JUMA-RX1

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Design background

The JUMA-RX1 receiver was designed for a RX-design competition announced by SRAL (The Finnish Amateur Radio League). The task was to design and build a receiver which is suitable for construction by a novice radio hobbyist, and which, due to its relative simplicity, is as educational and useful as possible. The rules of the competition were published in Nov, 2004 issue of Radioamatoori.

Designers' own goals

At least the 80 m and 40 m amateur bands
Sufficient sensitivity on these bands
Adequate dynamic performance and well-working AGC
Clear, simple construction based on modern techniques
Good frequency stability and precision frequency readout
Low power consumption

General receiver principles

The JUMA-RX1 receiver designed and built is based on the principle of Direct Conversion. The local oscillator (VFO) has been implemented by a microcontroller-driven DDS (Direct Digital Synthesizer). This facilitated compact and simple construction resulting in excellent frequency stability and general coverage reception between 100 kHz…7.1 MHz. JUMA-RX1 is basically a DSB-type (Double-SideBand) receiver suited for SSB and CW reception. Current consumption of the receiver is less than 50 mA.

Mechanical construction

The case (Fig. 1 and Fig. 2) is made of a small (142 x 42 x 72 mm) commercial aluminum box consisting of a chassis and its cover. The holes for display, controls and connectors have been drilled (and sawed) to the front and rear panels of the chassis. There's a small loudspeaker below the cover.


Fig. 1- JUMA-RX1 front view


Fig. 2 - JUMA-RX1 rear view

Building blocks of the receiver

There are two printed-circuit boards in the receiver, the RX-main board and the DDS-control board. The display is a ready-made LCD-module (Figure 3).

The RX-main board contains the mixer, necessary amplifiers, SSB-filter, AGC, and voltage regulation. The RX-main board provides the DDS board with S-meter voltage and 12 V supply voltage. Local oscillator signal is generated by the DDS board.

The DDS board incorporates a digital local oscillator driven by an on-board microcontroller. Frequency is adjusted by a rotary encoder read by the micro-controller which then sets the DDS frequency. In addition, the on-board microcontroller drives the LCD display indicating frequency and bar-type S-meter readings or supply voltage. The microcontroller also generates acknowledgement audio tones.

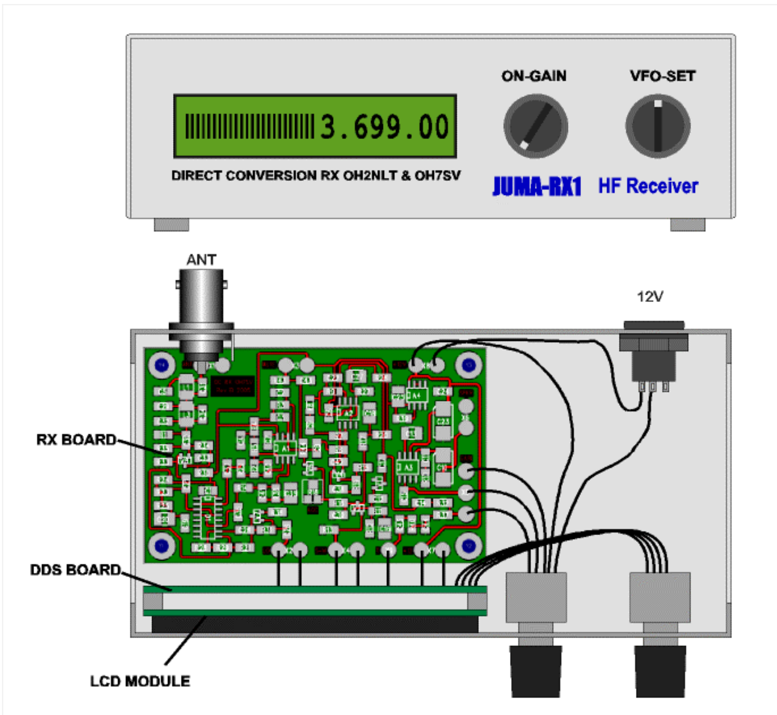

Figure 3 - JUMA-RX1 construction

Versatility

The PC boards of JUMA-RX1 have been designed with the idea that you can – should you so desire – build only either DDS-VFO or RX-main part and implement the rest with your own designs.

RX-MAIN section operation (also see block and circuit diagrams)

General

RX-main section is implemented on a small 50 x 80 mm single-clad PC board (Fig. 4). The antenna signal is connected to soldering pads marked X1 near the upper left corner of the board. The pads marked X2, X4, X9, and X7 near the bottom edge are connected to DDS-and-control section. Near the right-hand edge, loudspeaker leads connect to X6, and AF-gain control is connected to X5. Near the upper edge, supply voltage is connected to X8 and, if desirable, RX-mute signal can be applied at X3. All components are Surface Mounted Devices. There are four installation holes in the corners.

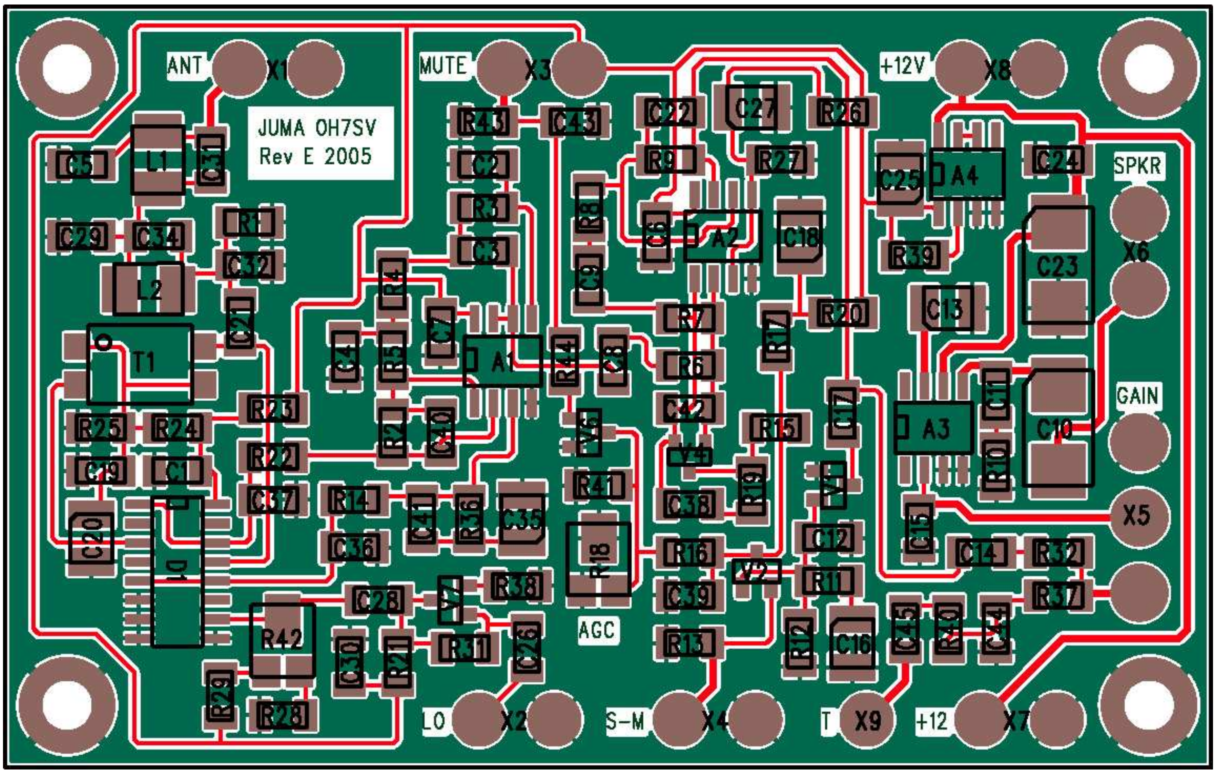

Figure 4. RX-main section

JUMA-RX1 employs the principle of direct conversion, ie. output from the mixer is CW or SSB audio signal. The unit basically is a DSB-type receiver listening to both sidebands. It is a general coverage receiver optimised for 80 meter and 40 meter amateur use.

7 MHz low-pass filter

Signal from the antenna is filtered with a 2-stage 7 MHz low-pass filter attenuating the 3f-response, a consequence of the principle of operation. The low-pass filter utilises commercial SMD chokes to avoid winding of coils. The receiver is useful on lower frequencies down to 100 kHz, but attenuation of spurious frequencies is not optimised there. The receiver can be optimised for lower frequencies if desired by modifying the cut-off frequency of the front-end low-pass filter to max. twice the listening frequency, eg. with a 4 MHz low-pass filter the RX is optimised for the 160 m…80 m bands.

Broadband transformer

After the low-pass filter there's a broadband transformer balancing the signal for the mixer. Another purpose of the transformer is to prevent the local oscillator from leaking into the antenna, because the VFO is on the listening frequency. A TDK commercial data filter, well suited for HF use, serves as the transformer. Alternatively, you can wind the transformer yourself by first twisting two 0.25 - 0.35 mm enamel copper wires together and then winding them on a ferrite core. A suitable ferrite core is the small two-hole type BN-43-2402 bead by Amidon, wound with 4 turns. Other ferrite cores can also be used. For example, the Amidon FT-37-43 toroid is suitable but requires 6 turns.

Mixer

The mixer is an HEF74HC4052 CMOS analog switch (D1), alternately switching the antenna signal between two sampling capacitors (C36 and C37). Due to required switching speed and 8 volt supply voltage, the only analog switch type suitable for D1 is the one made by Philips, easily identified by its HEF prefix. The Philips version is distinguished from other 74HC IC series by offering greater speed and wider supply voltage range. This type of mixer was selected because of its excellent dynamic performance and hence the front-end can be implemented using a wide-range low-pass filter without an RF amplifier. Other types of mixer usually necessitate separate band filters or even more narrow filters which are difficult to make and install. The sampling principle of the mixer by itself constitutes a narrow band filter around the VFO frequency. The width of this filter is ± 16 kHz and it attenuates already at the mixer all signals removed from the listening frequency with a slope of 6 dB/octave. For example, a station 100 kHz away has been attenuated at the mixer by 16 dB and 1 MHz away ca. 35 dB. This is beneficial in avoiding intermodulation caused by BC stations.

Differential preamplifier

The mixer is followed by a differential preamplifier (A1-A), a JFET operational amplifier TL082. The gain is set to a moderate level to avoid strong-signal clipping at the output. Nevertheless, the gain setting is high enough to allow for the signal-to-noise ratio to be determined by this stage. The noise characteristics of the amplifier are sufficient on the 80 meter and 40 meter bands, if properly tuned, full-size antennas (ie. dipoles) are used, because background noise level is high on these bands. If desired, noise characteristics can be improved by using a low-noise, pin-to-pin compatible amplifier such as the LT1113. This should not be necessary, however, unless poor antennas are used.

SSB-filter

Next stage is the 2.5 kHz SSB audio filter. It is implemented as active low-pass filter using an operational amplifier (A1-B). The gain within the passband of the filter is 0 dB, to maintain the good strong-signal performance attained in the preamplifier. The filter is designed for SSB reception, and it is usable in CW reception, too. Low-frequency (0…300 Hz) attenuation is achieved by appropriate selection of the values of coupling capacitors in the amplifier chain of the receiver. SSB-filter frequency response is depicted in Fig. 5.

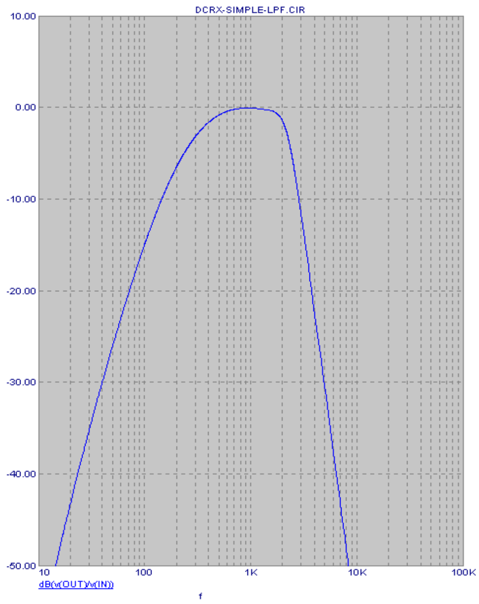

Fig. 5 – Simulated response of the SSB-filter

Automatic gain control (AGC)

JUMA-RX1 incorporates a good automatic gain control (AGC) system. It consists of an adjustable amplifier (A2-A and V4), postamplifier (A2-B), signal rectifier (V1), and control section (V2). Along with increasing antenna signal the resistance of JFET V4 decreases, as the control section adjusts gate voltage of the FET towards source. The FET acts as the feedback resistor of the operational amplifier thus adjusting gain accordingly. The idea behind a good distortion-free audio AGC is to keep signal level low across the controlling FET, only ca. 10 mVp-p. Then the FET will operate within its linear resistance range, and hence no distortion.
When the RX is switched on for the first time, the threshold voltage of AGC is adjusted with trimmer R18 to just start reducing noise with no antenna connected. See the details in chapter ”Operation and adjustments”. AGC also produces useful S-meter data, 0…0.3 V, exported to the DDS board and thereafter to the LCD display. Because of the "simple" circuit, S-meter begins to react only after AGC starts to decrease gain at ca. 10 uV antenna signal, corresponding to ca. S6-level. AGC time constant is determined by capacitor C16 and resistors R11 and R12. AGC speed, if desired, can be altered by changing the value of R12. For example, halving its value will double AGC speed. The dynamic AGC range of the receiver is good, ca. 110 dB, so even strong stations won’t hurt your eardrums. This wide adjustment range is achieved as follows: An

antenna signal of 10 uV is needed before AGC sets in. This corresponds to a signal increase of 33 dB. AGC gain control range is 70 dB. In addition, the AF signal is allowed to increase along with increasing RF signal ca. 7 dB in the AGC circuit. Summing it all up gives 110 dB.

AF-gain

Volume control (AF-gain) is connected to soldering pads X5. To the ”hot” end of the potentiometer, acknowledgement audio tones are imported from the DDS board (pad X9). The level of the tones has been preset, and their square waveform has been ”cleaned” with a simple RC-filter R37, R40 and C44. ACK tones can be heard from loudspeaker.

Loudspeaker amplifier

For loudspeaker amplification, a type LM386 amplifier is used, capable of delivering ca. 1 W to a low-impedance loudspeaker. This amplifier is critical in determining the highest allowable supply voltage for the receiver, 15 volts, because the amplifier is fed directly from supply voltage. Should you so desire, you can install a (switch-type) connector for external speaker or headphones in the rear panel of the case.

Voltage regulation

Voltage regulation of RX-main section, +8 V, is achieved using a low-drop type regulator, LP2951 (A4). This makes flexible dry cell or battery usage possible, because battery voltage may drop as low as 8.5 volts while the receiver still works impeccably. In setting the voltage, IC internal resistors are utilised by connecting R39 in series with them. Check output voltage for a value btw. +7.9V...+8.2V and change the value of R39 if necessary. The regulator IC can be replaced with a traditional 78L08 in SO-8 case. In this case minimum supply voltage is 10 V.

Buffer amplifier of the LO

RX-main board also contains a local oscillator buffer amplifier (V7), amplifying the 0.2 Vp-p LO-signal from the DDS section to a suitable level (ca. 5 Vp-p) for driving the analog muxer. With the aid of trimmer R42, the pulse ratio of LO signal going to muxer D1 is fine-tuned to exactly 50 % by adjusting the DC operating point of the LO signal. By adjusting this operating point, the 2f spurious response attenuation of the RX can be optimised. See chapter ”Operation and adjustments”.

Mute circuit

In addition, the board includes a mute circuit (V6), useful for muting the receiver during transmission. Muting works smoothly without additional "clicks" and is effected by short-circuiting soldering pads X3-1 and X3-2 together. Eg. a relay or a switch can be used. Alternatively, muting can be achieved by importing a positive voltage (+5V…+15V) to soldering pad X3-2 from your transmitter during transmission. It is not necessary to install the components of this mute circuit (V6, R43, R44, C43), if the receiver will not be used with a transmitter.

DDS and control section operation

General

The local oscillator of the receiver has been implemented using the DDS (Direct Digital Synthesis) principle. The entity is composed of an Analog Devices AD9833 IC and a low-pass filter following it. The DDS chip is controlled in the case of JUMA-RX1 with a Microchip PIC16F819 microcontroller. The same controller is also responsible for all other user interface functions of the receiver. The physical interface consists of a 1x16-character LCD display and a rotary encoder which also includes a non-locking pushbutton switch. All receiver controlling can be achieved by using ”two knobs”. User interface thus only means a volume control potentiometer (with supply voltage switch) and the rotary encoder with momentary switch mentioned above. Both design and component selection have been subject to the aim of low total cost.

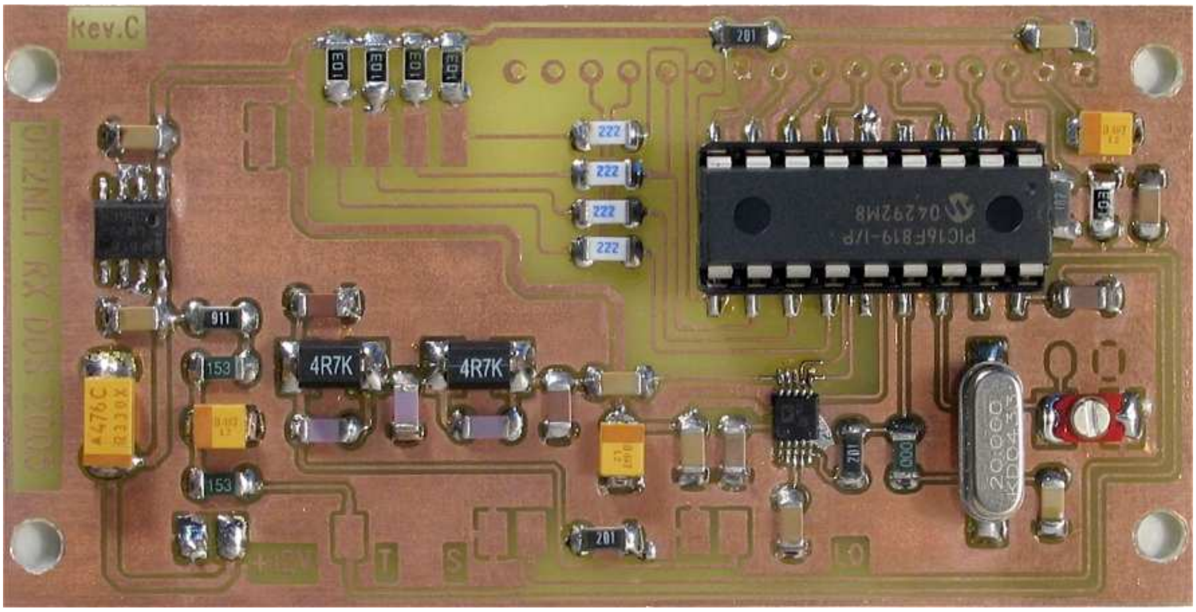

Figure 6 – DDS and control section

Mechanical construction

Mechanical construction of the DDS-and-control section has been reduced to minimum possible without compromising easy assembly of the device, however. The 1x16 character display and the box chosen determine the measurements of the circuit board. The height of the PCB, 40 mm, is derived from the height of the box, and its width , 80 mm, was chosen to coincide with the width of the LCD display. The PCB was designed to be installed with the same screws fixing the LCD display to the front panel of the box. All components are located on the ”rear” side of the PCB. Thus also the components with ”feet”, the crystal and the socket for the microcontroller (Figures 7, 8 and 10), are installed on the rear side of the PCB without drilling holes, just like SMD components.

Fig. 7 – Bending crystal ”feet”

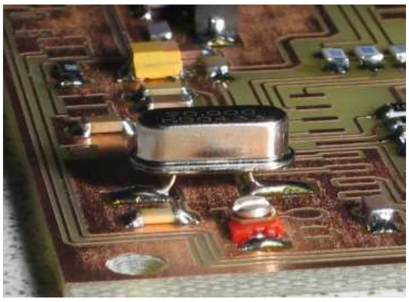

Fig. 8 – Soldering crystal, SMD style

The leads connected to the PCB can be soldered directly to PCB pads, or a 0.1” pin strip can be used for connections.

Operation of DDS-and-control section

The functions implemented are primarily dependent on programs controlling the device. The required signal paths and connections must naturally exist, too.

- Generation of LO frequency, implemented with DDS IC
- Setting of oscillator frequency with rotary encoder
- Indication of frequency on LCD display
- Selection of frequency step (fine/coarse tuning) with encoder
- Indication of settings on LCD display
- Saving default frequency and frequency step in non-volatile memory
- Graphic display of RX S-meter on LCD display
- Supply voltage measurement and numerical display on LCD display
- Generation of ACK tones of user interface
- Calibration of crystal oscillator frequency with trimmer

Microcontroller

The microprocessor (rather the microcontroller) chosen is a PIC16F819 made by Microchip (Fig. 7). It was decided to use an IC in a DIP case with feet because it is easier to handle in programming.

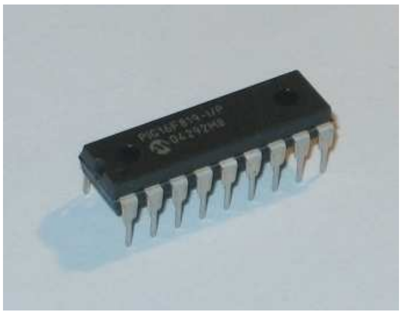

Figure 9 – The microcontroller

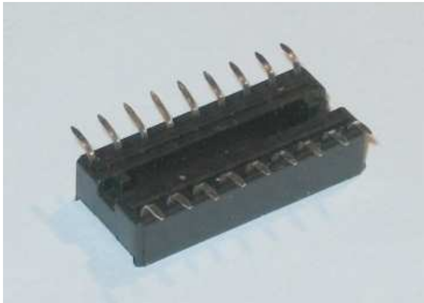

Fig. 10 – Bending DIP-18 socket pins

The IC or its socket, however, are intended to be installed like SMD components on the PCB (Fig. 8). The controller chosen (16F819) offers all the necessary qualities for controlling the receiver. There are two kilowords of Flash memory for program storage, 256 bytes of RAM memory, and 256 bytes of EEPROM memory for storage of settings in the IC. There is also a 10-bit A/D converter, which is used for S-meter and supply voltage measurements. The IC also contains the necessary amount of timers, I/O ports, and other functions. The greatest design challenge was the scanty amount of program (Flash) memory. Also, the minute amount of I/O signals in the IC has given rise to using most I/O pins for multiple tasks. These are described in the circuit diagram and operational descriptions of the blocks.

Oscillator

The oscillator was implemented by using one bargain-price 20 MHz crystal for timing the functions of the microcontroller and for generating the reference frequency of the DDS IC. For the microcontroller a lower frequency would suffice, but 20 MHz was chosen because of the DDS IC requirements. Oscillator circuitry was implemented by connecting the crystal to the oscillator circuit of the microcontroller, and using the output as the clock signal for the DDS IC as well. Oscillator frequency fine tuning is accomplished with a trimmer capacitor connected in parallel with the loading capacitor in the input of the oscillator. More information on the operation and characteristics of the oscillator can be found in the Microchip PIC16F819 data sheet.

DDS and low-pass filter

LO frequency is generated using DDS (Direct Digital Synthesis) principle from the 20 MHz reference frequency. The maximum usable frequency in the DDS principle is determined by Nyqvist theory. In a sampling system the signal frequency cannot be higher than half the sampling frequency. This means that in theory, the max. LO frequency would be 10 MHz. In practice, the highest good-quality signal is 40 % of the reference frequency. The DDS principle also generates a series of harmonic frequencies depending on fundamental frequency. These are filtered with a 8 MHz low-pass filter before LO signal is delivered to the RX board. After the filter, the signal produced by the DDS circuit is ca. 250 mVp-p. This is taken to a buffer amplifier on the RX board which is then driving the mixer.

The DDS principle can be used to generate frequencies which are tightly coupled to the reference and which can be adjusted with very fine resolution. In this implementation (20 MHz reference clock), the minimum frequency step is 0.0745 Hz, which is plenty more than enough. In accordance with the DDS principle, the phase noise of the reference oscillator can be observed directly at the output of the DDS. The phase noise characteristics of the reference oscillator implemented compare favorably with other qualities of the receiver.

What follows is a short description of the DDS priciple: During each cycle of the reference clock, a presettable constant (number) is added to the phase accumulator of the DDS. The contents of the phase accu is taken through a sine-conversion to the D/A converter, the output of which is the synthesized sine-wave signal. In the case of AD9833, the presettable number is 28 bits long. There are fine articles on the principle on the www-pages of Analog Devices. The same pages also carry the data sheet of the AD9833 IC used in the receiver.

Voltage regulation

The operating voltage of the DDS section is +5 V and the current consumption is ca. 20 mA. The voltage level is determined by LCD display which requires 5 V to operate. The DDS IC and the microcontroller would work even with a lower voltage. The required +5 V is derived from the 9 V...15 V supply voltage and it is stabilised with a 78L05 regulator. The 5 V operating voltage also serves as reference voltage for the analog converter of PIC16F819.

LCD display

The LCD display is a commercial 1x16 character alphanumeric bargain-price display module. For driving the display eight data bits and a couple of control signals are needed. The data bus is driven by I/O port B of the 16F819 controller. A portion of this bus is also used for driving the DDS IC and for reading the status of the rotary encoder. During different sequences the bus is controlled by different portions of the program suite. Driving the display is easy to accomplish. With an RS signal a selection is made whether a command or a character is written on the display. Examples of commands are clearing the screen and setting the location of next character. There is a pull-up resistor in the RS signal line because the line is 'floating' during analog measurements. With an E signal the contents of data bus is written on the display. The display module is able to display letters, numbers, and a selection of other characters. It is also possible to construct some of your own characters in the RAM of the module. This feature has been utilised in implementing the graphics needed for the S-meter. One visible line of the display has been divided into two logical eight-character sections. More information on this can be found in the program block descriptions below. More information on commands and timing can be found in the data sheet of TM161AB6A display module. The contrast of the display has been set by resistor R2 on the DDS PC board. See the details in chapter "Operation and adjustments".

Encoder

A crucial part of user interface is the rotary pushbutton encoder used in frequency selection. The price limit of the project didn't allow for even thinking about a high-density (100 pulses or more / turn) encoder, which would create the feel of a 'real' VFO knob. For the encoder, a low-price model producing 30 pulses per turn and equipped with a pushbutton switch, was selected. User interface is designed to support such a model. Any model capable of producing 15-30 pulses per turn will do as encoder. The encoder is constructed as a rotary switch with two contacts. These contacts are phased in order to produce two signals with 90-degree phase shift. This IQ signal can be interpreted to indicate encoder movement and direction of rotation. The signals from the encoder and its pushbutton are connected through separating resistors to the data bus of LCD display where their states are read by a section of the program. A more detailed assessment of the operation and features of the encoder can be found in the data sheet of the component.

Program suite

General programming notes

The whole program suite was written in C. The suite consists of modules, each doing separate tasks to implement desired characteristics. Most of the code conforms to ANSI-C standard and is portable to other environments. To secure the adequacy of memory space, deviations from ANSI-C standard have taken place when necessary. There is a pre-compiled HEX-type file available for programming the PIC16F819 IC. The source code of the suite is also available in case it is desirable to change or add to the features of the program. The 16F819 IC used includes two kilowords of Flash memory, which is almost totally used. If major additions are planned it is advantageous to change the IC to a type PIC16F88 IC, compatible with the former but containing four kilowords of Flash memory.

Programming tools

The project was carried out in Microchip's MPLAB 7.00 development environment. The program suite was compiled using Hi-Tech PICC_8.05PL2 compiler in the environment mentioned above.

Program functions

The program suite of the microcontroller carries out all user interface and some auxiliary functions. After start the I/O circuits of the microcontroller are set to appropriate states, the DDS IC is initiated for operation, the EEPROM memory is searched for user-saved frequency and step, and the latter are set as default values. After initiation the LCD display shows a bit of "JUMA-RX1 advertisement" and a greeting is sent on

CW through user interface audio port. After start-up the tasks described in the next chapter are addressed.

Program suite construction

There is no actual operating system in use. Instead, the program suite carries out the various tasks in a free-running main loop. However, some time-critical tasks (such as reading the rotary encoder) are executed in sync with 1 ms timer interrupts.

The execution cycle of the free-running main loop is ca. 6 ms, during which the following tasks are addressed:
- Both analog inputs (supply and S-meter voltages) are measured.
- A check is done whether the encoder pushbutton is depressed: if it is, the digit-selection loop is executed as long as the switch is depressed.
- When the switch is released, it is examined whether the desired function was either to set tuning step or to switch the state of the display.
- The frequency and step in use are saved in EEPROM memory, if the switch is depressed longer than for 2 seconds. Saving operation is acknowledged both on display and by an audible beep.
- A check is done whether there is a +/- adjustment number from the encoder. If there is, frequency is changed corresponding to the product of current step value and the adjustment number.
- If frequency was changed, the new setting is sent to the DDS IC.
- Depending on display state selected, either S-meter or supply voltage is measured and displayed.
- From the DDS set value, frequency is calculated and displayed with 10 Hz resolution.
- There is also a CW TX shift in the program, if the DDS is used for CW transmitting purposes. By grounding the J1-1 contact of the DDS board either with a relay or a transistor, the frequency of the control section is lowered by 700 Hz. The change is also shown on the display.

The microcontroller includes an internal timer. It is used to produce an 1 ms interrupt service which is responsible for the execution of the following tasks once every millisecond:
- The 1 ms counter used for timing is updated
- The I/O port B of the microcontroller is switched to operate as input and a sample is obtained
- From this sample the movement and direction of the encoder is determined

For further details, see chapter "Additional information on the operation of program modules".

DDS board assembly and soldering of parts

The greatest challenge in assembling the DDS-and-control section is the AD9833 DDS IC, only available in a very small SMD case (MSOP RM-10). If you haven’t got earlier experience with SMD components, the handling of this IC may seem impossible. The MSOP RM-10 case is only 3 mm long and 3 mm wide, and it has 10 pins. The distance between pins is 0.5 mm. In practice though, you don’t need anything else than a magnifying glass, some good-quality flux, and a clean small-size soldering iron tip to solder the IC in place. Peaceful mind and steady hand bring good results. There are various methods of assembly, but here’s a good one: Cover the IC installation area with a thin layer of flux. Pre-solder PCB pads by melting a small amount of solder on top of the flux and spread it evenly on the pads. Be careful not to exert any pressure on the PCB with the tip. Thin (0.5 mm) foils are easily detached from the PCB. After pre-soldering some flux is added, if required, and the AD9833 IC is aligned in its place. This is best done using a magnifying glass. After making sure the IC is properly oriented it is soldered in place. You don’t usually need more solder for this. It is sufficient to heat with soldering iron tip the pre-soldered pads in order to attach the IC pins. Should there be any short-circuits between the pins, they are carefully removed using desoldering braid. If for one reason or another you must remove the IC, it is easily done with two soldering irons, both with tips broad enough to cover all pins of the IC on each side.

DDS board assembly order and other hints

In assembling, the builder is usually guided by his personal preferences. The following hints are, however, worth noting:
- It is advantageous first to install the DDS IC. While soldering the IC, free working space and good handling capability of the PCB are definite advantages.
- There are a few components under the microcontroller, and they must, of course, be installed before the microcontroller or its socket.
- Prior to soldering the microcontroller socket it is worth your while to check with an ohmmeter that there are no short-circuits to ground or to adjacent foils from the foils located under the IC.

- Next it is best to install the +5 V regulator and its components, and measure the 5 V voltage after connecting supply voltage to the PC board.
- The order of assembly for other components can be selected freely.
- If the LCD display is mechanically different from the model given in the parts list, it can be connected to the DDS PC board by using insulated wires of suitable length.
- If the encoder model available lacks the pushbutton switch, a separate pushbutton can be used.
- Other components, too, can be replaced with available parts. The pads of the PCBs have been dimensioned to allow eg. for lead-type tantalum or electrolytic capacitors to be used instead of SMD tantalum capacitors (Figure 11).

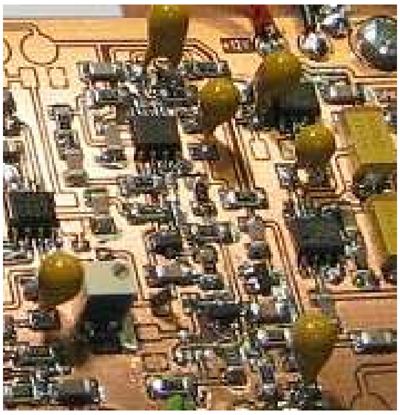
Fig. 11 – Using lead-type tantalum capacitors

Connecting LCD module and DDS board together
The display module and the DDS board are best attached together with screws and sleeves. Next the connecting wires between the display module and the PCB board are threaded and soldered. This is done to ensure the display module and the PCB remain at proper distance from each other.

Wiring and connections

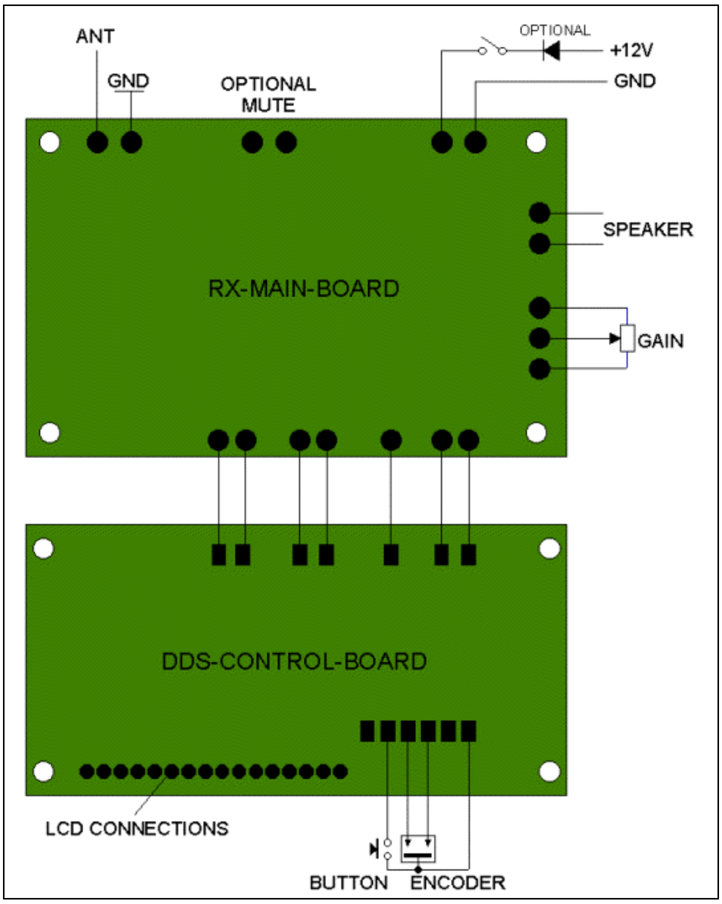

Fig. 12 – PCB wiring and other connections

Construction hints

It is easiest to solder SMD components by first pre-soldering one pad with small amount of solder. Then the SMD component is placed in position with tweezers, and the pre-soldered pad is heated without using additional solder. When the component is correctly placed with one ”foot” soldered, the other pads (and perhaps the original, too) are soldered using additional solder.

If you need to remove an SMD component, two-pole components can be easily detached by heating both ends in turn with soldering iron. Removing multi-pole SMD components, such as integrated circuits, is more difficult. First all extra solder must be removed by using desoldering braid. Then, by carefully heating one pin at a time, bend it loose with the aid of eg. a needle. Alternatively, a special tip or two soldering irons can be used.

Making the opening for the display in the front panel requires patience, in particular. After marking the opening you can drill the required number of holes and finish the opening off with a file. Another alternative is to use a jigsaw or some other narrow-blade saw, whose blade can be pushed through holes drilled in the corners of the display opening.

Checking your soldering work

The most common errors in component installation are as follows:
- A component is incorrectly oriented
- There is a short-circuit between a soldering pad and ground
- Unsoldered connections
- Incorrect values of components

These errors can be avoided with careful visual inspection

Operation and adjustments

DDS-and-control section adjustments

The DDS section doesn’t necessarily require adjustment. However, the frequency of the LO and hence also the frequency precision of the RX depend on the frequency of the reference oscillator. For adjusting the reference oscillator, a special adjustment mode is included in the program suite. If the pushbutton switch of the encoder is kept depressed during start-up of the device, it will enter the adjustment mode. To indicate this mode, the display will show 1 MHz. In this mode, the setting of the DDS is an exactly calculated number corresponding to 1 MHz output frequency. While in this mode, the frequency generated by the DDS is measured with a precision frequency counter or other similar means, and it is adjusted in place with trimmer capacitor C20, affecting the frequency of the reference oscillator.

Due to stepped values and varying precision of resistors and to distribution in the precision of +5 V regulators, the displayed value of supply voltage probably isn’t quite accurate. The display can be adjusted to be ”on the nose” by adding a suitable resistor in parallel with R23 (910R). A suitable value can be found by temporarily soldering eg. a 100 k trimmer in parallel with R23. When the voltage display is accurate, the trimmer can be replaced with nearest standard value resistor.

LCD display contrast is set by voltage present in pin #3 of the display module connector. This implementation uses one 1k8-ohm resistor (R2) to set the voltage. The voltage producing ”suitable” contrast depends on display module type, production lot, and to a lesser degree, on temperature of operation. If you use a different type display than the one in parts list, or if the contrast is not satisfactory, it can be adjusted by changing the value of R2. Lowering the value will make the display darker and increasing it will make the display lighter. Adjustment range is between zero and a few kilo-ohms. A suitable value can be found by soldering a temporary eg. 5k trimmer in parallel with R2.

RX-main section adjustments

The AGC threshold voltage of RX-main section should be adjusted with trimmer R18 to just start attenuating noise when listening without an antenna. JFET V4 threshold voltages vary quite a bit from one unit to another. The circuit is designed to allow for all V4 FET specimens, Vishay Siliconix SST177 or Philips PMBFJ177, to be adjusted precisely, but large adjustment range results in coarse adjustment and it may be necessary to turn the trimmer close to one end. In this case, parallel resistor R41 can be changed to put the trimmer in the middle of ”nice and easy” adjustment range. Although it is possible to adjust the AGC threshold voltage to an useful setting by ear, a more accurate method is to use an S9 signal. This is accomplished by feeding a 50 uV carrier wave signal into the antenna connector, and by adjusting with trimmer R18 the S-meter reading to half-way mark, or S9, on the LCD display. Thus the S-meter has been "tuned". The following marks on the LCD display correspond to ca. 10 dB steps.

Trimmer R42 in LO buffer amplifier is used for fine-tuning the phase ratio of LO signal going to muxer D1 to exactly 50 %. This is accomplished by adjusting the DC operating point of the LO-signal. By this adjustment the 2f spurious frequency attenuation can be optimised. Optimisation is done by feeding to the antenna connector ca. 1 mV of 7.2 MHz signal from signal generator, and listening to it on 3.6 MHz. Any detected signal is adjusted to minimum or even non-discernible with trimmer R42.

JUMA-RX1 specifications and measurement data

Supply voltage: +9VDC…+15VDC
Current consumption: Less than 50 mA at normal volume level
Max. current consumption: 200 mA at high volume level
Max. audio output power: 1 W

Mechanical dimensions: 142 x 42 x 72 mm (width x height x length)
Connections: Antenna and DC connectors. Optionally headphones and RX-mute input
Display: 16 x 1 character LCD module with frequency, S-meter and supply voltage display
Controls: AF-gain/ON/OFF and rotary encoder with pushbutton momentary switch

Frequency range: General coverage 3.5MHz…7.5 MHz
Expanded freq. range: General coverage 100 kHz…7.5 MHz with reduced performance
Frequency selection: Mechanical encoder with 10 Hz, 100 Hz and 100 kHz steps
Frequency readout: Six-digit LCD display, resolution 10 Hz
Frequency stability: Equal to 20 MHz crystal used
Modes of reception: SSB/CW and digimodes utilising these. Zero-beat AM usable
Filter bandwidth: 300 Hz...2.5 kHz
Bar-type S-meter on LCD display, 24 divisions

Sensitivity: Minimum discernible antenna signal (PREAMP TL082) -120 dBm = 0.22 uV
Dynamic performance: Max. undistorted antenna signal on listening frequency -12 dBm = 160 mVp-p
Strong signal handling: Endures 20 dBm antenna signal without blocking
Third order intercept point (IP3) = 23 dBm
LO leakage to antenna: 5 nW = -53 dBm on 3.7 MHz

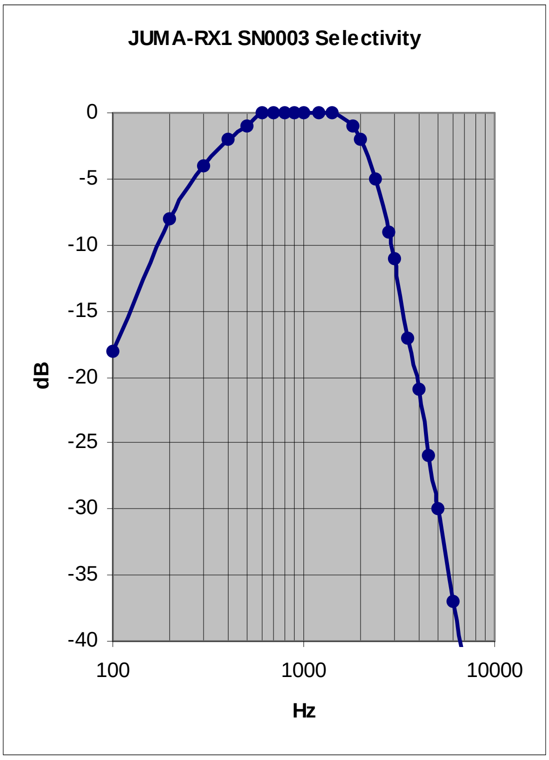

Figure 13 – Measured SSB filter frequency response

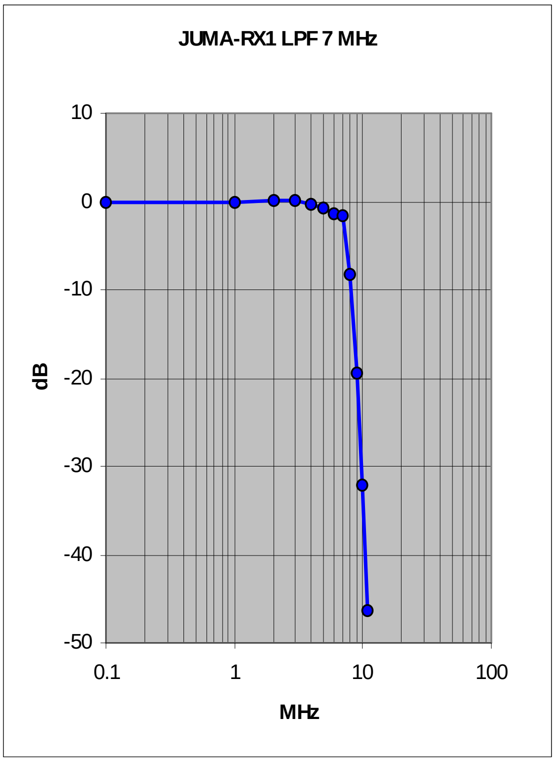

Figure 14 – Measured front-end RF filter

JUMA-RX1 instructions of use

Switching on and volume control: Turn AF-gain knob
Frequency selection: Rotate encoder knob left or right, selected frequency is displayed
Frequency step selection: Depress encoder knob and turn. Display shows Step1, Step2 or Step3
Display status selection: Depress encoder knob briefly. S-meter/supply voltage are displayed alternately
Saving settings: Depress encoder switch for 2 seconds until acknowledgement is seen and heard
Adjustment mode: Switch RX on by simultaneously depressing encoder switch until ”1 MHz” is displayed

Purchasing parts

Due to variations in component availability and suppliers in different countries, it is impossible to give any meaningful information here. However, your local ham radio organisation may be able to help. In addition, Google may prove to be your friend. Just search for ”SMD component seller” in your local language, perhaps adding nearest town or city.

Most SMD component suppliers sell SMD resistors and capacitors in pouches containing 10, 25 or 50 units. Some of them will sell ”mixed assortment” pouches for hobbyists. Buying them will allow for other projects to be considered.

Additional information on the operation of program modules

LCD routines (dcrxlcd.c)

LCD module addresses the display in 8-bit operating mode. The program does not examine the READY bit of the display. Instead, timing is achieved using delays. In this application that fact has no significant effect on performance. The module contains routines for writing commands and data on LCD display. The module also includes routines for number conversion and presentation required by the application. The specialty of the 1x16 display used is the fact that an apparent 16-character line is in fact two logically separate 8-character lines. The first line begins at address 0 and the second at address 64.

S-meter (dcrxlcd.c)

The LCD module also includes a routine calculating and composing a graphic bar on LCD display. The bar is used to display S-meter readings. The routine also depicts a rough scale for the meter. The meter is controlled with numbers 0-48. The drive is obtained from S-meter signal measured with an A/D converter. The output of the A/D converter is used without scaling to drive the S-meter. Maximum ”deflection” of the S-meter is achieved with a voltage of ca. 234 mV. The graphics of the meter allow of 24 separate display steps, an ample amount for a S-meter display. The module also includes routines for creating and transferring onto display the ”home-made” graphic characters necessary for the S-meter.

Reading the encoder (dcrxtim.c)

The essential task of the ’Timing and interrupt handling’ module is reading and interpreting the changes in encoder switches. The states of these switches are read once every millisecond by turning the I/O port B of the controller into input. Status changes of the switches are verified by requiring that two subsequent numbers must be equal until a signal is interpreted. After verification, if a change is observed when compared with previous state, both previous and present state are used in interpreting the direction of rotation of the encoder. The rotation counter of the encoder is either increased or decreased with one, depending on direction. Several pulses can be accumulated in the rotation counter until it is summed up in the frequency setting of the main program.

DDS IC control (ad9833.c)

Although AD9833 is the most modest member of Analog Devices DDS IC family, it is both versatile and demanding about its control. The AD9833 DDS IC is controlled by serial-mode SPI signaling. Both signaling and necessary timing signals are generated by the program. The AD9833 IC contains several features in addition to those used in this application. In any case, the IC must initially be set up into appropriate operating mode. Once the 16-bit control register defining IC operation has been properly set, and the phase register has been cleared, a frequency can be set for the DDS IC. Frequency is set by writing a 28-bit control word into two 16-bit registers. The frequency generated by the DDS is calculated from the following equation:

Fout = control word * reference clock / 2^28.

As a consequence of this equation, the lowest bit of the control word corresponds to 0.0745 Hz on the 20 MHz reference frequency used. As such, that fact is neither significant nor interesting as far as the setting of the DDS IC is concerned. It turns interesting, however, when RX frequency is selected and displayed. How does one obtain the DDS set number from display, or vice versa? A new setting is written into the DDS IC only when frequency is changed. This method reduces the level of interference at the output of the DDS.

Calculations for frequency display (dcrx.c and large_mul.c)

Due to limited performance of the microcontroller used, a lot of thought was given to calculation of frequency display and RX frequency selection. The matter was finally solved by maintaining the tuning of the receiver in the form of DDS control word. When tuning, the control word is added or subtracted by a previously calculated number in accordance with frequency step selected. These steps are: 10 Hz, 100 Hz and 100 kHz. Out of the impressive tuning precision of the DDS, only a portion is thus utilised. The 10 Hz step is small enough in practice. It is possible to calculate displayed frequency with the aid of an 8-bit microcontroller by employing a couple of tricks. Long divisions or floating point operations are not feasible in practice. To calculate displayed frequency, a constant was calculated in advance. This constant is 0.07450581 Hz/bit * 2^32, resulting in 320000000. When DDS setting is multiplied by this constant, the result is a 64-bit number whose 32 uppermost bits correspond to the frequency displayed. Now only 32-bit * 32-bit multiplication is needed to obtain the 64-bit product. It was necessary to write the calculation routine by oneself because C language libraries do not support calculation with large numbers such as these. From performance viewpoint the principle described above works well. All calculations are performed during each cycle of the main loop, and they are included in the 6 ms cycle mentioned earlier. Due to the way of implementation, the least significant digit of the display and frequency will not always stay steady when tuning is changed.

A/D measurements (dcrxadc.c)

To save memory space, a bare-bones driver measuring supply voltage and S-meter signal has been constructed for the A/D converters. The voltage is measured and saved for calculation by using 10-bit resolution. S-meter signal is saved with only 8-bit resolution to conserve space. For the duration of measurement, RA0, RA1, and RA3 signals of port A of the microcontroller are reserved for A/D converter use. After measurement the port is returned for I/O use. 5 volt supply voltage is directly used for A/D converter reference purposes. This implies the resolution of the converter is 5 V/1024, corresponding to 4.88 mV/bit.

Voltage meter (dcrx.c)

With an external voltage divider, supply voltage has been scaled down in such a way that with the resolution mentioned above, the output of A/D conversion is a number representing supply voltage divided by two. The display, operating at 20 mV resolution, is easily calculated by multiplying the output of the A/D converter by two.

ACK tones (dcrx.c)

User interface is equipped with ACK tones to facilitate easier frequency step selection. The step selected is indicated by three tones of different pitch. Audio frequencies are generated by program loops and delays. Due to limitations in the I/O capacity of the microcontroller, a somewhat unusual signal path was utilised for the tones. The tones are taken out of the same I/O pin which measures supply voltage. From this pin a 5 volt square wave is exported to the RX board where it is filtered and delivered to the loudspeaker amplifier.

Saving frequency and tuning step (dcrx.c)

The frequency selected and the step in use can be saved in non-volatile EEPROM memory, where they are read from and used as defaults in next startup. For saving and reading, simple routines have been appended to the main program. There is also a routine for checking the limits of usable frequency range. If these limits are exceeded, ”factory settings” are employed. This happens in particular when the device is switched on for the first time, and EEPROM memory is still empty. Saving is done by pressing the pushbutton switch of the encoder for longer than two seconds. A save is acknowledged by sending the letter R in Morse code from an ACK tone routine.