Poor Man's Logic Analyzer

Zeroes and ones on an analog scope

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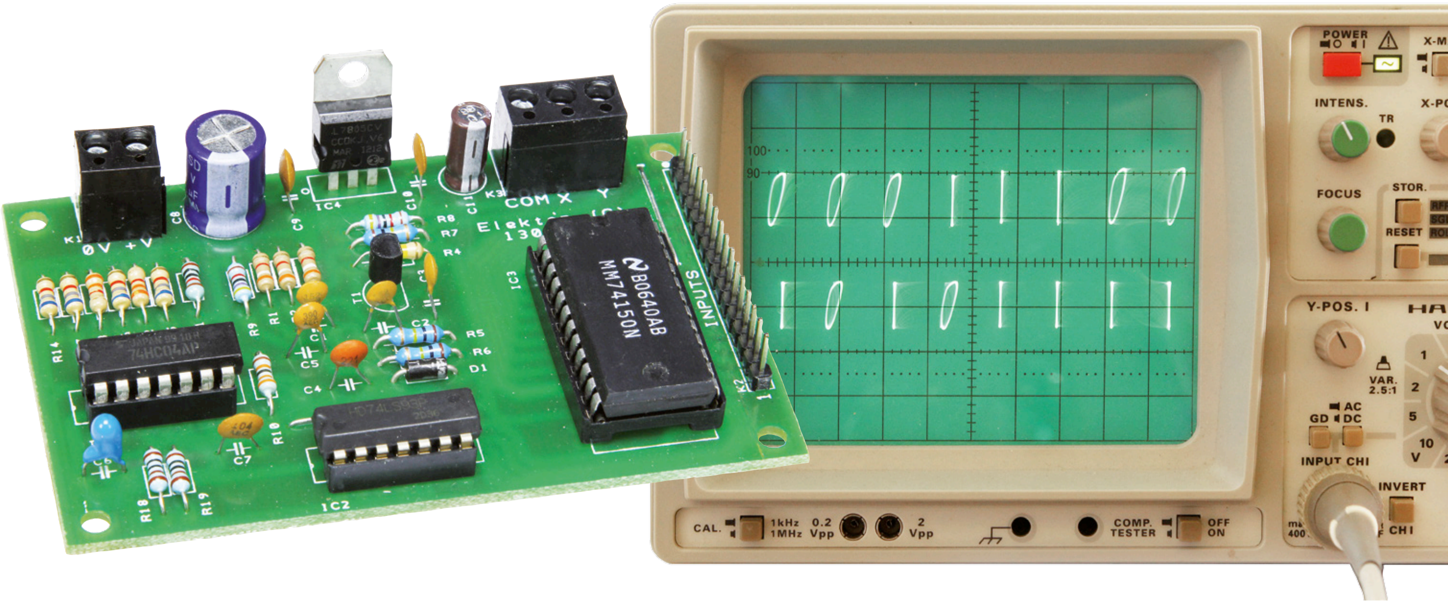


For occasional measurements of digital circuits there is no need to get hold of a real logic analyzer. With the help of several ICs it's possible to measure the signal levels of 16 channels and to display them simultaneously on a standard oscilloscope. There's no problem if this is an old-fashioned device with a cathode ray tube, which many hobbyists still use at home.

A modern digital scope usually has the facility to display several digital signals on the screen at the same time. However, on older scopes (those with cathode ray tubes) this feature is often lacking. In that case, you can use the circuit described here, which can display the signal levels of 16 digital channels simultaneously, shown as zeroes and ones on the screen.

The circuit

Before we'll describe the circuit we're going to give a quick summary of the operation of an oscilloscope with a cathode ray tube. When a sinusoidal voltage is connected to the Y-input of the oscilloscope, you'll see a neat sinewave on the screen. This is due to the fact that the electron beam inside the tube of the oscilloscope is deflected vertically by the sinusoidal input voltage. At the same time, the beam is deflected horizontally by an internally generated sawtooth waveform. During the vertical movement the beam is deflected from left to right.

If no sawtooth was applied, the beam would stay in the middle of the screen and the vertical movement would appear as a vertical line. If we connect a DC voltage to the X-input (external time-base), we can display such a line at any position on the oscilloscope screen. When a sinewave is connected to the X input, with an identical frequency of the signal on the Y input, but out of phase compared to the Y-input, a lissajous figure will appear, which in this case is a simple ellipse. When a DC offset is added to the signals at the X and Y inputs, this ellipse can be shown at any position on the screen.

This principle is used in the circuit to display the level of 16 digital inputs on an oscilloscope screen, in two rows of eight. The level is shown as a ‘0’ (ellipse) or a ‘1’ (vertical line). You should be aware that this ‘logic analyzer’ can only display static signals, and it’s not possible to observe rapidly changing digital signals. Despite this, the circuit comes in very useful when you need to see the state of a large number of digital signals in a circuit. The circuit diagram for the analyzer is shown in **Figure 1**. The signals to be measured (up to 16) are connected to the sixteen inputs of IC3, a 16-to-1-multiplexer. The input selection is carried out by IC2, a 4-bit binary counter, which outputs the values 0 to 15 to the selector inputs (A to D) of IC3. For example, when the counter outputs the number 0000 to the

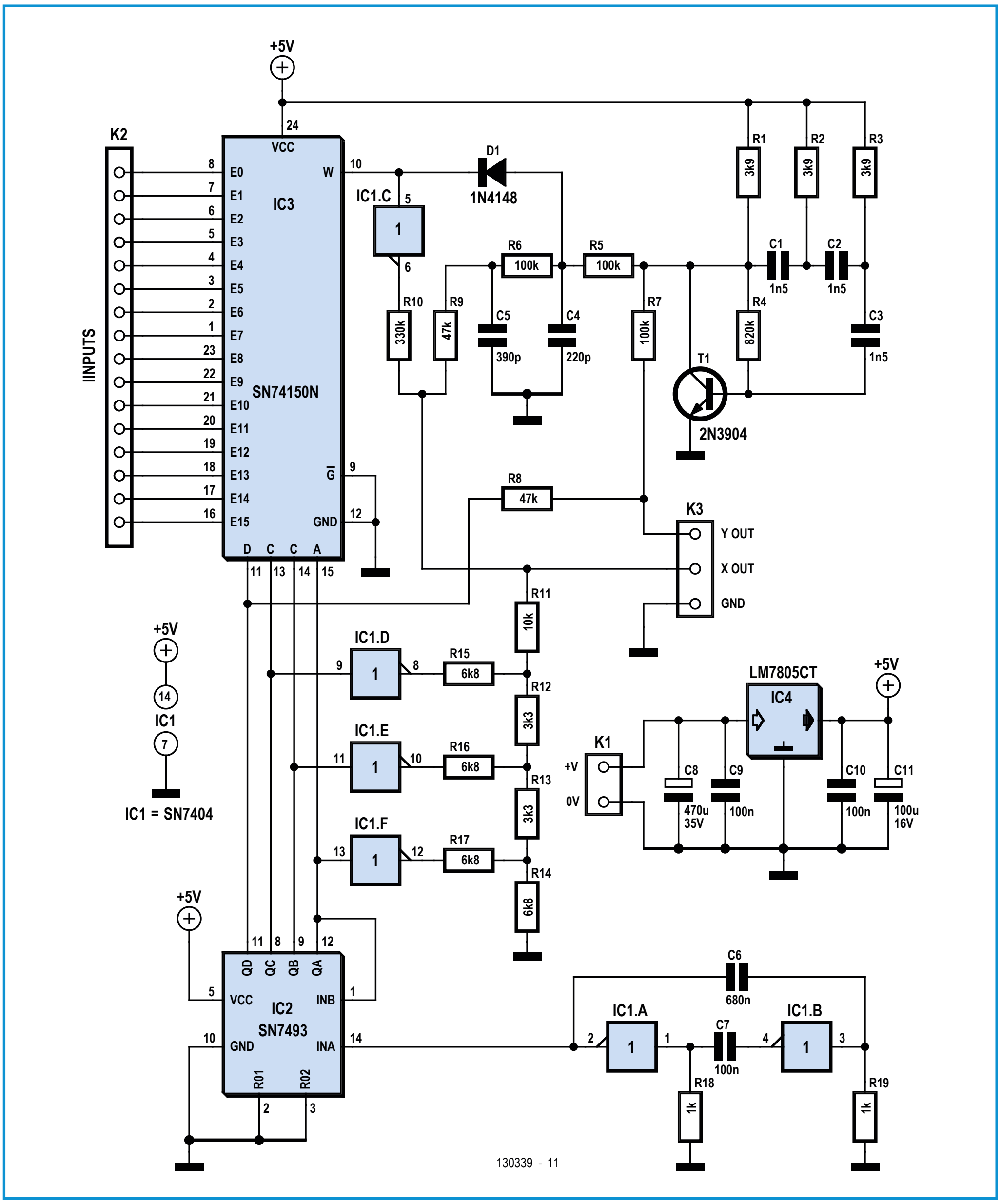


Figure 1.
With the help of this circuit you can display the levels of 16 digital signals on any oscilloscope.

selector inputs of IC3, the inverted level of the signal present at input E0 (pin 8 of IC3) will appear on output W (pin 10) of this IC. In this way, all 16 input levels will appear at output W at the same rate as the clock signal from IC2.

When the selected input signal is at logical one, the output on pin 10 will be a logical zero. The output of inverter IC1.C will then be high and the junction of R5/R6 will be tied to ground via D1, with the result that the voltage at X OUT is solely determined by the state of the binary counter.

An oscillator is built around T1, which produces a sinusoidal signal. This sinewave is fed to the Y-output via R7. This results in the creation of a '1' somewhere on the oscilloscope screen, with the position depending on the state of the binary counter. R5/C4 and R6/C5 form a phase shifting network. When the voltage on pin 10 of IC3 is low, the junction of R5/R6 is shorted to ground, so the network won't affect the signal to the X-output. However, as soon as the voltage at pin 10 becomes high, the sinewave is fed to the X-output via R9, with its phase shifted compared to the sinewave at the Y-output.

In addition, a DC voltage is added to the X-output, with a value depending on the state of the binary counter. This DC voltage is derived from outputs A-C of IC2 via a discretely built D/A converter, consisting of IC1.D to IC.1F and R11 to R17. The result is a '0' on the oscilloscope screen, with a position depending on the binary counter. Since the X-output increases with every count, the information will be shown in a neat row on the screen.

The D output of the binary counter is coupled via R8 to the Y output. This adds a DC component to the Y output, with a value that depends on whether the first or the second set of eight inputs is processed via IC3. This results in a display with two rows of information. The first eight inputs of IC3 are on the top row; the second eight are on the bottom row.

The supply for the whole circuit is taken care of by a 7805 voltage regulator. The input voltage to the regulator can be between 7 V and 18 V DC. The current consumption of the circuit is only a few tens of milli-amps.

Component List

Resistors

R1,R2,R3 = 3.9kΩ
R4 = 820kΩ
R5,R6,R7 = 100kΩ
R8,R9 = 47kΩ
R10 = 330kΩ
R11 = 10kΩ
R12,R13 = 3.3kΩ
R14,R15,R16,R17 = 6.8kΩ
R18,R19 = 1kΩ

Capacitors

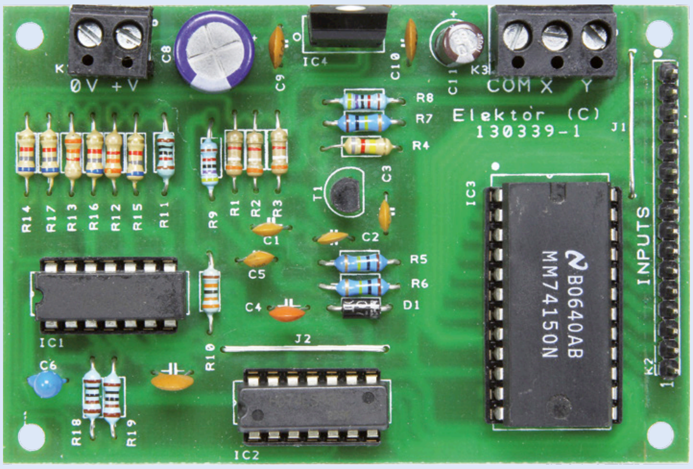
C1,C2,C3 = 1.5nF
C4 = 220pF
C5 = 390pF
C6 = 680nF
C7,C9,C10 = 100nF
C8 = 470µF 35V radial
C11 = 100µF 16V radial

Semiconductors

T1 = 2N3904
D1 = 1N4148
IC1 = SN7404
IC2 = SN7493
IC3 = SN74150N
IC4 = LM7805

Miscellaneous

K1 = 2-way PCB screw terminal lock, 5mm lead pitch
K3 = 3-way PCB screw terminal lock, 5mm lead pitch
K2 = 16-pin pinheader
PCB no. 130339-1



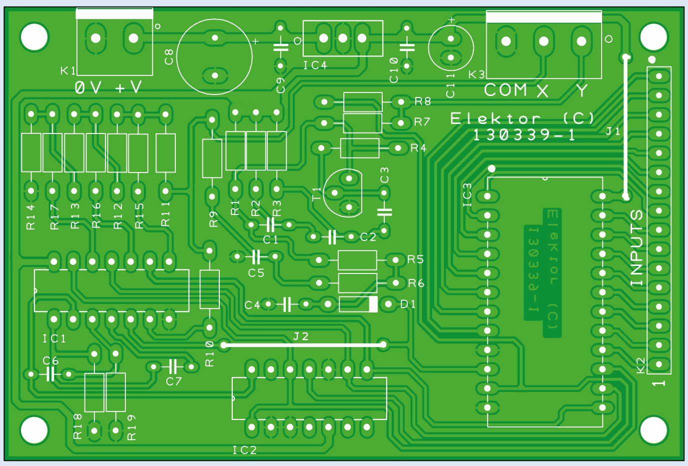


Figure 2. The PCB for the analyzer is single-sided. This makes it much easier to etch yourself, but this means that two wire-links are required.

PCB and construction

A PCB has been designed for the circuit (**Figure 2**), which uses only standard through-hole mounted components. The board layout can be freely downloaded from [1]. Since the board is single-sided, two wire-links had to be added. The construction should be straightforward for anybody with some soldering skills. There are two terminal blocks on the board. One is for the connection of the power supply (K1) and one is for the connection to the oscilloscope (K3). The digital signals are connected to pin header K2. These can be taken from various points on the circuit under test using test clips.

Note that this circuit is only suitable for use with digital signals with a voltage of 5 V.

Another point to bear in mind is that the ground of the circuit is connected directly to the ground of the oscilloscope. When an input is not connected, it will be shown as a '1' on the screen.

(130339)

Web Link

[1] www.elektor-magazine.com/post