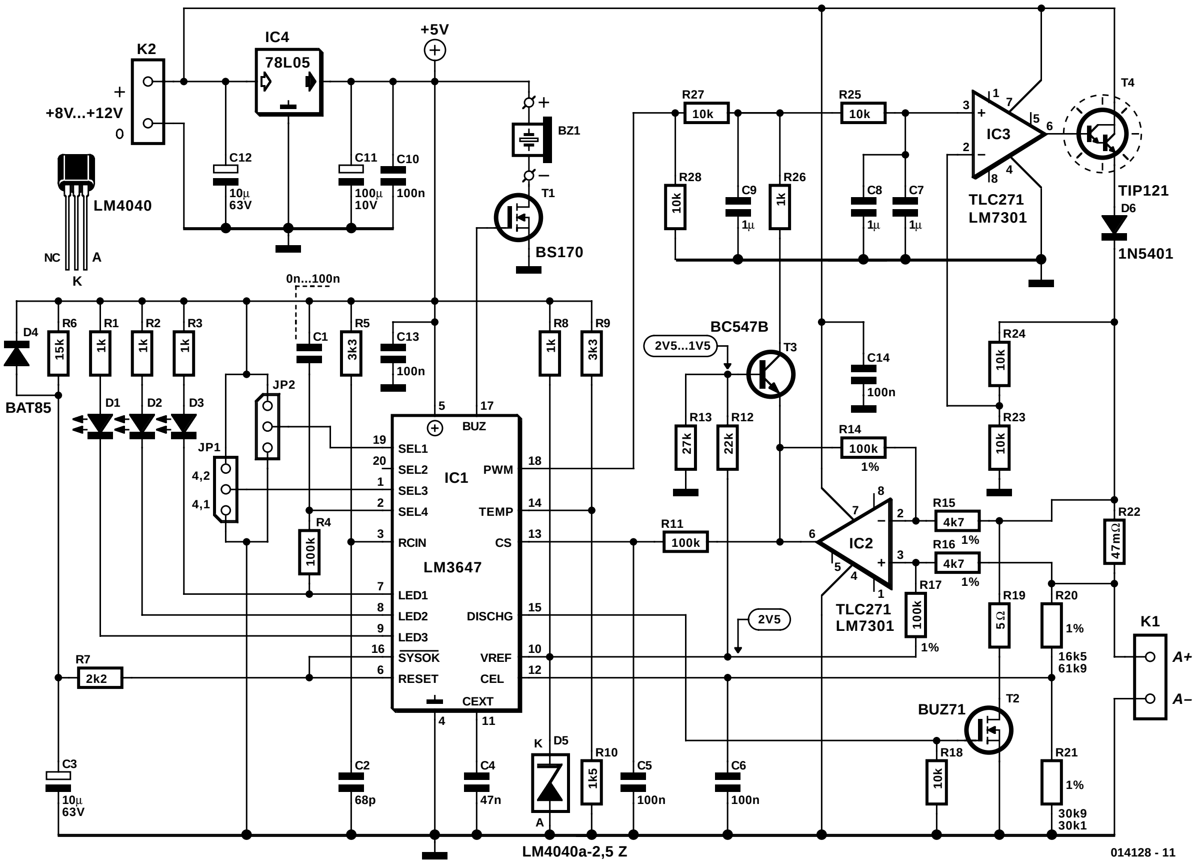
The circuit described here is only suitable for Li-Ion batteries. The discharge function is not used here because Li-Ion batteries do not require this.

Before you enthusiastically start building the circuit, it is wise to check that the IC is actually available. It is very recent and we had to work with samples that came direct from the manufacturer. Due to the lack of space we can only give a general overview of the operation of the IC and its use in the circuit based on that in the application note. We would advise that constructors download the data sheet and 'reference design user's manual' from the website at www.national.com. These contain much more detailed information.

For those who don't like to use the latest ICs and/or complex charge methods, we'd like to point out that there are also simpler solutions. Another article, 'Lithium-Ion charger II', which can be found elsewhere in this issue describes a method of charging Li-Ion batteries without the use of dedicated ICs.

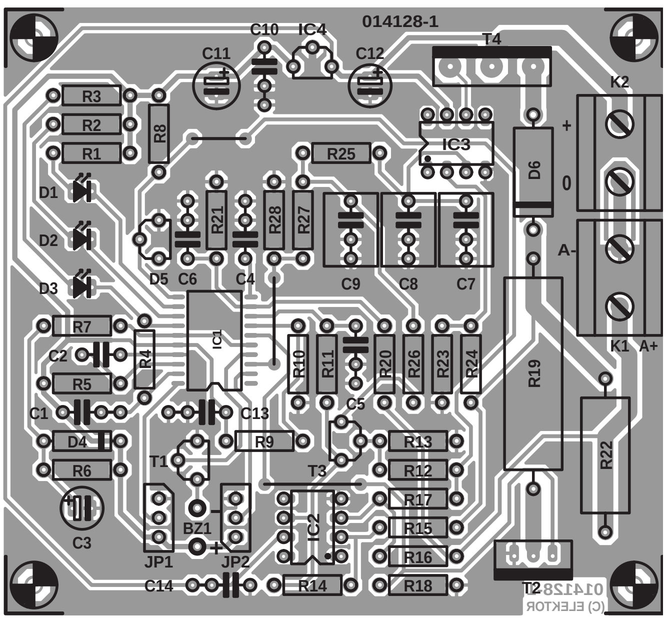
The circuit shown here generally works as follows. A mains-derived supply is connected to K2 and the Li-Ion battery goes to K1. The controller (IC1) detects when a battery is connected and begins a test phase during which the charging current is 0.2 of its maximum. If the battery voltage remains too low it is assumed that the battery is defective and an error condition is indicated by the LEDs. If the battery voltage rises too much during this period, the battery is fully charged and the charging process stops.

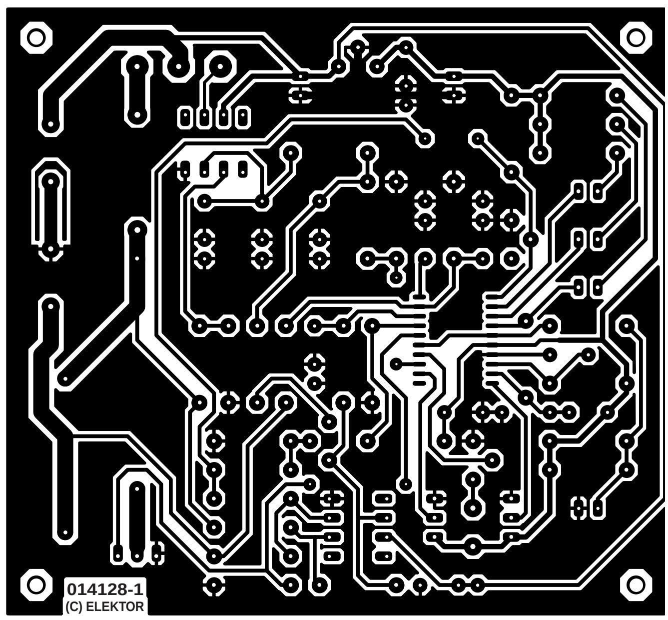
If the battery voltage is between these two limits, the battery will be charged at the maximum current (charge phase 1) after a short period of time (anywhere between tens of seconds to several minutes). That continues until the maximum battery voltage is reached; the current is then



reduced such that the battery voltage remains constant (charge phase 2). When the current drops below 0.2 of the maximum charge current the battery is fully charged. Each of these conditions is listed in **Table 1**.

In fact, only the charge voltage is regulated by the controller via its pulse width output (pin 18). This PWM signal is averaged and fed to IC3, which makes the voltage at the junction of D6 and R22 correspond to the PWM signal. With an oscilloscope it can be clearly seen how IC1 carefully increases the pulse width until a current begins to flow through the battery. This current is measured using R22. The voltage drop across R22 is amplified by IC2 and fed to the CS input of IC1. At the same time the charging voltage is measured via R20/R21 and the CEL input. This provides





COMPONENTS LIST

Resistors:
R1,R2,R3,R8,R26 = 1kΩ
R4,R11 = 100kΩ
R5,R9 = 3kΩ3
R6 = 15kΩ
R7 = 2kΩ2
R10 = 1kΩ5
R12 = 22kΩ
R13 = 27kΩ
R14,R17 = 100kΩ 1%
R15,R16 = 4kΩ7 1%
R18,R23,R24,R25,R27,R28 = 10kΩ
R19 = 5Ω 10W
R20 = 16kΩ5 1% (61kΩ9 1%)
R21 = 30kΩ9 1% (30kΩ1 1%)
R22 = 0.05 Ω 1W

Capacitors:
C1 = 0-100nF (22nF)
C2 = 68pF
C3,C12 = 10µF 63V radial
C4 = 47nF
C5,C6,C10,C13,C14 = 100nF
C7,C8,C9 = 1µF MKT
C11 = 100µF 10V radial

Semiconductors:
D1,D2,D3 = LED, high efficiency
D4 = BAT85
D5 = LM4040a-2.5 Z
D6 = 1N5401/SB530
T1 = BS170
T2 = BUZ71/BUZ 11
T3 = BC547B
T4 = TIP121/TIP142
IC1 = LM3647 IM (National Semiconductor)
IC2,IC3 = LM7301 / TLC271
IC4 = 78L05

Miscellaneous:
JP1,JP2 = 3-way jumper
K1,K2 = 2-way PCB treminal block, lead pitch 7.5mm
BZ1 = buzzer 6V
Heatsink for T4: e.g., Fischer type SK59 (Dau Components)

the IC with all the details to charge the battery.

The IC has an extra safety feature that terminates a charging phase after a certain amount of time, which is dependent on the value of C1 (see **Table 2**). Apart from that, the temperature of the battery can also be monitored. In that case R9 is replaced by a NTC, mounted in the battery holder. More information on this can be found in the previously mentioned data sheets.

Construction of the charger shouldn't cause any problems when the PCB shown here is used. There are a few practical points that should be mentioned.

As we said earlier, the battery is connected to terminal block K1 and the supply is connected to K2. This needs to be at least 8 V when one cell is charged or 12 V for two cells; obviously the supply should be capable of providing the required charging current. Transistor T4 has to dissipate a fair amount of heat and requires a heatsink.

The pins marked 'BZ1' (next to T1) are intended for an active buzzer. Components R19, T2 and R18 can simply be left out. These are never used in Li-Ion mode. But because these components are shown on National Semiconductor's application note, they were inadvertently added to the circuit. You should also pay attention to the value of oscillator capacitor C2; this really should be 68 p and not 8p2 as stated by the manufacturer.

When jumper JP1 is connected to earth, 3.6 V cells are charged, a jumper to the positive is for 3.7 V cells. Connecting JP2 to earth causes a small maintenance current to flow after charging is complete and the controller will automatically restart the charging process should the battery voltage become too low.

When charging one cell, R20 and R21 should have values of 16k5 and 30k9, for two cells in series they should be 61k9 and 30k1. In this design the maximum charging current is about 1 A (50 mV across R22). As you can see from the photograph, we've used two resistors of 0.1 Ω in parallel for R22, because we could not obtain one with a value of 0.05 Ω. Other currents can be selected by changing the value of R22.

And finally a very important observation: check that the maximum output voltage is not exceeded during the charging process. The voltage may never rise above 4.1 (4.2) volt per cell. If it seems that this limit may be exceeded the values of R20/R21 should be adjusted accordingly. Above this voltage there is a real chance that the battery could explode, **so pay particular attention to this**!

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