The operation of the circuit is quite simple. If the cells are not fully charged, a charging current flows freely from the voltage regulator, although it is limited by resistor R3 and transistor T1. The limit is set by the formula

$I_{max} = (0.6\ V) \div R3$

For I_{max} = 200 mA, this yields R3 = 3 Ω. The LED is on if current limiting is active, which also means that the cells are not yet fully charged.

The potential on the reference lead of the voltage regulator is raised by approximately 2.9 V due to the voltage across the LED. This leads to a requirement for a certain minimum number of cells. For an LM317, the voltage between the reference lead and the output is 1.25 V, which means at least three cells must be charged ($3 \times 1.45\ V > 2.9\ V + 1.25\ V$). For a 78xx with a voltage drop of around 3 V (plus 2.9 V), the minimum number is four cells.

When the cells are almost fully charged, the current gradually drops, so the current limiter becomes inactive and the LED goes out. In this state, the voltage on the reference lead of the regulator depends only on voltage divider R1/R2. For a 7805 regulator, the value of R2 is selected such that the current through it is 6 mA. Together with the current through the regulator (around 4 mA), this yields a current of around 10 mA through R1. If the voltage across R1 is 4 V (9 V – 5 V), this yields a value of 390 Ω. The end-of-charge voltage can thus be set to approximately 8.9 V. As the current through the regulator depends on the device manufacturer and the load, the value of R1 must be adjusted as necessary.

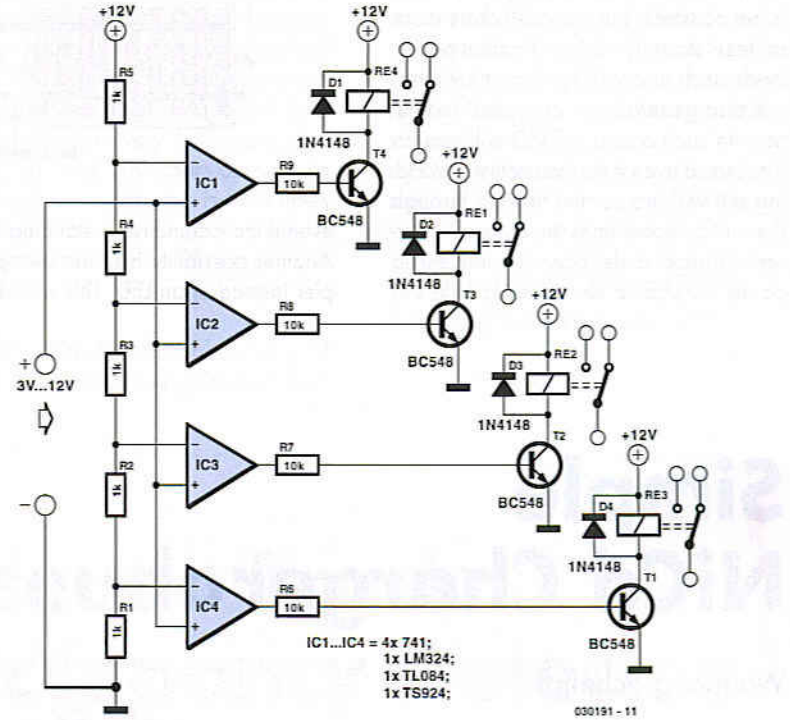
The value of the storage capacitor must be matched to the selected charging current. As already mentioned, it can also be omitted for pulse charging.

(040020-1)

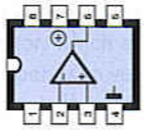
030 Voltage Levels Control Relays

Raj. K. Gorkhali

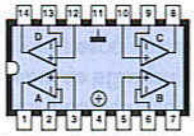
This circuit proves that microcoprocessors, PCs and the latest ultra-accurate DACs are overkill when it comes to controlling four relays in sequence in response to a rising control voltage in the range 2.4 V – 12 V. By using equal resistors in ladder network R1-R5, equal intervals are created between the voltages that switch on the relays in sequence. Each resistors drops 1/5th of the supply voltage or 2.4 V in this case, so we get +2.4 V = Re1, +4.8 V = Re2, +7.2 V = Re3, +9.6 V = Re4. Obviously, these switching levels vary along with the supply voltage, hence the need to employ a stabilised power supply.



741



LM324
TL084
TS924



Looking at the lowest level switching stage, when the control voltage exceeds 2.4 V, IC1 will flip its output to (nearly) the supply level. The resulting current sent into the base of T1 is limited to about 1 mA by R6. With T1 driven hard, relay Re1 is energised by the collector current. Because the BC548 has a maximum collector current spec of 100 mA, the relay coil resistance must not be smaller than 120 ohms. Nearly all current consumed by the circuit goes on account of the relay coils, so depending on your relays a pretty hefty power supply of up to 500 mA may be required.

When dimensioning the ladder network to create the desired switching levels, it is good to remember that the 741 will not operate very well with input voltages below 1.5 V or above 10.5 V, while voltage levels outside the supply range (i.e., negative or above +12 V) are out of the question.

If you do need a switching level in the range 0-1.5 V, consider using an LM324, which contains four opamps in one package. For the high side of the range (10.5 to 12 V), a TL084 or a 'rail-to-rail' opamp like the TS924 is required. However, the TS924 cannot be used with supply voltages above 12 V.

(030191-1)