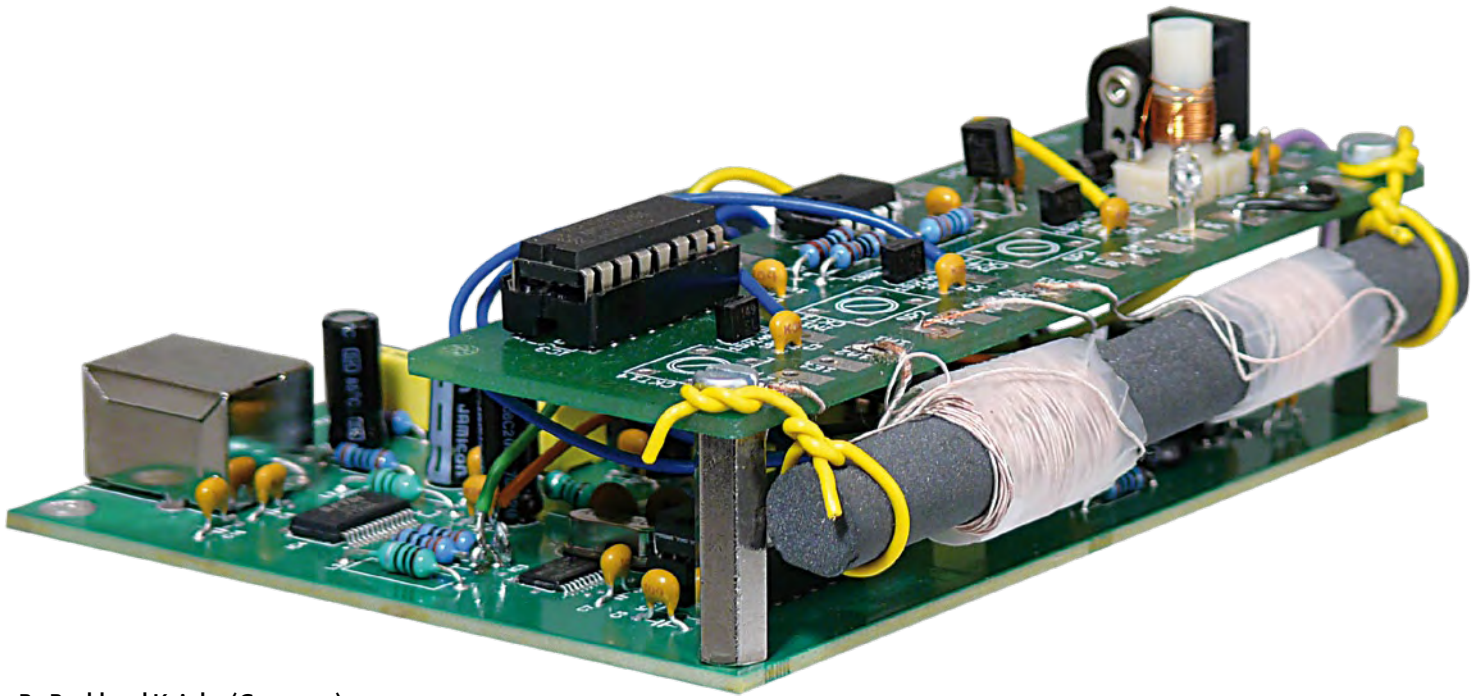# Preselector for Elektor SDR
Here's the automatic tuning upgrade!

By Burkhard Kainka (Germany)

The performance of a receiver depends to a large extent on its input filters. A selective input circuit improves antenna matching and immunity to interference from other strong signals. The preselector described here allows the use of up to four filters, tuned under software control using varicap diodes. A tuned loop antenna is also described that lets you use the Elektor SDR receiver without an outdoor antenna.

Almost three years since its publication, the Elektor Software Defined Radio (SDR) [1] is still a blockbuster project, and here at Elektor we were gratified by comments from the radio amateur community like 'good value for money' and 'an excellent entry-level SDR'. The publication of the SDR hardware was also followed by a flurry of tuning and control software like Peter Carnegie's 'G8JCFSDR'.

The SDR covers practically the whole of the radio frequency range up to 30 MHz. In the design, a 74HC4051 is used as an input multiplexer, offering a total of eight inputs A0 to A7. Under software control it is possible to use the multiplexer to switch between a wideband input (A0, displayed as In1 by the software), a low-pass filter for medium wave (MW) reception (A1, or In2), and a high-pass filter for shortwave (SW)

reception (A2, or In3). Input A7 is used for a 5 MHz self-test input. There are thus four spare inputs to the multiplexer, and these can be used, for example, to connect ferrite

Features

- Four tuneable front-end circuits
- Controlled by free SDR tuning software
- I²C bus control
- Long-, medium- and short wave reception
- 500 pF varicap diodes
- Suitable for use with a wire antenna, a loop antenna or a ferrite rod

antennas or front-end circuits. The inputs have a high impedance and can therefore also be used to connect a tuned magnetic

loop antenna, as shown in the examples in **Figure 1**. An annoyance when using these circuits with a software controlled radio is that the variable capacitors have to be adjusted manually, which can be rather fiddly. For this reason we have developed an automatically tuneable preselector, controlled over an I²C bus, using varicap (variable capacitance) diodes.

Four front-ends

The preselector circuit (**Figure 2**) sports four front-ends using 1SV149 varicap diodes. Depending on the tuning voltage, these devices have a capacitance that varies from around 20 pF to 500 pF. The tuning voltages are generated using a PCF8591 digital-to-analogue converter, which is controlled over an I²C bus. Since the Elektor SDR already incorporates an I²C bus, adding the facility

for software tuning control to the preselector is just a matter of making two additional connections (SDA and SCL).

Each front-end circuit employs a coil (L1 to L4) with four connections. Each output is coupled to one of the high-impedance inputs A3 to A6 (referred to as In4 to In7 in the software) of the SDR receiver's input multiplexer via a 100 nF capacitor (C3 to C6), via an individual coupling winding. Alternatively ferrite antennas or loop antennas with just two connections may be used. The details of these choices are left to the reader, as is the choice of which frequency ranges each preselector channel will work with. Also, inputs A0 to A2 (In1 to In3) of the SDR remain available for use.

Construction matters

Populating the printed circuit board (**Figure 3**) should be straightforward. First mount all the semiconductors, resistors and capacitors, but leave the c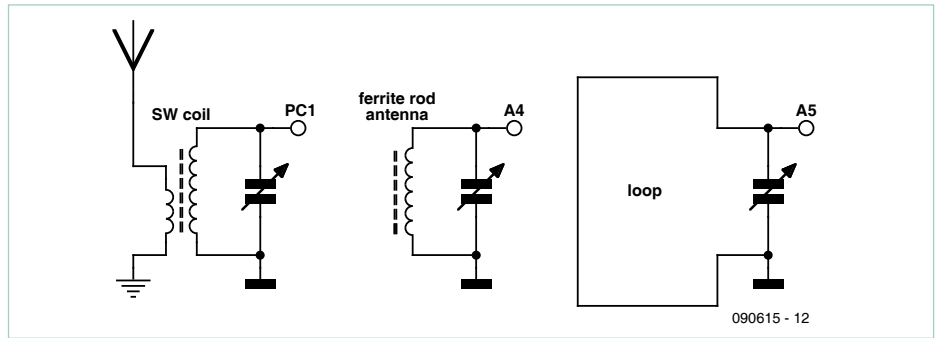oils for now. The board is also available in this partially-assembled state from the Elektor Shop: the board comes with four suitable coil formers plus a ferrite rod with ready-wound coils suitable for long wave and medium wave use. You can wind the other coils to suit the particular frequency ranges you wish to use. Here are two suggestions: to receive the shortwave band from 2.2 MHz to 8 MHz via output OUT3, wind L3 with 40 turns between 3E1 and 3A1 plus a 2-turn antenna coupling winding between 3E2 and 3A2; to receive the shortwave band from 4.5 MHz to 16 MHz via output OUT4, wind L4 with 15 turns between 4E1 and 4A1 plus a 1-turn antenna coupling winding between 4E2 and 4A2.

The 10 mm by 90 mm ferrite rod is used to cover the lower frequency ranges: coils for MW and LW use can be mounted on the same rod. You can either use the ready-wound coils provided or wind your own using either litz wire or 0.2 mm enamelled copper wire. A high Q factor is not essential in this case as it will be used for relatively wideband reception. To receive longwave between 140 kHz and 450 kHz via output OUT1, use 170 turns of litz wire or 0.2 mm enamelled copper wire on the ferrite rod,
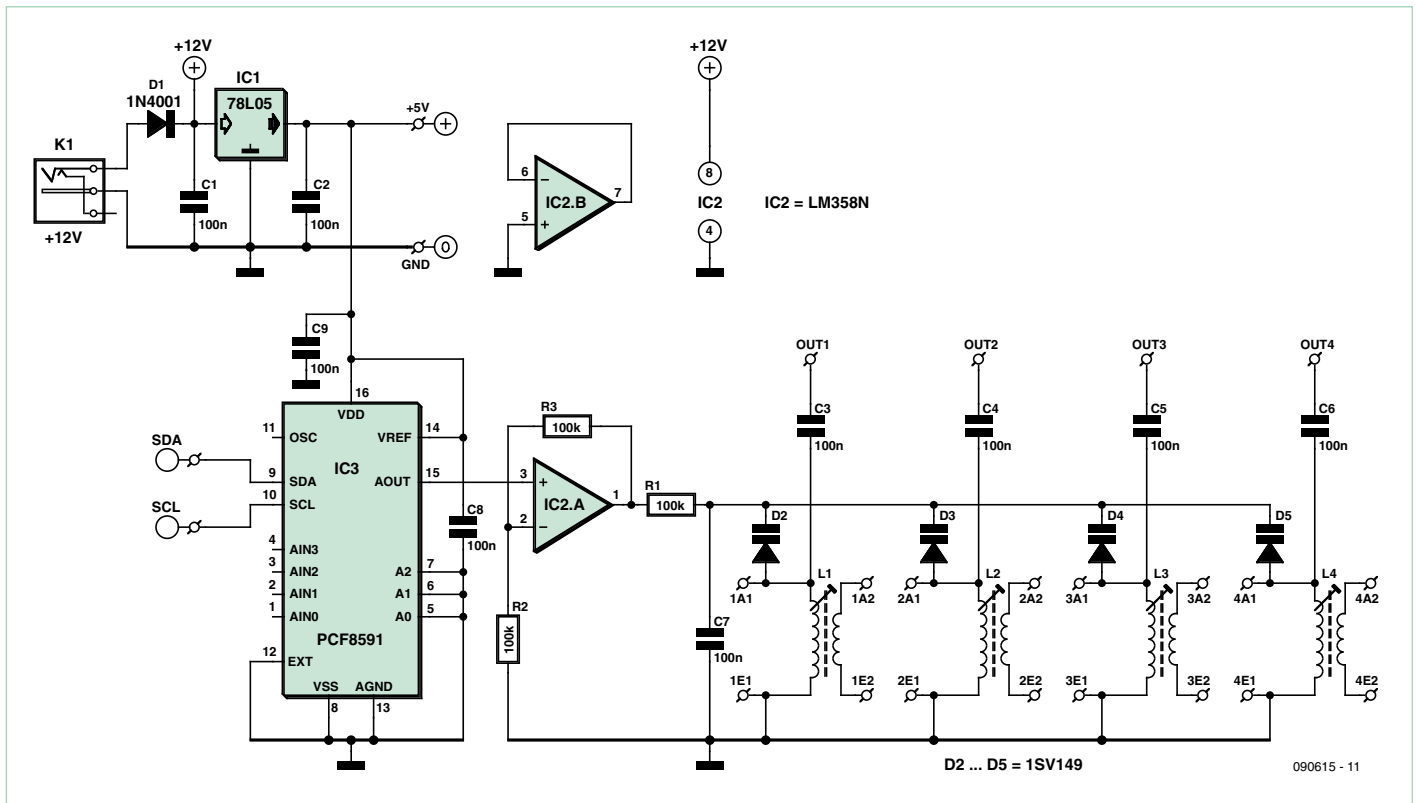

Figure 1. Simple front-end circuits, manually tuned using a variable capacitor, suitable for direct connection to the SDR board.

Figure 2. The circuit of the 'digital' preselector with four front-ends tuneable over an I²C bus.
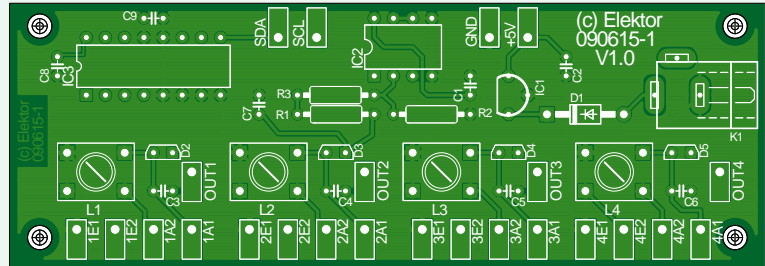
Figure 3. Printed circuit board for the preselector. All the coil connections are brought out to one edge of the board.

between 1E1 and 1A1; to receive medium wave between 550 kHz and 1600 kHz via output OUT2, use 40 turns of litz wire or 0.2 mm enamelled copper wire on the ferrite rod, between 2E1 and 2A1.

The two shortwave antenna coupling coils, between 4E2 and 4A2 and between 3E2 and 3A2, can be wired in series if desired and connected to the antenna cable without an earth, as illustrated in **Figure 4**. This has the highly desirable feature of isolating the PC ground (which connected to the ground of the circuit) from the antenna ground, which can help reduce interference considerably. There are essentially no signal voltage losses incurred by this series connection, as the coils are only in resonance at their own selected frequency and otherwise present a low impedance.

Mounting and wiring

The fixing holes of the add-on board are placed so that it can be fitted directly over the SDR board using spacers. The necessary wires can then be added. **Figure 5** shows the connection points on the SDR board; GND is connected to C21. The +5 V supply connection between R4 on the SDR board and the +5 V point on the preselector board should be omitted for now: see the section on the power supply below. The
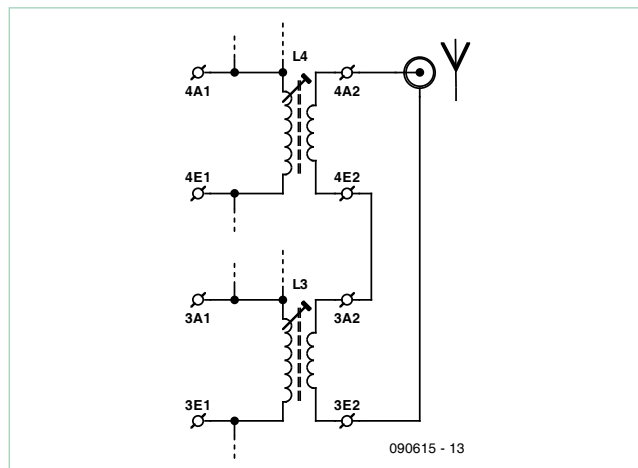
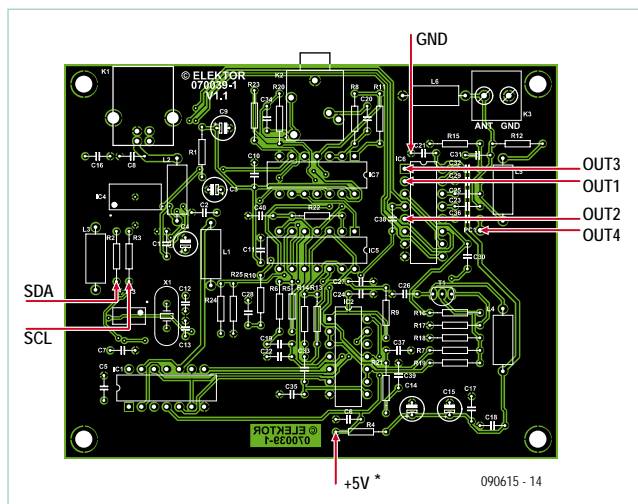Figure 4. Antenna wiring for two short wave bands.

Figure 5. The points on the SDR receiver board where the preselector is connected.

I²C bus connections SCL and SDA are soldered to R2 and R3. The outputs of the preselector board (OUT1 to OUT4) are taken from the points indicated in Figure 5 to inputs A3 to A6 of multiplexer IC6. In the software these are selected as In4 to In7 (see **Figure 6**).

Software and operation

The original tuning software for the Elektor SDR receiver has been extended with the necessary features to control the varicap diodes. The new version, ElektorSDRpre.exe, can be downloaded free of charge from [1] and [2]. As Figure 6 shows, there is now an additional slider that allows the input circuits to be tuned. The actual digital value sent, from 0 to 255, is displayed in a window. The D/A converter turns this into a voltage from 0 V to 5 V. The voltage is doubled by IC2.A, and a tuning voltage of 0 V to 10 V appears across the varicap diodes. There are two modes of operation: manual ('Man') and automatic ('Auto'). By default the software starts up in manual mode.

Start the software up as usual, along with a decoder such as Dream, SoDiRa, G8JCFSDR or SDRadio. Now choose input In1 or In2 for medium wave, or In3 for shortwave. Connect the antenna to the ANT terminals of the SDR board. Set the frequency to that of a known station, for example in

the 49 m broadcast band.

Now disconnect the antenna and reconnect it to the preselector board. Switch to input In4 (second shortwave input). Adjust the position of the preselector tuning slider on the screen to obtain maximum signal strength. You should now see a stronger signal here than at the wideband input, as the tuned front-end circuit provides better matching to the antenna. Sensitivity is considerably improved, especially in the higher frequency bands,

In the same way, test the first shortwave band using In5. A common problem when receiving lower-frequency shortwave stations using the wideband antenna input is interference from stations at three and five times the frequency of the wanted station. The preselector considerably attenuates these images, giving access, for example, to many new stations in the 80 m amateur radio band.

The improvement is even more pronounced when listening to long and medium wave stations using the ferrite rod antenna. The signal strength obtained is similar to that from a longwire antenna connected to the wideband input, but there is considerably less interference. This is due to the suppression of images from higher-frequency stations and to the fact that the ferrite antenna receives the magnetic component of the signal, which gives better immunity to the kinds of interference found in domestic environments.

Automatic tuning

In manual operation mode it is necessary to adjust the tuning of the front-end circuit whenever you switch stations. This process can be automated, with the software calculating and setting the necessary tuning voltage. As the main tuning slider control is moved, the preselector tuning control automatically moves in sympathy. The calculations are based on a precalculated table of reference values, and the software comes with a file InitPreselector.txt which contains suitable settings for the recommended set of front-end coils.

If you are winding your own coils or making other alterations to the circuit, you will need to edit the table using a text editor such as Notepad. The structure of the file must be carefully preserved. For each of the four input resonators there are exactly ten entries in the file: each entry consists of a frequency in kHz and the corresponding
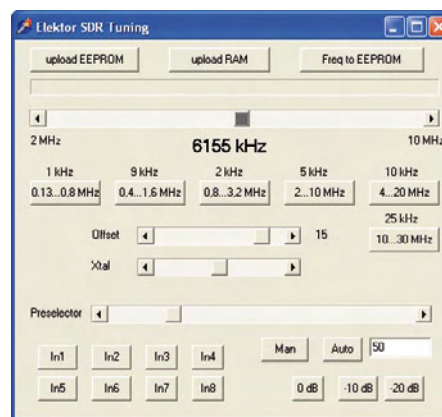

Figure 6. The tuning software now also drives the preselector.

Figure 7. The SDRadio software in action.

tuning figure (in the range 0 to 255). The table is introduced by one comment line (saying 'In4', 'In5' etc.) and terminated by a blank line. The provided file InitPreselector.txt can be used as a starting point to create your own file.

Proceed as follows to determine the correct tuning values to enter into the file. Find ten stations in the required tuning range; tune to each in turn and manually find the optimum position for the front-end tuning slider. The spacing of the reference frequencies is up to you, but it is best if they are more closely spaced over any part of the tuning range where the front-end tuning value changes rapidly. It is also important to sort the values so that the lowest frequency (tuning value 0) appears first and the highest frequency (tuning value 255) last. Enter the values into the file and save it, preserving the filename. When the software is next restarted it will read the table and use the values in it. For any given frequency the software calculates a suitable tuning value by interpolating between the two nearest reference frequencies on either side. The relationship between frequency and tuning value is highly non-linear, changing much more rapidly in the middle of the tuning range than at the ends.

Tuned loop antennas

If it is not feasible or desirable to use an outdoor antenna, the best choice for long- or medium wave reception is the ferrite rod antenna. For shortwave reception, an alternative solution is to use a tuned magnetic loop antenna. This can give reception almost as good indoors as a longwire antenna can outdoors. We therefore have the ability to receive the whole range of stations without an outdoor antenna.

To use a shortwave loop antenna, omit coils L3 and L4 and replace the resonator coil with the wire of the antenna loop. A coupling coil is not required as the antenna is being connected to a high-impedance input. The diameter of the loop, the length of the wire, and the thickness of the wire jointly determine the inductance of the antenna and hence the operating frequency range. Web pages are available to help do the necessary calculations: see, for example, [3].

One practical arrangement is to use two

metres of 0.75 mm² flexible (multi-stranded) power cord wire to make a circle of diameter 60 cm. The inductance of this loop will be around 2.5 µH, which, in parallel with 500 pF, gives a resonant frequency of about 4.5 MHz. Empirically, a tuning range of 4 MHz to 12 MHz can be achieved. If you use the same length of wire to make a two-turn loop, the diameter will be halved, resulting in a higher inductance. A two-turn loop with a diameter of 20 cm makes a useful shortwave antenna for the band from 3.5 MHz to 14 MHz. This can be used as an indoor antenna to receive DRM signals with comparable quality to a longwire antenna.

A good option is to construct an antenna from two 25 cm diameter loops mounted at right-angles to one another. One loop should consist of just one turn and covers higher-frequency shortwave reception up to 30 MHz, while the second consists of two turns and operates from about 3 MHz (see **Figure 8**). The loops can be wired so as to replace coils L3 and L4 on the preselector board: the one-turn loop between 4E1 and 4A1, and the two-turn loop between 3E1 and 3A1.

The antenna is rather directional and it is therefore worth mounting it so that

Figure 8. Construction of an antenna consisting of two loops mounted at right-angles to one another.

it can be rotated — in some cases, to kill interference!

On power supplies

The system uses two separate power supplies. The SDR receiver board takes a +5 V supply from the PC's USB port, while the preselector board uses a 12 V mains adaptor, connected to K1. The 12 V supply is necessary because the varicap diodes require a drive voltage of up to 10 V to cover the full tuning range. A 5 V regulator on the preselector board provides power for the D/A converter.

Depending on the PC or laptop computer used the supply provided by the USB port can be noisy. This is particularly noticeable when a low intermediate frequency (IF) is used, as there is considerable noise up to around 2 kHz. With an IF of 10 kHz to 15 kHz this interference does not normally cause any problems.

However, with the addition of the preselector board, we have the opportunity to improve the power supply of the SDR receiver board by connecting the +5 V point on the preselector board with the +5 V point on the receiver board as indicated in the figure.

To ensure that the preselector board does not supply power back into the PC's USB port, it is **essential** to replace L1 on the SDR board with a diode (type 1N4001, cathode towards C2). The result will be that V_{CC} on the receiver board will be supplied from the preselector's power supply, much reducing interference at lower intermediate frequencies.
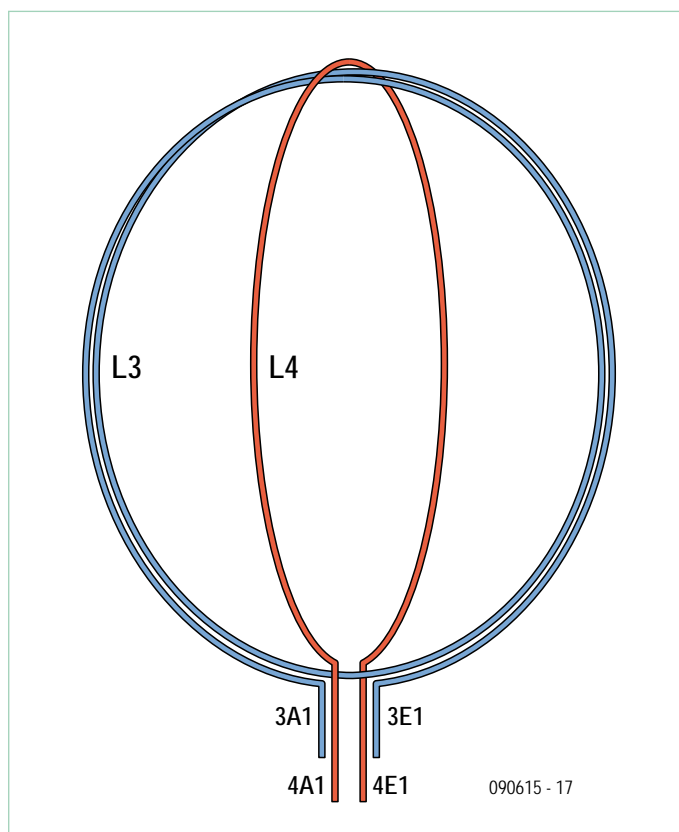
Internet Links

[1] www.elektor.com/070039

[2] www.elektor.com/090615

[3] www.technick.net/public/code/
cp_dpage.php?aiocp_dp=util_inductance_circle