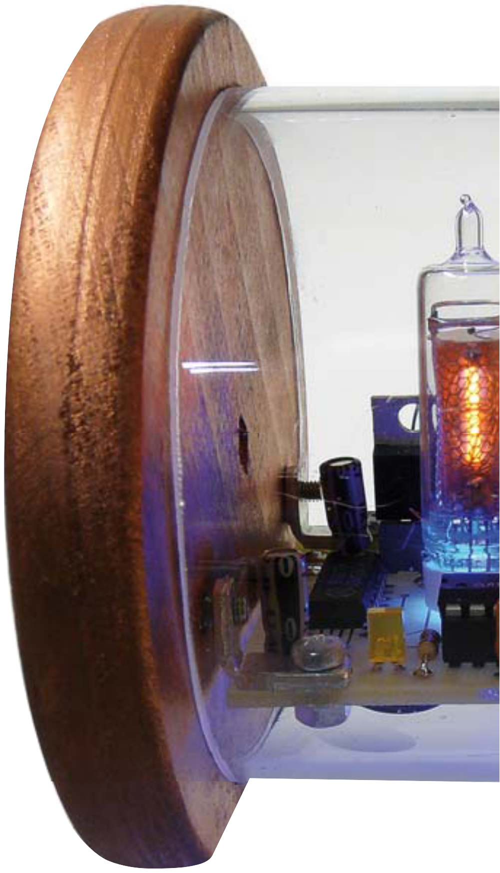
Nixie Tube Thermometer

Retro temperature display

By Dieter Laues (Germany)



In this article we describe the union of a modern microcontroller with a classic display technology to create a novel temperature indicator. In its transparent enclosure the device will set off any mantelpiece to advantage and what's more, the unit even doubles up as a night light. An external sensor allows the temperature at any desired location to be displayed.

Nixie tubes have a special charm all of their own. The author's Sputnik-style digital clock using the tubes appeared in *Elektor* in January 2007, and many variations on the theme have appeared on the internet. This digital thermometer, which uses just two tubes, is a little bit different. The temperature measurement itself is done by a DS1820 one-wire sensor, while an AT89C2051 microcontroller processes the temperature information and drives the Nixie tubes.

Hardware

Special attention was paid when designing this circuit to make construction as straightforward as possible. There are only a few components, no SMDs, and no adjustments to be made. The circuit is shown in **Figure 1** and is arranged as follows.

An external mains power supply provides between 12 V and 15 V DC to the circuit. From this voltage IC6 generates the 5 V operating voltage for microcontroller IC1 and nixie drivers IC2 and IC3.

The high voltage supply required for the tubes is generated using a step-up converter based around IC5. The MC34063 device used is a tried-and-tested PWM controller that is easy to find, inexpensive, and available in a leaded package. External MOSFET switching transistor T1, coil L1 and Schottky diode D6 generate and smooth the high-voltage output. The output voltage of the regulator is given by

$V_o = V_{ref} \times R9 / R10$

and with the values given in the circuit diagram, we have

$V_0 = 1.25\ V \times 820k / 5.6k = 183\ V.$

This relatively high voltage has the advantage that the display will be bright. In his prototype the author used a value of 680 kΩ for R9 in the interests of reducing power dissipation: in this case the voltage across C4 is about 152 V. Using values between 680 kΩ and 820 kΩ for R9 you can adjust the voltage and hence the display brightness to taste.

R4 and R5 take the high voltage supply to the anodes of the IN-16 tubes, giving an operating voltage of around 143 V (with 180 V across C4), and an anode current of about 1.72 mA. This is a suitable operating point for Nixie tubes of Russian manufacture, which are inexpensive and easy to obtain. Also, the Russian Nixie driver IC type K155ID1 can be substituted for the 74141, which is now hard to obtain.

In the interests of maximising brightness, it was decided not to multiplex the displays. The tiny MCS-51-compatible microcontroller fits all the software required to read temperature values and convert them to BCD format for output in its 2 KB of program memory. The 12 MHz clock is produced using X1, which is a resonator with built-in load capacitors. The RC network comprising R6 and C1 provides a power-on reset function, and IC4 (a Maxim-Dallas DS1820) is the temperature sensor itself. The device comes factory-calibrated and delivers temperature readings serially over its one-wire bus to pin P1.3 on the microcontroller. If jumper JP1 (on P3.4) is fitted, the temperature is shown in Fahrenheit.

Options

LEDs D1 to D4 and their series resistors R2, R3 and R7 are optional and can be dispensed with if desired. D1 and D2 show the temperature trend, while D3 and D4 provide a little additional effect lighting to the tubes.

D1 and D2 indicate whether it is getting warmer or colder. Red LED D2 lights when the temperature is rising, while blue LED D1 lights when the temperature is falling. If the temperature is steady from one reading to the next, neither LED lights.

A temperature reading is taken more than once a second, and so it can happen that the display alternates fairly rapidly between two adjacent values. To make the display less distracting it would be possible to average readings over a longer period: readers are welcome to experiment in this direction as there are a few bytes of program memory to spare, and commented source code can be downloaded at [1] free of charge.

LEDs D3 and D4 illuminate the Nixie tubes from below, one LED for each tube. Holes are provided at suitable points on the printed circuit board to allow the light through, with the LEDs soldered to the underside of the board, pointing upwards. The brightness of the LEDs can be adjusted by changing the value of R7, and of course

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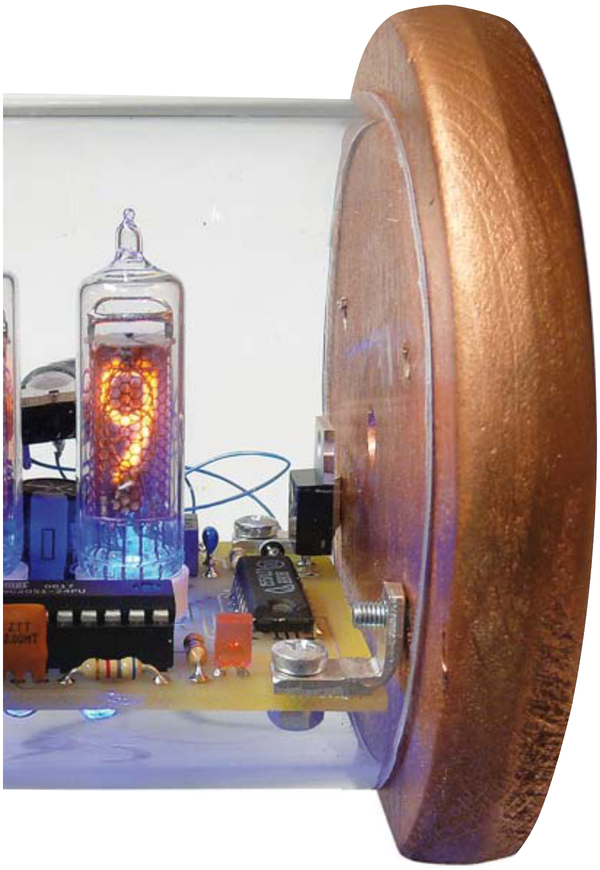

Features

Display range:	0 to 99 (Celsius or Fahrenheit)
Temperature sensor:	Maxim-Dallas DS1820, accuracy 0.5 K
Power supply:	AC power adaptor, 12 V to 15 V DC
Current consumption:	170 mA at 12 V
Tubes:	Russian IN-16, 13-way solder connections
Microcontroller:	Atmel AT89C2051 (available ready-programmed)
Firmware:	BASCOM (source and hex files available for free download)
Options:	Choice of Celsius or Fahrenheit display Tube illumination LED trend (warmer/colder) indicators

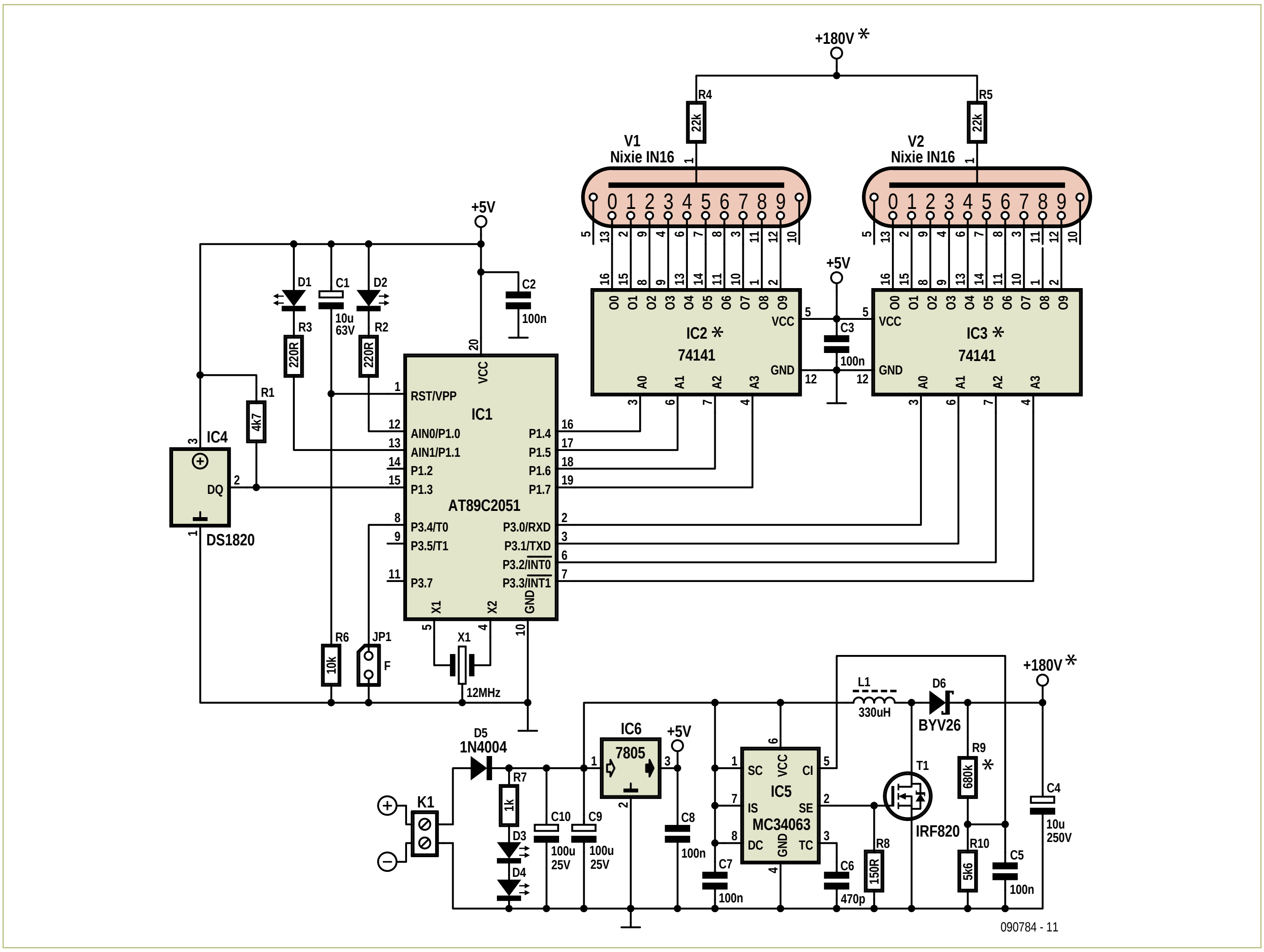

Figure 1. Simplicity is the watchword: only a few components, no SMDs, and no adjustments.

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COMPONENT LIST

Resistors
R1 = 4.7kΩ
R2,R3 = 220Ω
R4,R5 = 22kΩ
R6 = 10kΩ
R7 = 1kΩ
R8 = 150Ω
R9 = 820kΩ
R10 = 5.6kΩ

Capacitors
C1 = 10µF 63V, radial, 0.1 in. lead pitch
C2,C3,C5,C7,C8 = 100nF ceramic, 0.2.in. lead pitch
C4 = 10µF 250V, radial, 0.2 in. lead pitch
C6 = 470pF, 0.2 in. lead pitch
C9,C10 = 100µF 25V, radial, 0.1 in. lead pitch

Inductor
L1 = 330µH, 1A, axial, DxL = 11x32.5 mm max., e.g. Epcos B82500CA8 or Fastron 77 A-331 M-00

Semiconductors
D1,D3,D4 = LED, 3mm, blue
D2 = LED, 3 mm, red
D5 = 1N4004

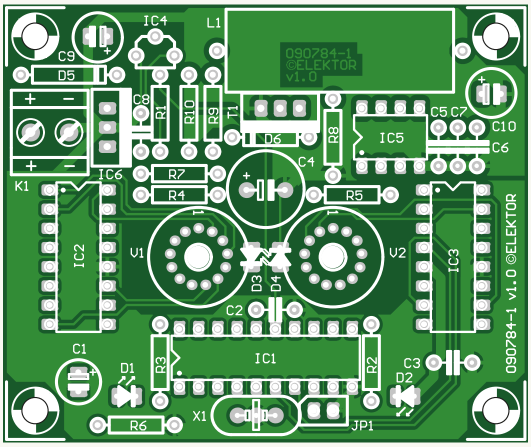

Figure 2. The easy-to-populate printed circuit board is available from the *Elektor* Shop.

D6 = BYV26 (e.g. Vishay)
T1 = IRF820 (Vishay, International Rectifier IRF820PBF)
IC1 = AT89C2051-24PU, programmed, Elektor # 090784-41 *
IC2,IC3 = 74141 or K155ID1 (Russian: К155ИД1)
IC4 = DS18S20 (Maxim/Dallas)
IC5 = MC34063
IC6 = 7805 (TO220)

Miscellaneous
X1 = 12MHz resonator, 3-pin, e.g. AEL Crystals type C12M000000L003
JP1 = 2-pin pinheader, 0.1 in. lead pitch (optional jumper, see text)
K1 = 2-way PCB screw terminal, lead pitch 5mm
V1,V2 = Nixie tube type IN-16 (e.g. Sovtek ИН-16)
PCB # 090784-1 * (artwork free download at [1])

* see www.elektor.com/090784 or Elektor Shop page.

you can select the size and colour of the LEDs as you wish. In the author's prototype he used blue LEDs, which were particularly effective in the dark in conjunction with the orange glow of the tubes. Unfortunately, the IN-16 tubes bought for the Elektor lab prototype came with an opaque grey plastic base, and so it was not possible to recreate the LED illumination effect.

Software

The software running in the microcontroller was written using the BASCOM 8051 compiler from MCS Electronics, which includes commands to support the one-wire bus interface.

After initialisation of all variables and of the sensor the software runs in an infinite loop fetching a new temperature reading roughly every 750 ms. The value is converted to Fahrenheit if required, the fractional part is discarded, and the result converted to tens and units digits in BCD format to be passed to the Nixie drivers. The reading is also stored and used in the next iteration of the loop to drive the trend indicators D1 and D2.

Despite the simplicity of the software structure, it turned out to be harder than expected to get the timing of communications with the DS1820 right. The bus must be reset between requests, and the chip must not be disturbed by a request while it is carrying out a measurement. Sometimes a mistimed request can make the chip get into a state where it stops responding altogether and must be reset. However, none of this need concern the constructor, who can just use the software downloaded from [1] or a ready-programmed microcontroller from the *Elektor* Shop.

If the temperature should go negative the display will simply show '00' (the minimum reading) and temperatures above 100 °C are displayed as '99' (the maximum reading). The display also flashes '99' if the temperature sensor is not connected or is faulty.

Construction and operation

All components apart from the Nixie tubes are fitted to the printed circuit board **(Figure 2)**, which is available from the Elektor Shop. At first, just solder in sockets for IC1, IC2 and IC3. Take care to check the polarity of the electrolytic capacitors, and in particular of C4, before applying power! Now plug in the mains adaptor, and check that a voltage of approximately 180 V appears across C4 (if R9 is 820 kΩ). Take care here with the high voltages, and do not touch the printed circuit board while power is applied.

Now allow C4 to discharge and fit the tubes. On the back of each tube, exactly in the centre behind the glass there is a light stripe that indicates pin 1 (see also the datasheet). It can be quite fiddly to thread thirteen wires of identical length through the holes in the board, so it is a good idea to trim the wires to different lengths so that each one is a little shorter than the next, like organ pipes. It is then easy to thread the wires one at a time, starting with the longest. Finally make sure the tube is vertical and solder the connections.

Now fit the Nixie driver ICs and the programmed microcontroller in their sockets. When power is reapplied the temperature should appear on the displays.

Enclosure

The prototype was mounted in a clear acrylic pipe of diameter 80 mm cut to 75 mm in length. This type of pipe is hard

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to come by in the DIY sheds, but a wide selection of sizes and wall thicknesses is available from online emporia. It is important to cut the pipe exactly perpendicular to its axis as any unevenness in the end faces will look unsightly, although it is relatively easy to work acrylic by hand using a file or sandpaper. A circular saw is the best way to cut the pipe, but if necessary it can be done by hand, for example using a hacksaw with a fine-toothed metal blade. A U-shaped mitre block of the type intended to help with cutting skirting boards makes a good guide for a clean square cut. The side cheeks were made from solid wooden wheels bought from a DIY shop with a diameter of 100 mm. A single cut created a flat on the wheel on which the unit stands. It would be possible to paint the side cheeks, or to make them from acrylic sheet with a thickness of around 4 mm. Two holes were made in the pipe, one for a jack socket for the temperature sensor and the other for the power socket. The side cheeks were each drilled for two M3 screws at exactly the right height for the fixing bracket, which must be threaded on at least one side.

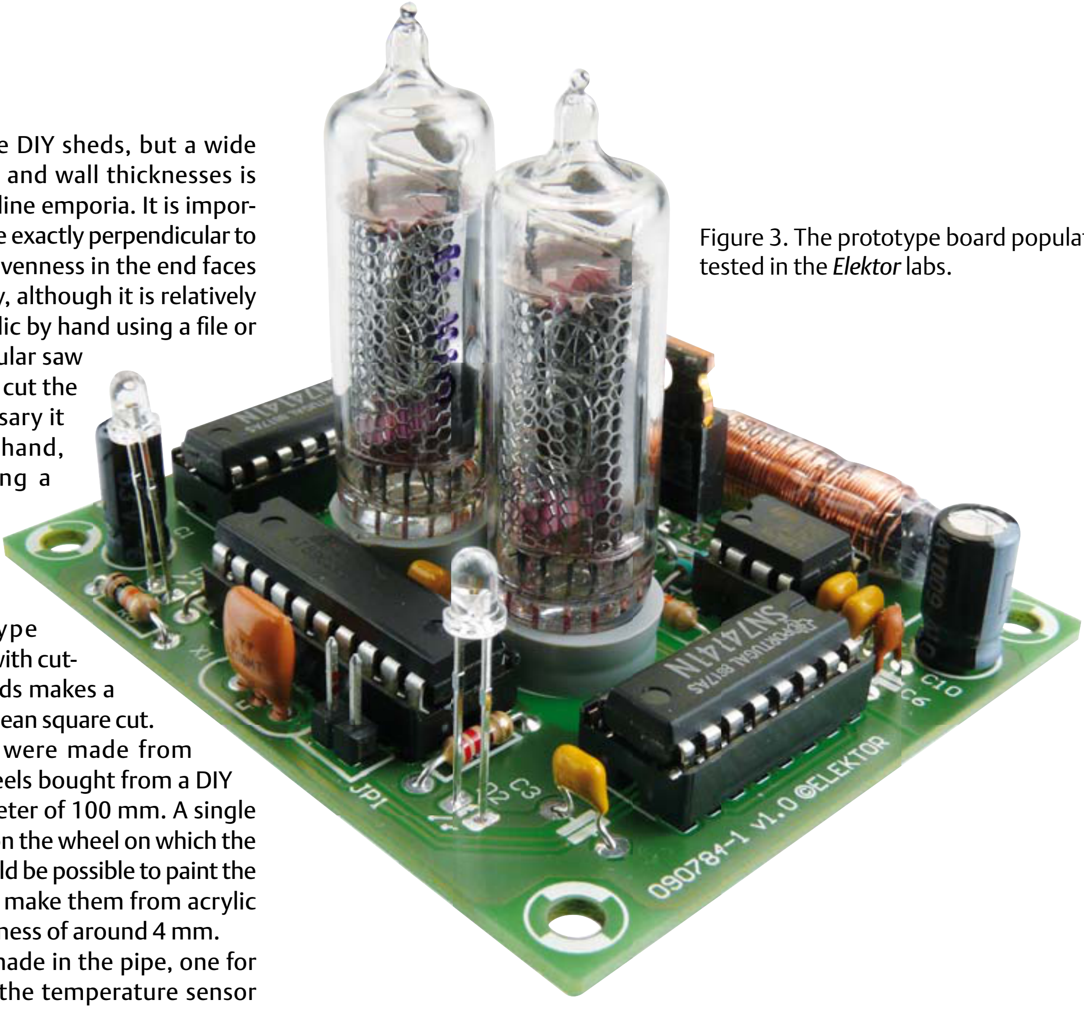

Figure 3. The prototype board populated and tested in the *Elektor* labs.

Next the sockets were wired to the appropriate points on the printed circuit board for the sensor and power supply, and the assembly slid into the pipe. The side cheeks were screwed to the interior brackets from outside using M3 screws. The board is now suspended between the two side cheeks, which in turn are fixed to the acrylic pipe. With a little judicious twisting of the assembly things can be arranged so that the board is inclined upwards, making it easier to see the Nixie tubes from slightly above.

Because of the heat generated by the tubes and the voltage regulator it is not practical to mount the temperature sensor on the board or inside the enclosure. To measure the ambient temperature, place the sensor away from the device on the end of a cable. Of course, the thermometer can be used for other purposes too, such as measuring the temperature inside another device (perhaps that tube amplifier you have alongside it?).

Conclusion

The circuit generates high voltages internally, and so it is important to use an insulating enclosure with no exposed metal parts. Nylon screws and insulating sockets should also be used, or alternatively the mains adaptor and the temperature sensor can be connected permanently using well-insulated wires with suitable strain relief and grommets for the holes in the enclosure. The connections to the DS1820 should also be insulated, or the whole sensor assembly can be enclosed in heatshrink tubing. The reward for all this effort is the pleasure of seeing warm orange, occasionally flickering digits lighting up your living room!

(090784)

Internet Link

[1] www.elektor.com/090784 (web pages for this project)

Design Resources

www.atmel.com/atmel/acrobat/doc0368.pdf (AT89C2051 datasheet)

http://datasheets.maxim-ic.com/en/ds/DS18S20.pdf (DS1820 datasheet)

http://www.tube-tester.com/sites/nixie/data/in16.htm
(information on the IN-16 tube)

http://gadget.mda.or.jp/pdf/K155ID1 (K155ID1 datasheet)

www.onsemi.com/pub_link/Collateral/MC34063A-D.PDF (MC34063 datasheet)

www.die-wuestens.de/
(Nixie tubes and drivers)

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