Sputnik Time Machine

Nostalgia and microcontroller technology merged in a single design

Dieter Laues

Sputnik 1, the first artificial satellite, was launched in 1957. It captured the attention of the entire world with the eerie beeps it transmitted, which could be received by radio amateurs everywhere in the world. Fifty years after this historic event, it seems fitting to build a clock in the shape of the Sputnik satellite that combines a nostalgic Nixie tube display with a modern microcontroller.

Technology has changed a lot in recent decades. Launching a satellite that simply transmitted a beep signal was a major achievement in 1957, but now we routinely put satellites into orbit that can transmit hundreds of television channels.

This design uses a combination of modern and old-fashioned technology. The shape of the Sputnik and the Nixie tubes are elements of old-fashioned technology, while the low-loss switching regulators for the supply voltages and the microcontroller-based control logic are examples of modern technology.

Nixie tubes

Nixie tubes were introduced commercially in 1954 to display numbers in electronic equipment. A Nixie tube is a cold-cathode valve, which means it does not have a heated filament. The valve thus remains quite cool during operation.

The valve is also not evacuated, but instead filled with a gas mixture consisting primarily of neon. If a sufficiently high voltage is applied to the electrodes, the gas molecules around the cathode become ionized and emit light ranging in colour from reddish-orange to purplish. The valve contains a separate cathode in the form of a numeral for each digit to be displayed.

'Nixie' is a trademark name given to these valves by the Burroughs Corporation, which incidentally didn't actually develop them but instead purchased the company that developed them, Haydu Brothers Laboratories.

Schematic diagram

The clock is controlled by a small microcontroller – an Atmel 89C2051, which has 2 KB of flash memory. The digit cathodes of the Nixie tubes are driven by type 74141 driver ICs. Although these ICs may appear to be standard TTL devices, they are specially designed to handle the high voltage level of Nixie tubes. Like the Nixie tubes, they are readily available through 'regular' commercial channels. We thus strongly advise readers who want to build this clock to first see whether they can find these parts before they invest in the rest of the hardware. The first digit of the display,

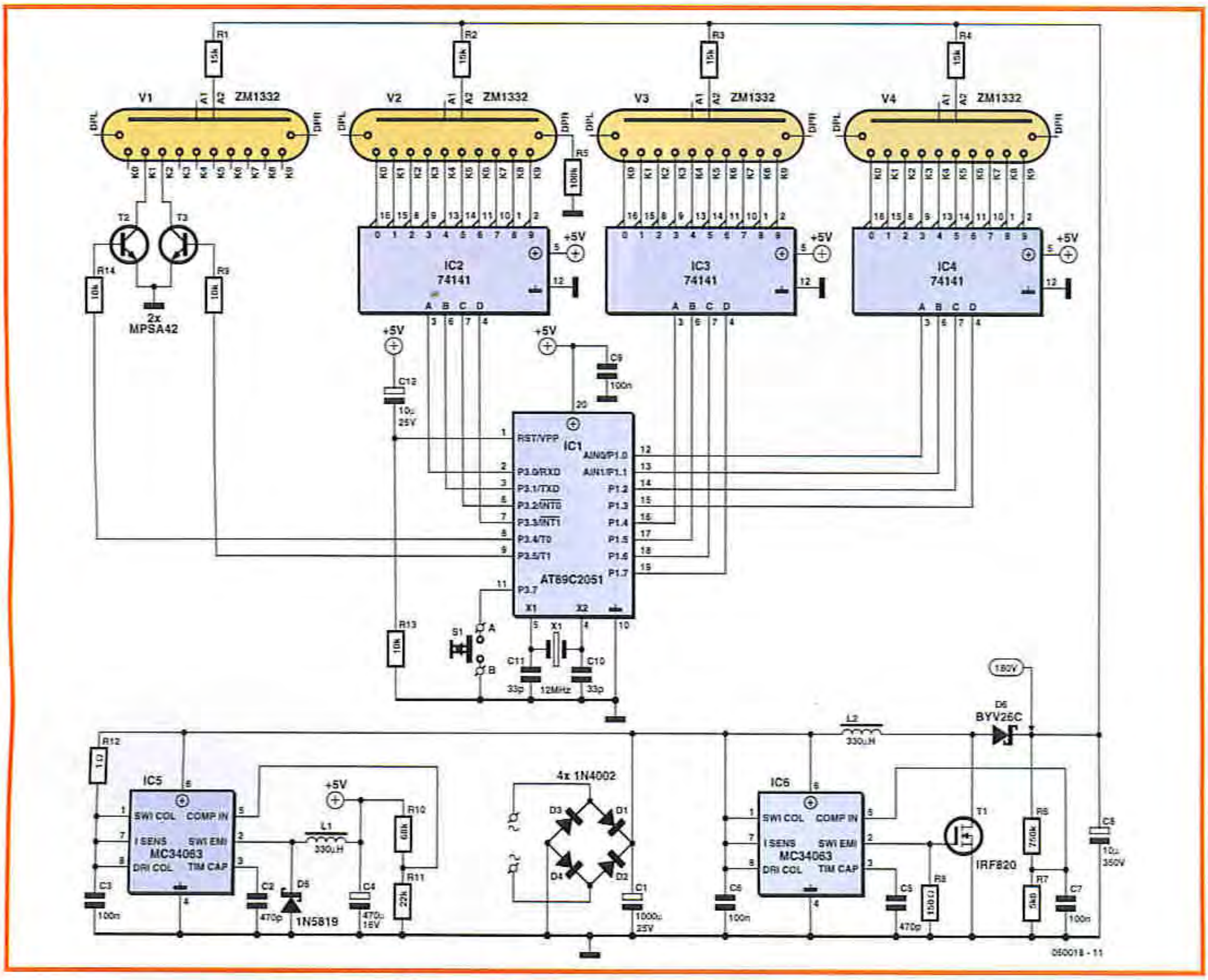


Figure 1. The circuit of the Sputnik clock consists of a microcontroller, four Nixie tubes and their drivers, and two supply voltage regulators.

which shows tens of hours, is driven by two discrete transistors instead of a driver IC – since only the numerals '1' and '2' are necessary.

The power supply section consists of two independent switching regulators, each of which is built around an MC34063 general-purpose PWM regulator IC. IC5 operates as a step-down converter and provides +5 V for the low-voltage portion of the circuit. IC6 operates as a step-up converter and provides the high voltage for the Nixie tubes. FET T1 is included in the circuit because the MC34063 is not rated for operation above 40 V. One of the advantages of not using conventional voltage regulators is that the circuit is not choosy about the raw input voltage, so an AC mains adapter with an output voltage in the range of 14–25 V can be used. In addition, this power supply arrangement generates relatively little heat. This is important because the circuit is fitted in a closed housing and would otherwise become quite warm.

Software

The software is written in assembly language. This yields a very compact program that implements a 24-hour clock, the user interface, display brightness control, and smooth display transitions in just 568 bytes of code.
The clock operates on the usual principle of dividing down the interrupt rate of the timer interrupts. The information to be displayed in hours and minutes is output in BCD format via I/O ports to the Nixie drivers. The tens of hours digit forms an exception here. As only the '1' and '2' have to be driven here, only two output lines are necessary.
There is only one user control, consisting of a pushbutton that can be used to set the time, adjust the brightness, and display the software version number. Refer to the inset for the details of the operator interface.

The brightness of the Nixie tubes is controlled by varying the duty cycle of the drive signals instead of varying the anode current. Every time the minutes display changes, the clock makes a smooth transition from the one number to the next. This is also implemented using the variable duty cycle. The duty cycle of the old number decreases gradually while the duty cy-

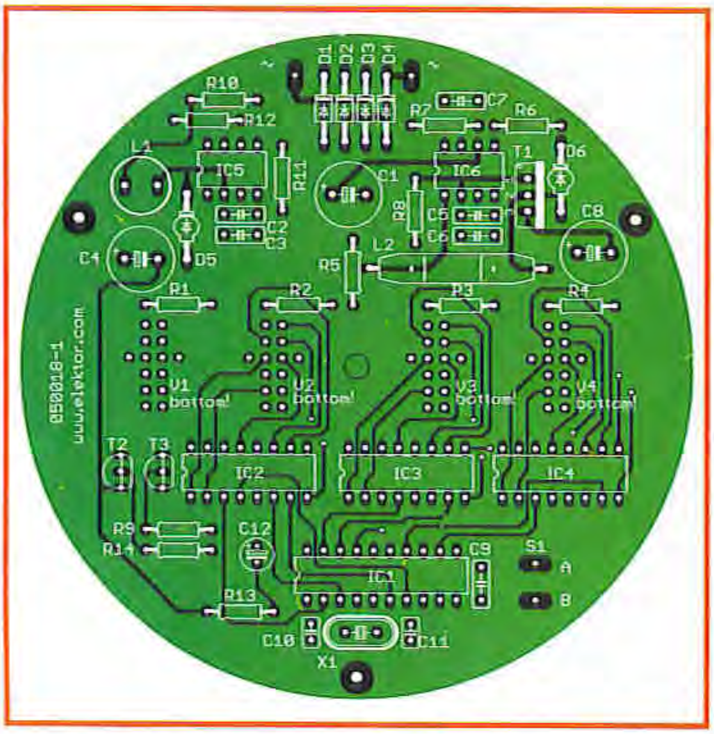


Figure 2. The double-sided PCB has a round outline so it can be fitted in a plastic ball.

cle of the new number increases gradually. The brightness setting of the display is also maintained during this transition.

Construction

Building the circuit should not present any particular difficulties. Only 'standard' components are used (no SMDs). Start by fitting all the parts on the component side of the board.

Operating instructions

Setting the time

1) Press and hold the button until the hours display starts blinking. After this, the time will be advanced by 1 hour each time you press the button briefly.

2) Press and hold the button until the minutes display starts blinking. After this, the time will be advanced by 1 minute each time you press the button briefly.

3) Press and hold the button until the display returns to non-blinking mode. The seconds are set to 0 at this time.

Setting the brightness

Press the button briefly. The current brightness setting will be displayed. The brightness setting is increased by 1 each time the button is pressed briefly, from 01 (minimum) to 09 (maximum). The clock returns to the time display mode if the button is not pressed for several seconds.

Displaying the version number

With the AC mains adapter unplugged, press and hold the button while plugging in the adapter. The version number of the software will then be displayed (such as '1.07'). After releasing the button, you can set the time as described above.

Use sockets for all of the ICs. Then turn the board over and solder the Nixie tubes on the copper side of the board. It is a good idea to trim the leads of the Nixie tubes stepwise and then insert them in the holes in pairs starting with the longest ones, since it is rather difficult to get all the leads into the holes if they all have the same length. Align each Nixie tube exactly perpendicular to be board before soldering the leads.

Initial checkout

Start by fitting only the voltage regulator ICs (IC5 and IC6) in the sockets, and check the polarity of C8 before plugging in the AC mains adapter. Then use a meter to check the supply voltages. The voltage for the low-voltage portion must be +5 V, and the voltage on C8 (for the Nixie tubes) must be approximately +180 V. If everything's OK, you can unplug the AC adapter. Be sure to give C8 enough time to discharge before proceeding further. **(Caution: high voltage!)**
After this you can fit the remaining ICs. After being powered up or after a voltage dropout, the display shows a blinking value of '0.00'. The default brightness value is set to '7'. The time is shown in the European 24-hour format. A zero in the first digit is not displayed, so this digit remains dark every morning until 10 o'clock

Mechanical construction

We know that electronics hobbyists often find it difficult to do a nice job of fitting a circuit in a rectangular enclosure, so how can we expect them to manage with a spherical enclosure? The answer is that it takes a certain amount of skill and patience.

Transparent plastic balls are available in hobby shops. For this project, we used one with a diameter of 10 cm, consisting of two hemispheres. In one of these hemispheres, we drilled holes for the three legs (along the upper rim), the control pushbutton (lower middle), and power supply connector (diagonally to the rear). You must drill carefully. The best results can be obtained using a drill press, but if necessary you can manage with a battery-powered drill. Drill the holes from the inside with the material supported on a firm surface, since otherwise the plastic can crack. The legs are made from aluminium rods, which you can buy in a DIY shop by the metre. Cut three lengths of 15 cm and bend one end of each rod in a vice (depth of bend approximately 2 cm) to give them the right shape. The angle of the bend should be approximately 100 degrees. The sharper the bend, the closer the legs will be together in the assembled clock. The legs must all have the same shape (as close as you can manage), since otherwise the finished clock will stand crooked. After bending the ends of the legs to the right angle, cut a 4-mm thread on the short end of each leg.

Cut a round cover plate for the circuit board from a sheet of plastic. Make a hole for the fastening screw in the middle and four larger holes for the display.
Before assembling the clock, paint the bottom hemisphere and (if you wish) the cover plate. Spray-paint canisters available in DIY model shops are quite suitable for this. After painting the ball black, you can use silver paint to give it a 'starry sky' effect by pressing the spray button very lightly. You can also use an airbrush to create attractive effects. Here you can give your creativity free rein, but make sure the paint

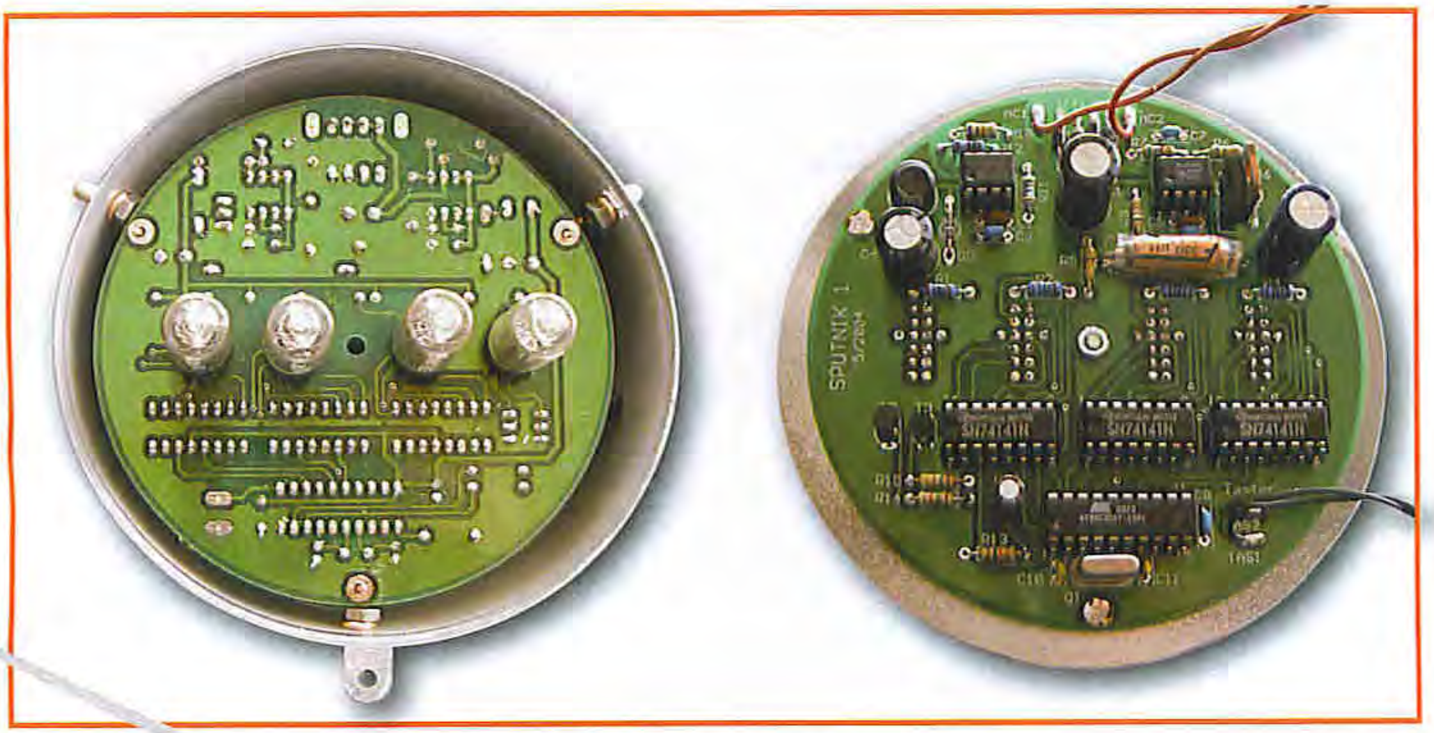
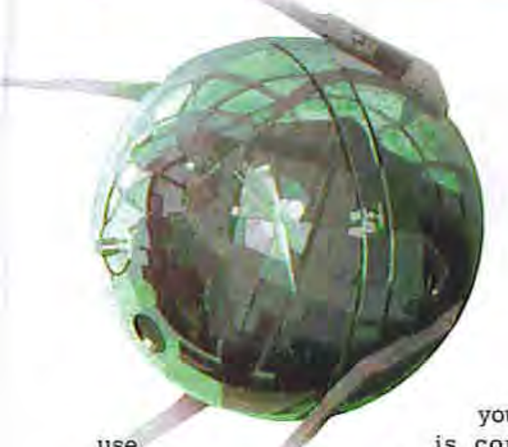


Figure 3. Top and bottom sides of the assembled circuit board.



you use is compatible with the plastic of the ball – otherwise you may end up with an unattractive, spotty surface. You can also use a transparent cover coat to protect the paint against scratching. Another option is to paint the inner surface of the ball. Although the colours may not be as bright with this option, the paint coating is absolutely scratch-resistant.

After the painting is finished, you can assemble the clock Thread an M4 nut onto each of the three legs and then fit the ends of the legs through the holes in the ball. Secure each of them with a second M4 nut on the inside. Before tightening the inner nut, fit a length of copper wire with a loop formed on one end. Later on, you can solder the circuit board to these three wires to secure it in the enclosure.

Next, fit the power supply socket and the pushbutton and connect them to the circuit board with flexible wire leads. Finally, align the circuit board so it is level and solder it in place on the three copper wires, and then fit the cover board.

After checking to ensure that everything works properly, you can fit the top half of the ball.

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Web links

Mike's Gallery – a collection of several types of Nixie clocks
www.electricstuff.co.uk/nixiegallery.html

A recording of the original Sputnik beeps
www.muenster.de/~dambergj/Sputnik.htm

COMPONENTS LIST

Resistors
R1,R2,R3,R4 = 15kΩ
R5 = 100kΩ
R6 = 750kΩ
R7 = 5kΩ6
R8 = 150Ω
R10 = 68kΩ
R11 = 22kΩ
R12 = 1Ω
R13,R14,R15 = 10kΩ

Capacitors
C1 = 1000µF 25V
C2 = 470pF
C3 = 100nF
C4 = 470µF 16V
C5 = 470pF
C6 = 100nF
C7 = 100nF
C8 = 4.7µF 400V
C9 = 100nF
C10,C11 = 33pF
C12 = 10µF

Inductors
L1,L2 = 330µH

Semiconductors
D1,D2,D3,D4 = 1N4003
D5 = 1N5819
D6 = BYV26C
T1 = IRF820
T2,T3 = MPSA42
IC1 = 89C2051, programmed, order code **050018-41**
IC2,IC3,IC4 = 74141
IC5,IC6 = MC34063

Miscellaneous
Q1 = 12.000MHz quartz crystal
AN1,AN2,AN3,AN4 = ZM1332
IC sockets: 2 off DIL 8-pin; 3 off DIL 16-pin; 1 off DIL 20-pin
PCB, ref. 050018-1 from ThePCBShop
Source and hex code files, free download # 050018-11.zip from project page at www.elektor-electronics.co.uk
Drilling templates, free download # 050018-W.zip, from project page at www.elektor-electronics.co.uk