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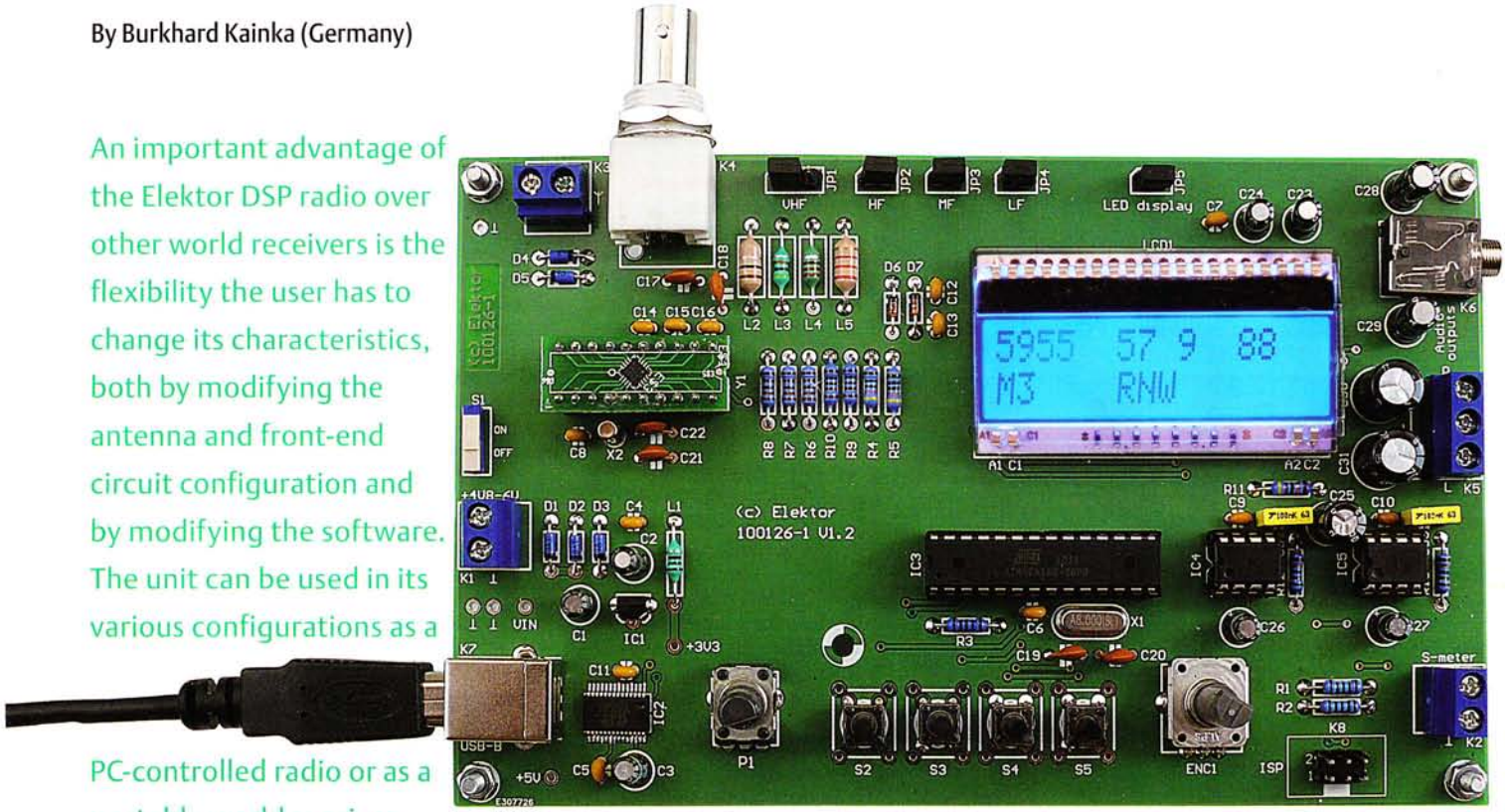
The Elektor DSP Radio (2)

Antennas and PC software

By Burkhard Kainka (Germany)



An important advantage of the Elektor DSP radio over other world receivers is the flexibility the user has to change its characteristics, both by modifying the antenna and front-end circuit configuration and by modifying the software. The unit can be used in its various configurations as a PC-controlled radio or as a portable world receiver.

The circuit diagrams shown here illustrate the input circuit of the receiver we published in the first article in this series. For each possible antenna configuration the relevant jumper settings appear in red and the connected antennas and their accompanying coils appear in green.

Figure 1 shows the standard configuration of the front-end circuit, with all jumpers in their default positions. Switching diodes D6 and D7 are represented symbolically as shortwave and mediumwave switches. You can see from the diagram how in each case a part of the inductance in the circuit is shorted. A common antenna is used for all frequency ranges: one example of a suitable design is a 50 cm whip. Another possibility is to use an outdoor antenna: the author has successfully used a 10 m longwire antenna connected via 30 m of coaxial cable. Although this antenna is not ideal for FM reception, it nevertheless gave good results over all frequency bands from longwave to FM.

If separate antennas are to be used for FM and AM reception, JP1 can be fitted to take the bottom of FM coil L2 to ground. The open pin at JP1 (connected to L3 and C15) then forms the new AM antenna input for long-, medium- and shortwave (Figure 2).

For indoor operation on long- and mediumwave ferrite antennas are often better than wire antennas as they have greater immunity to the types of electric field interference often found inside houses. Figure 3 and Figure 4 show two alternative possibilities. In the first example the coils on the ferrite rod form an additional part of the receiver circuit, while in the second example they replace the fixed inductors on the receiver board, which are taken out of circuit by removing jumpers JP2, JP3 and JP4.

The suggested turn counts given are suitable for use with a 10 mm diameter ferrite rod with a length of between 9 cm and 15 cm. The automatic tuning function of the receiver means that the exact inductance value is not critical. Experiments show that the ferrite rod provides good signal amplitude and interference rejection at frequencies of up to 10 MHz, and this is why both circuit variations also include a shortwave coil on the ferrite rod.

A further interesting option is the tuned loop antenna shown in Figure 5. A wire loop with a total length of 4 m takes the place of JP2. It is possible to make the loop smaller, and the wire length and shape can also be varied. Again, because of the automatic tuning, high signal levels can be achieved, approaching the performance possible with longwire antennas. The radio's display will show the capacitance in the tuned circuit:

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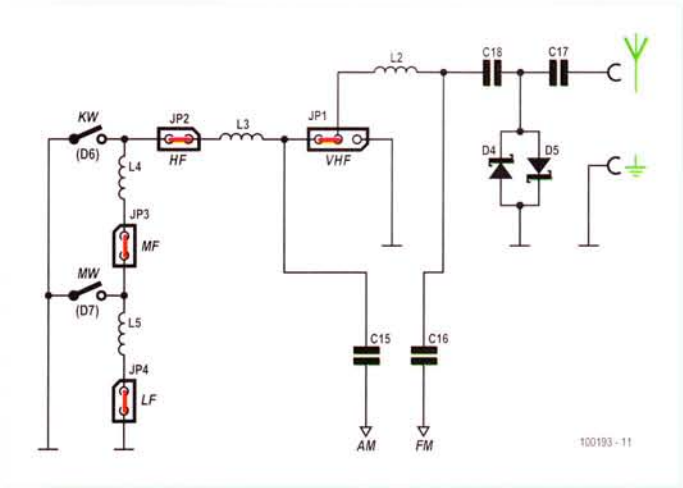

Figure 1. Standard configuration of the front-end circuit.

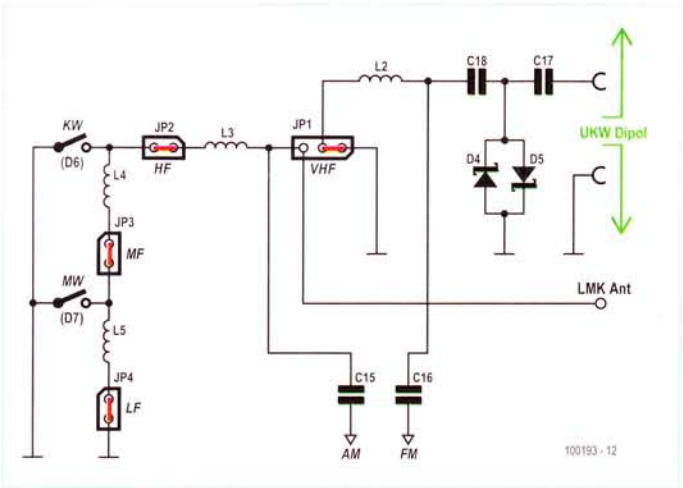

Figure 2. Separate connection of FM and AM antennas.

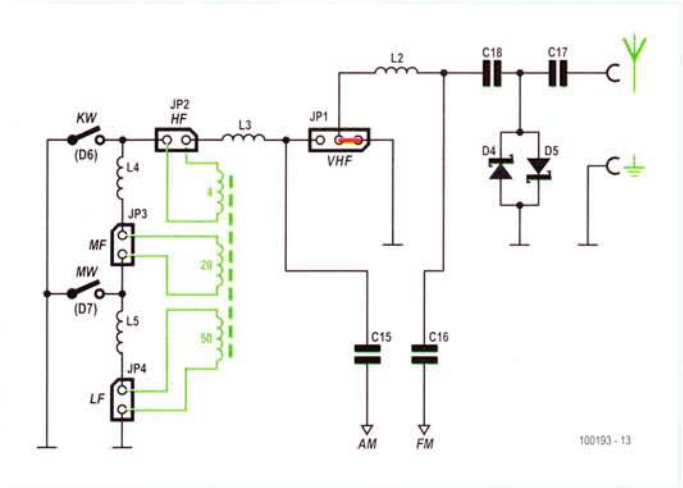

Figure 3. Connecting a ferrite rod antenna for use up to around 10 MHz.

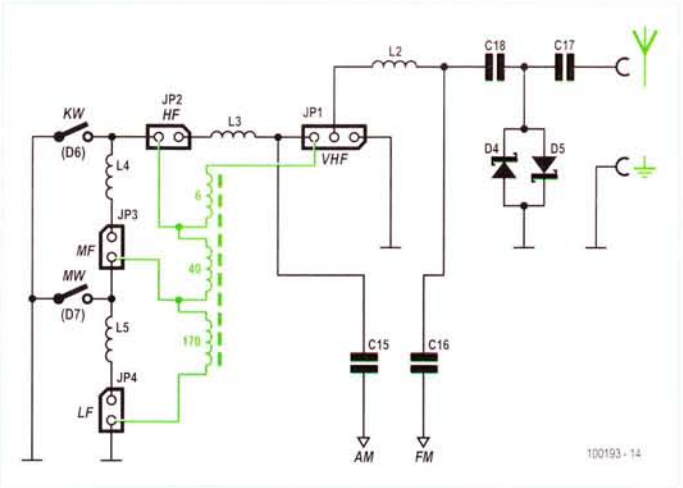

Figure 4. In this variation the coils on the ferrite rod antenna replace the inductors on the receiver board.

as long as this remains between 10 pF and 500 pF the antenna will operate optimally. It is worth noting that the same antenna can be pressed into service for medium- and longwave reception, in each case forming a part of the total inductance in the tuned circuit.

Finally, Figure 6 shows a possibility for shortwave DXing. Jumpers JP2 to JP4 are not fitted and instead we fit a small transformer at the AM input. The turn counts given are intended for use with a 5 mm former with a tuning slug suitable for operation up to 15 MHz. The same coil was used in the 'Preselector for Elektor SDR' article in the December 2009 issue of Elektor and is available from Conrad Electronics (order code 516651) or from ModulBus (RF coil kit T1.4) [1].

The input coil replaces the inductor in the tuned circuit on the receiver board, and opens up the possibility of changing the turn count on the antenna side to optimise matching to the antenna. For example, a small coupling winding as shown, consisting of just one turn, will give good matching to a 50 Ω antenna.

PC control

PC control opens up a whole new dimension of possibilities to the Elektor DSP radio beyond its use as a portable receiver. The radio can be controlled over a USB interface using a specially-developed program called ElektorDSP1, written in Visual Basic. The program, including source code, is available for free download from the Elektor web pages accompanying this article [2].

The first step on starting the program is to establish which COM port is to be used: the default is COM1. If, for example, COM4 is to be used, edit the 'COM' text box in the user interface (Figure 7) appropriately and click on 'Open'. When the program is closed the COM port setting is saved in the file COM.ini, and the value will be restored when the program is next started. All frequencies and station names are stored in the file DSPfreq.ini, and these are also loaded when the program starts.

The program allows the user to choose a frequency from 20 presets for the FM band and a further 20 presets for the AM bands. The frequencies can be edited individually. For each preset a station name can be given for reference: in the case of an FM preset this string will be shown on the PC's screen, but the display on the receiver will show the station name as transmitted by RDS. In the case of AM presets the station names are sent to the receiver along with the frequency data, and the receiver will display this string when the preset is selected

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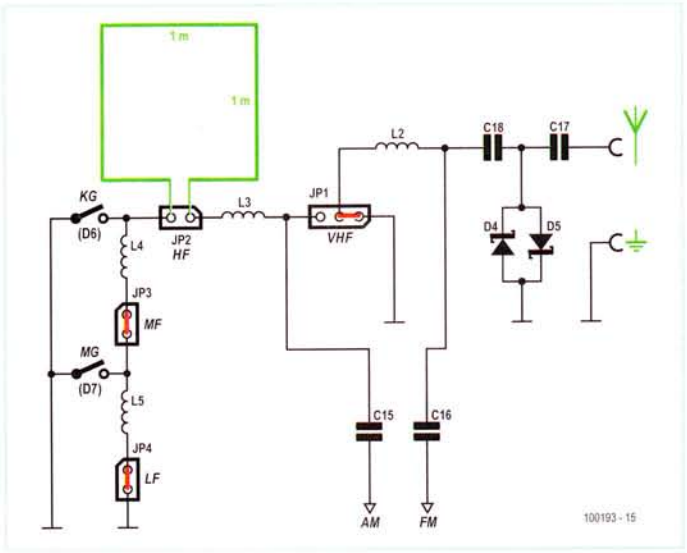

Figure 5. Connecting a loop antenna for AM.

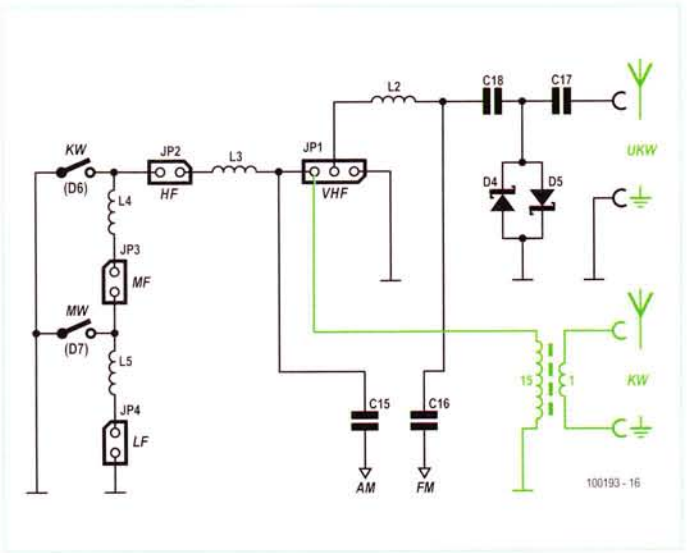

Figure 6. Antenna coupling using an input coil for DX reception.

(by pressing S5 for longer than 0.5 s). This makes tuning to AM presets a little more user-friendly.

The settings can be stored in the receiver as power-up defaults by pressing S5 for more than two seconds. All settings, including any changes to the various parameters described below, will then be copied into EEPROM. To erase all these stored settings, hold down S5 when turning the receiver on: everything will then be reset to standard values.

The Si4735 device in the DSP radio can be configured in a wide variety of ways that determine its reception characteristics. At power-up all these parameters are set to sensible default values, but it is possible to alter their values to suit particular reception requirements or conditions. This possibility was kept in mind when developing the embedded software for the radio, and it is possible to control eight important parameters for AM and FM reception from the PC. If desired, it is possible to set up the receiver with an entirely fresh batch of settings and then save them for when the radio is used as a portable receiver.

Table 1. FM properties

Property	Valid range	Effect
De-emphasis	0 to 2	Treble cut
Stereo	0 to 80 dBµV	Stereo mode above this signal strength
Mono	0 to 80 dBµV	Mono mode below this signal strength
Mute rate	0 to 100 dB/s	Soft mute rate of volume change
Mute max	0 to 32 dB	Soft mute maximum attenuation
Mute SNR	0 to 25 dB	Soft mute SNR threshold
Seek SNR	0 to 20 dB	Automatic search SNR threshold
Seek RSSI	0 to 60 dBµV	Automatic search signal strength threshold

Table 2. AM properties

Property	Valid range	Effect
De-emphasis	0 to 1	Treble cut
Filter	1 to 6 kHz	Filter bandwidth
Mute rate	0 to 100 dB/s	Soft mute rate of volume change
Mute slope	0 to 100 dB/s	Soft mute attenuation function slope
Mute max	0 to 32 dB	Soft mute maximum attenuation
Mute SNR	0 to 25 dB	Soft mute SNR threshold
Seek SNR	0 to 20 dB	Automatic search SNR threshold
Seek RSSI	0 to 60 dBµV	Automatic search signal strength threshold

FM parameters

In the interests of reducing noise, FM transmitters add 'emphasis' (boost of high frequencies) to the signal. This must be compensated for in the receiver ('de-emphasis'). The Si4735 features a switchable de-emphasis filter.

When signal strength is low many FM receivers produce a poor stereo output with considerable interference; some radios automatically switch to mono mode in these conditions. The DSP radio offers a better solution, smoothly and almost imperceptibly transitioning between stereo and mono modes. The upper and lower signal strength limits for the transition are adjustable.

In very weak signal conditions the DSP radio chip uses a 'soft mute' function rather than the sudden muting provided in some receivers, gently attenuating the output and thus also the noise. The parameters controlling this are the 'mute rate' (speed of volume change), the maximum attenuation ('mute max') and the SNR (signal-to-noise

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ratio) threshold below which muting is triggered. It is worth experimenting with these parameters, especially when tuning in to weak stations.
The 'seek SNR' and 'seek RSSI' parameters affect the behaviour of the automatic station search function. Stations will only be found if they exceed the specified signal strength (RSSI) and SNR thresholds.
Table 1 gives an overview of the FM parameters.

AM parameters

The parameters governing AM reception (Table 2) are similar to those for FM. An extra is that the bandwidth of the receiver is adjustable to one of a number of predefined values. The parameter can take on the value 0 (6 kHz), 1 (4 kHz), 2 (3 kHz), 3 (2 kHz) or 4 (1 kHz). Here '2 kHz' (the default value) means that the will accept signals out to 2 kHz away from the tuned frequency on either side, and thus corresponds to an actual IF filter bandwidth of 4 kHz. For strong stations, using a wider bandwidth can improve audio quality, while for DX reception a narrower bandwidth will help reduce interference. The de-emphasis control has a similar effect, and can be used as a crude treble control.

In AM mode there are four parameters that control the soft mute function. The highly effective automatic level control in the receiver IC increases gain when the signal level falls, which as a consequence also increases noise. If the input level falls below a preset threshold, however, the volume will be reduced in proportion. The signal level threshold, the slope of the muting function, the speed with which the function acts and the maximum degree of muting are all adjustable. The default values are designed to work well when

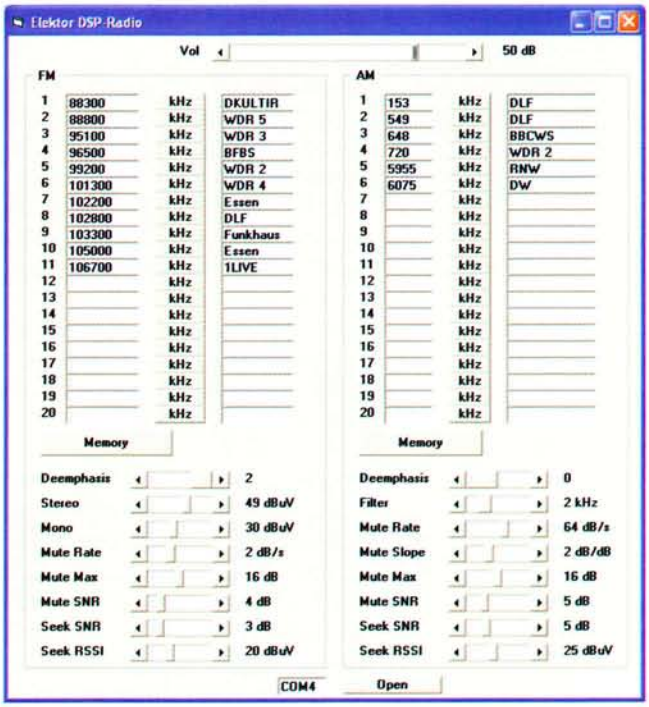

Figure 7. The user interface presented by the ElektorDSP1 program.

Listing 1

Low-level subroutines

```
Declare Sub Get_int_status()
Declare Sub Rx_volume()
Declare Sub Power_down()
Declare Sub Init_am()
Declare Sub Init_fm()
Declare Sub Am_tune_freq()
Declare Sub Fm_tune_freq()
Declare Sub Fm_seek_freq_up()
Declare Sub Fm_seek_freq_down()
Declare Sub Am_seek_freq_up()
Declare Sub Am_seek_freq_down()
Declare Sub Fm_tune_status()
Declare Sub Fm_rsq_status()
Declare Sub Am_tune_status()
Declare Sub Am_tune_status_stop()
Declare Sub Am_rsq_status()
Declare Sub Fm_start()
Declare Sub Am_start()
Declare Sub Am_seek_step_9khz()
Declare Sub Am_seek_step_5khz()
Declare Sub Am_seek_step_1khz()
Declare Sub Init_rds()
Declare Sub Fm_rds_status()
Declare Sub Rds()
```

Listing 2

AM tuning and band switching

```
Sub Am_tune_freq()
  If Fam > 500 Then
    If Fam > 2000 Then
       Portb.0 = 1      'SW
       Portc.3 = 0
    Else
       Portb.0 = 0      'MW
       Portc.3 = 1
    End If
  Else
       Portb.0 = 0      'LW
       Portc.3 = 0
  End If
  I2cstart
  I2cwbyte 34
  I2cwbyte &H40
  I2cwbyte &H00
  H = High(fam)
  L = Low(fam)
  I2cwbyte H
  I2cwbyte L
  I2cwbyte &H00
  I2cstop
End Sub
```

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Listing 3

Decoding serial commands

```
$baud = 38400
'************ RS232 control *********************
    D = Inkey(#1)
    If D = 102 Then F_control            'f, Freq
    If D = 109 Then Mam_control          'm, Memory AM
    If D = 110 Then Mfm_control          'n, Memory FM
    If D = 112 Then Properties           'p, Property
    If D = 105 Then Pc_control_i2c       'i, I2C command
    If D = 106 Then Rdsout = 1           'j: RDS output
    If D = 107 Then Rdsout = 0           'k: RDS output off
    If D = 114 Then Print Rssi           'r: RSSI
    If D = 115 Then Print Snr            's: SNR
```

receiving strong stations. The volume is attenuated by a maximum of 16 dB when the input signal level falls below 10 dBµV. DXers will likely not find this behaviour ideal as weak stations will fluctuate unnecessarily in volume. So, decide whether the primary purpose of the receiver is to listen to stronger stations or DX reception, and set the parameters accordingly. Many DXers will want to disable the soft mute function entirely: the simplest way to do this is to set 'mute max' to zero.

Listing 5

Adjustable properties

```
Sub Properties
  Print "Property"
  Input D
  If D = 1 Then Prop = &H1100        'FM_DEEMPHASIS
  If D = 2 Then Prop = &H1105        'FM_BLEND_STEREO_THRESHOLD
  If D = 3 Then Prop = &H1106        'FM_BLEND_MONO_THRESHOLD
  If D = 4 Then Prop = &H1300        'FM_SOFT_MUTE_RATE
  If D = 5 Then Prop = &H1302
'FM_SOFT_MUTE_MAX_ATTENUATION
  If D = 6 Then Prop = &H1303
'FM_SOFT_MUTE_SNR_THRESHOLD
  If D = 7 Then Prop = &H1403
'FM_SEEK_TUNE_SNR_THRESHOLD
  If D = 8 Then Prop = &H1404
'FM_SEEK_TUNE_RSSI_THRESHOLD
  If D = 9 Then Prop = &H3100        'AM_DEEMPHASIS
  If D = 10 Then Prop = &H3102       'AM_CHANNEL_FILTER
  If D = 11 Then Prop = &H3300       'AM_SOFT_MUTE_RATE
  If D = 12 Then Prop = &H3301       'AM_SOFT_MUTE_SLOPE
  If D = 13 Then Prop = &H3302
'AM_SOFT_MUTE_MAX_ATTENUATION
  If D = 14 Then Prop = &H3303
'AM_SOFT_MUTE_SNR_THRESHOLD
  If D = 15 Then Prop = &H3403       'AM_SEEK_SNR_THRESHOLD
  If N = 16 Then Prop = &H3404       'AM_SEEK_RSSI_THRESHOLD
  If N = 0 Then Prop = &H4000        'Volume
  Input Dat
  Property
End Sub
```

Program-it-yourself

The firmware in the DSP radio was developed using Bascom, and the source code is available, along with a hex file, for free download at [3]. The DSP radio printed circuit board has an in-system programming connector for the ATmega168, which allows you to modify the firmware in the radio to your heart's content. If low-level programming is not your cup of tea, the ElektorDSP1 PC control software described above allows you to customise the receiver without writing a line of code. Furthermore, it is possible to use the USB interface to communicate directly with the firmware and alter the receiver's behaviour. In most cases a simple terminal program is all you need, although it is of course possible to develop programs on the PC to control the radio in specific ways.

The Bascom software runs to over a thousand lines of source code, too much to describe in detail here. However, the program includes a large number of ready-made subroutines with self-explanatory names that control some of the basic functions listed in the Si4735 datasheet (see Listing 1).

The subroutine Am_tune_freq (Listing 2) is worth a closer look. It shows how a command is typically constructed for transmission to the Si4735 over the I2C bus: the device responds to address 34. In this instance the command code is &H40. After that come four bytes of parameters, including the frequency in kilohertz as a more-significant and a less-significant byte. The AM tuning command also selects the required band via the switching diodes connected to ports B.0 and C.3.

Another aspect of the software worth a look from the point of view of developing special software for manipulating the receiver's parameters is the way the serial port is handled. The interface runs at 38.4 kbaud and appears to the PC as a virtual COM port (see Listing 3). Each command is headed by a single character. For example, a lowercase 'f' results in the subroutine F_control being called, which sets a new frequency. Commands 'm' and 'n' allow the preset

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memory to be programmed. The 'p' command gives access to the various 'properties' or 'parameters' of the DSP IC and the 'i' command gives direct low-level access to the Si4735 via the subroutine Pc_control_i2c. Read commands are also available. For example, it is possible to read the current signal strength or signal-to-noise ratio, and to gain access to the RDS data.

Listing 4 shows how a frequency is set. A frequency in the AM band is set by a command such as 'f5955<Enter>': you can try this out using a simple terminal program. In this example, the receiver is tuned to 5955 kHz. FM band frequencies are also given in kilohertz, such as 'f102800<Enter>' for 102.8 MHz. The firmware carries out appropriate initialisations when switching between FM and AM modes. After a frequency command the unit returns to normal manual operation mode, and so PC commands and manual commands can be executed alternately. The source code of the ElektorDSP1 program gives an example of how to control the receiver in this way using Visual Basic.

Listing 5 shows the range of functions available via the 'p' command. A total of sixteen different receiver properties can be adjusted. For example, to increase the receiver bandwidth, use a terminal to send the sequence 'p10<Enter>2<Enter>'. To disable the soft mute function, adjust property number 13 (AM_SOFT_MUTE_MAX_ATTENUATION) by sending the sequence 'p13<Enter>0<Enter>'. Even the overall volume can be adjusted in this way, using property number 0. For maximum volume send 'p0<Enter>63<Enter>'.

Listing 6 shows how to access the low-level features of the Si4735. Each command is introduced by the lower-case letter 'i'. For I2C data transfer the next character (which specifies the subcommand) should be 'C'. The following bytes are transferred as raw binary values. The first two bytes are counts of the number of bytes to be sent and received respectively, and the following bytes are then sent verbatim in the natural order. The microcontroller takes care of prefixing the bytes on the I2C bus with the

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Listing 4

Tuning over the serial port

```
Sub F_control()
  Print "Tune"
  Input Fin
  If Am = 1 Then
    If Fin >= 60000 Then
      Power_down
      Waitms 10
      Am = 0
      Fm_start
      Waitms 100
    End If
  End If
  If Am = 0 Then
    If Fin < 60000 Then
      Power_down
      Waitms 10
      Am = 1
      Am_start
      Waitms 100
    End If
  End If
  If Am = 1 Then
    Fam = Fin
    Am_tune_freq
    Waitms 250
    Am_tune_status
  End If
  If Am = 0 Then
    Fin = Fin / 10
    Ffm = Fin
    Fm_tune_freq
    Waitms 250
    Fm_tune_status
  End If
End Sub
```

Listing 6

Direct I2C bus access

```
'*** PC I2C commands ****
Sub Pc_control_i2c
  Print #1 , "I2C"
  Do
    Get #1 , Command    'I2C write and read to Si4735
    If Command = 67 Then        '"C"
       Get #1 , Bytesout
       Get #1 , Bytesin
       For N = 1 To Bytesout
         Get #1 , Di2c(n)
       Next N
       I2cstart
       I2cwbyte 34
       For N = 1 To Bytesout
          I2cwbyte Di2c(n)
       Next N
       I2cstop
       If Bytesin > 0 Then
         I2cstart
         I2cwbyte 35
         While Bytesin > 1
           Bytesin = Bytesin - 1
           I2crbyte D , Ack
           Put #1 , D
         Wend
         I2crbyte D , Nack
         Put #1 , D
         I2cstop
       End If
    End If
    If Command = 65 Then  'LCD Line 1
      Input #1 , Text1
      Locate 1 , 1
      Lcd Text1
    End If
    If Command = 66 Then  'LCD Line 2
      Input #1 , Text1
      Locate 2 , 1
      Lcd Text1
    End If
  Loop
End Sub
```

start command and the device address. The receiver IC is then addressed again in read mode. The requested number of bytes is then read and passed back to the host PC. The 'A' and 'B' subcommands of the 'i' command are used to send text to be shown on the receiver's LCD panel: the two commands allow the two lines of the display to be written independently.
The receiver does not automatically return to manual mode after the 'i' command is completed; instead, the device remains under PC control.

In summary, the Elektor DSP radio offers a wide range of options, well beyond those offered by a conventional world receiver. In particular, it offers an unprecedented array of customisation possibilities. We hope that many readers will build the receiver and exchange their experiences on the forum on the Elektor website, and we feel sure that you will come up with ideas far in advance of anything we have thought of!

(100193)

Internet Links

[1] www.ak-modul-bus.de
(site only available in German: search for 'HF Spulen Bausatz T1.4')

[2] www.elektor.com/100193
(web pages accompanying this article)

[3] www.elektor.com/100126
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