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A Software Controlled Radio Preselector

A Tunable Bandpass Filter Bank for the HF Bands (1.8 MHz to 30 MHz).

The SCR-Preselector prototype is packaged in a Hammond Instruments case.

Features:

- PC controlled through a graphical user interface (GUI).
- USB v2.0 compliant, for data communication with PC. Plug and Play feature.
- Tested under *Windows XP* and *Windows Vista32* Operating Systems (OS).
- Can perform its functions as a stand-alone unit.
- Compatible with software defined radios (SDR).
- Removes the strong signals radiated back to the antenna from quadrature mixers.
- Improves your average receiver or scanner to lead with strong signals, on the most noisy and crowded bands.
- Connected to an exciter as a tunable band pass filter, it reduces harmonics generated in the exciter.
- Complete receiver front-end for your projects.
- Joined to a VFO, the preselector can perform a tracking tuning function.

The SCR-Preselector — A First Line of Defense Against Interference and Static

The SCR-Preselector, pictured in the lead photo, is connected in series between the antenna and the receiver. Tuning to desired signal keeps the preselector bandwidth centered at the operating frequency, adding selectivity and protection to your receiver. The SCR-Preselector rejects or reduces out of band unwanted interfering signals, improves signal to noise ratio and protects against interference from strong signals like AM/FM broadcast stations. It can also be helpful in preventing interference during multi-multi contest operations.

The high linearity of the preselector is preserved thanks to a passive design that uses large toroidal cores and reliable mechanical relays for switching functions, instead of nonlinear semiconductors that cause distortion and exhibit low tolerance against strong signals and static.

Direct sampling SDRs are protected against false images since the SCR-Preselector incorporates a low pass filter (LPF) with an enhanced stop band of more than 60 dB. This filter has the ability to provide a very sharp transition from pass band to stop band at a cut-off frequency of 30 MHz, attenuating signals in the VHF region that could mix with the sampling frequency of its analog to digital data converter.[1]

The SCR-Preselector incorporates gas discharge tubes to provide safety against static and voltage transients. Further, the unused antenna input is short-circuited to ground.

Brief History

In September 2006 I attended a conference at the Whitton Amateur Radio Group, at which Jeffrey Pawlan, WA6KBL, had the kindness to give us during his European tour.[2] The talk was all about Software Defined Radio, and the *WinRAD* computer program, how it came about, how it works and where will be going in the future.

Motivated by his speech I became truly interested in SDR. I began playing around with quadrature sampling detectors, also called Tayloe detectors. This is a nice piece of radio technology. Soon I noticed that despite its excellent features, it still needs a good front-end circuit to condition signals before they reach the mixer. I focused my interest on this problem, and with the help of my old friend Xavier Junqué de Fortuny, a software engineer, we started the job. First of all, because Xavier lives in Barcelona, Spain, and I live in London, England, we established a broadband link through the Internet, with audio/video capabilities. One year later, the SCR-Preselector was born.

Overview

The core of the SCR-Preselector is the tunable band pass filter bank, which is complemented with the necessary switching, protection, filters, amplifier and control circuitry as shown the block diagram in Figure 1 and the assembled prototype of Figure 2. The incoming signals pass through the antenna selector relay, and then go to the bypass relay. From there, the signals either bypass the preselector or enter a step attenuator that offers a selection of 0 dB, 6 dB, 12 dB or 18 dB. Those attenuation values match the standard calibration of S meters.

Next, the input signals enter a broadcast band (BCB) high pass filter. This is a so-called "brick-wall filter," which attenuates spurious signals from strong AM broadcast stations as much as 120 dB. Such signals are well known enemies of shortwave receivers. I have stretched the effects of this filter into the medium wavelength band. It has a very sharp slope, as Figure 3 shows. The filter has minimum attenuation of all signals at 1.8 MHz and higher frequencies, including the CW portion of the 160 m band.

At this point, the input signals reach the tunable band pass filter bank, which is arranged in five overlapping bands that are user selectable. Each filter is a classic serial tuned LC circuit, and offers narrow bandwidth with little attenuation. A set of eight switchable capacitors of 1 pF, 2 pF, 4 pF, 8 pF, 16 pF, 32 pF, 64 pF and 128 pF emulates the variable capacitor needed to tune the series resonant circuit. The control program

[1]Notes appear on page 18.

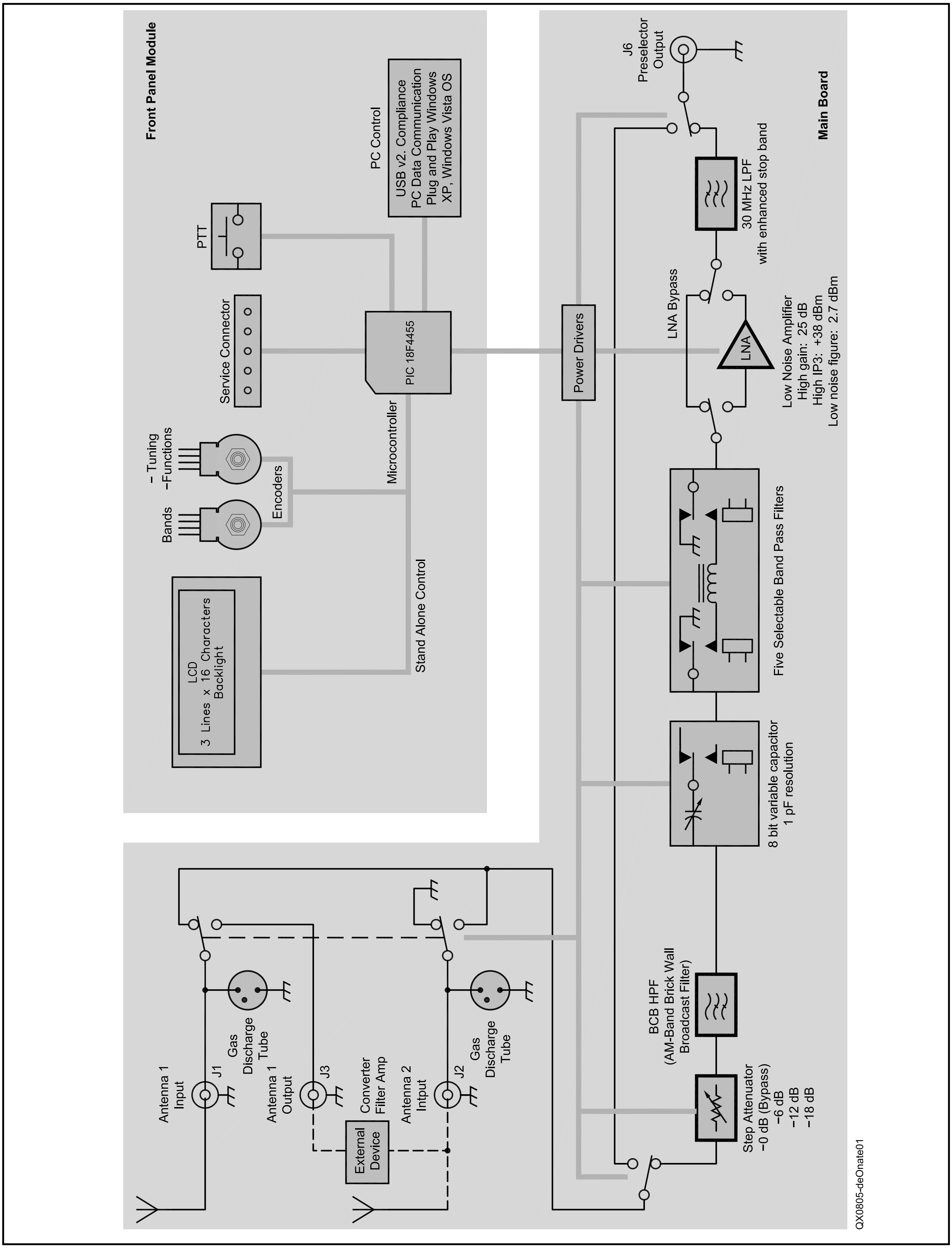


Figure 1 — SCR-Preselector block diagram.

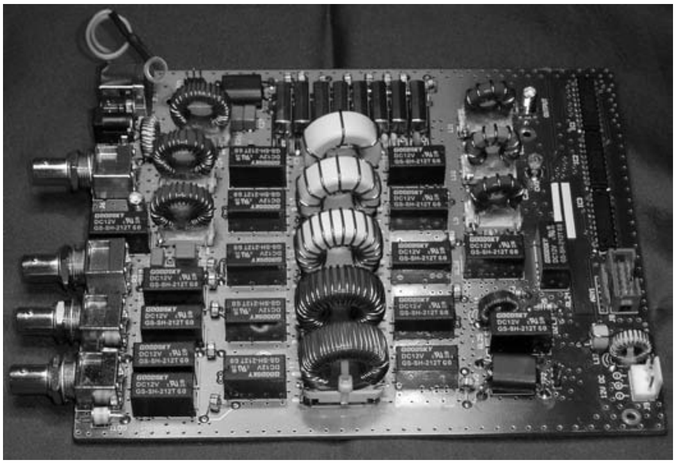


Figure 2 — This photo shows the main circuit board for the preselector.

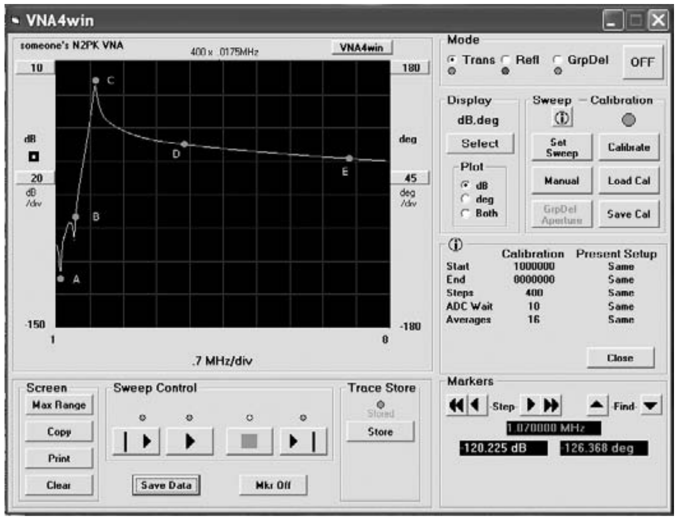


Figure 3 — The SCR-Preselector was tested with an N2PK Vector Network Analyzer. Point A: –120.2 dB at 1.07 MHz; Point B: –81.12 dB at 1.4 MHz; Point C: -3.5 dB at 1.8M Hz; Point D: –39.5 dB at 3.6 MHz; Point E: –48.1 dB at 7.05 MHz.

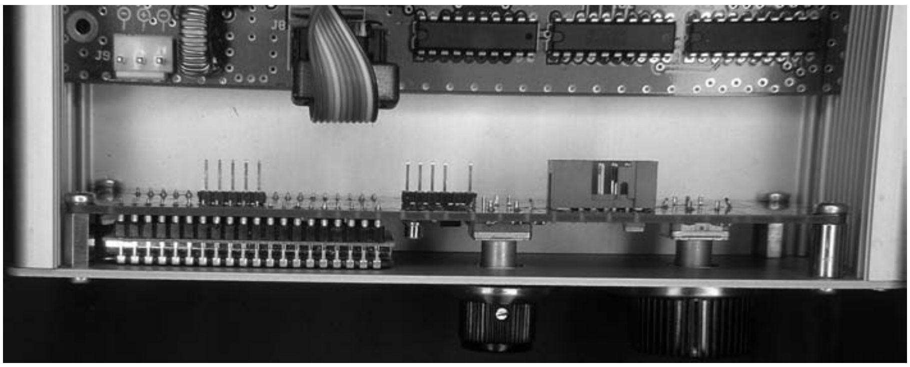


Figure 4 — A photo of the front panel circuit board module, assembled on the front panel of the Hammond Instrument case.

Figure 5 — Here is a screen shot of the SCR-Preselector Graphic User Interface display on my computer.

performs this task by adding or subtracting capacitor values in binary fashion, in direct relationship with the tuning knob operated by the user. Increments or decrements are done in steps of 1, 2, 5 or 10 units. One of five toroidal inductors is selected by the front-panel switch to form the filters. The selectable bands are:

- A) 1.8 MHz to 4 MHz
- B) 3 MHz to 6 MHz
- C) 4 MHz to 10 MHz
- D) 9 MHz to 18 MHz
- E) 16 MHz to 30 MHz.

Filtered signals are amplified or bypassed in the following stage, a low noise amplifier (LNA). I chose a Gali74 MMIC device, with an average gain of 25 dB, a noise figure (NF) of 2.7 dB and high dynamic range.[3] Because it is a high gain, wideband amplifier that operates to more than 1 GHz, we need to "hold its horses." The gain of this amplifier can be regulated through the input attenuator. An LPF connected at the output, limits the bandwidth to 30 MHz.

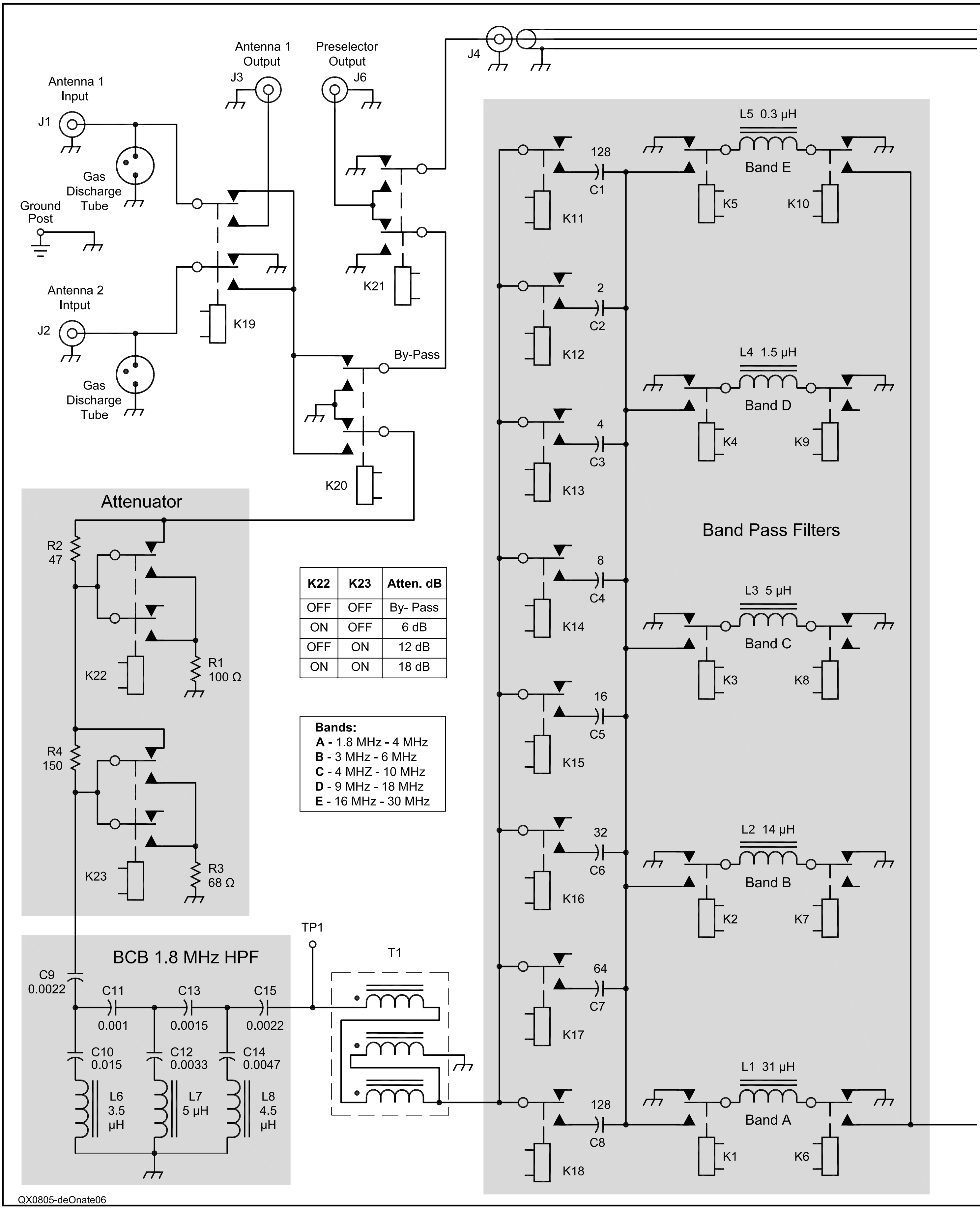
To make the SCR-Preselector compatible with computerized receivers we needed it to operate not only as a stand-alone unit, but also to perform its functions under computer control. For all that, a PIC microcontroller 18F4455 was selected, which includes an integrated USB peripheral, 35 I/O ports and in circuit programming (ICSP), among other features. It is assembled on a front panel circuit board module apart from the main circuit, along with a liquid crystal display (LCD) and two incremental rotary encoders for band switching, tuning and other functions. See Figure 4. Also, it offers the possibility to command the SCR-Preselector by other external means.

The software program on the PC runs under *Windows XP* or *Windows Vista32*. The user, through the GUI, commands the SCR-Preselector in the same way as it does in stand-alone mode. See Figure 5. Switching between USB or standalone modes is done when the USB cable is plugged in or unplugged. This adds a "Plug and Play" feature to the project. The program can work at the same time with any SDR software running on the PC, allowing to the user to control both simultaneously.

Circuit Description Main board

The SCR-Preselector main board schematic is shown in Figure 6. K19 is the antenna selector relay. The SCR-Preselector is designed to operate with antennas (and feed lines) that have a 50 Ω impedance. An optional external device, such as a converter, amplifier or filter can be inserted between J3 and J2, with antenna 2 selected.

Relays K20 and K21 drive signals to J6, the preselector output in bypass mode, or to the attenuator section. Switching to either K22, K23, or both configures the desired attenuation, or bypasses signals. Next, the circuit built around C9 to C15 and L6, L7,



K22	K23	Atten. dB
OFF	OFF	By- Pass
ON	OFF	6 dB
OFF	ON	12 dB
ON	ON	18 dB

Bands:
A - 1.8 MHz - 4 MHz
B - 3 MHz - 6 MHz
C - 4 MHZ - 10 MHz
D - 9 MHz - 18 MHz
E - 16 MHz - 30 MHz

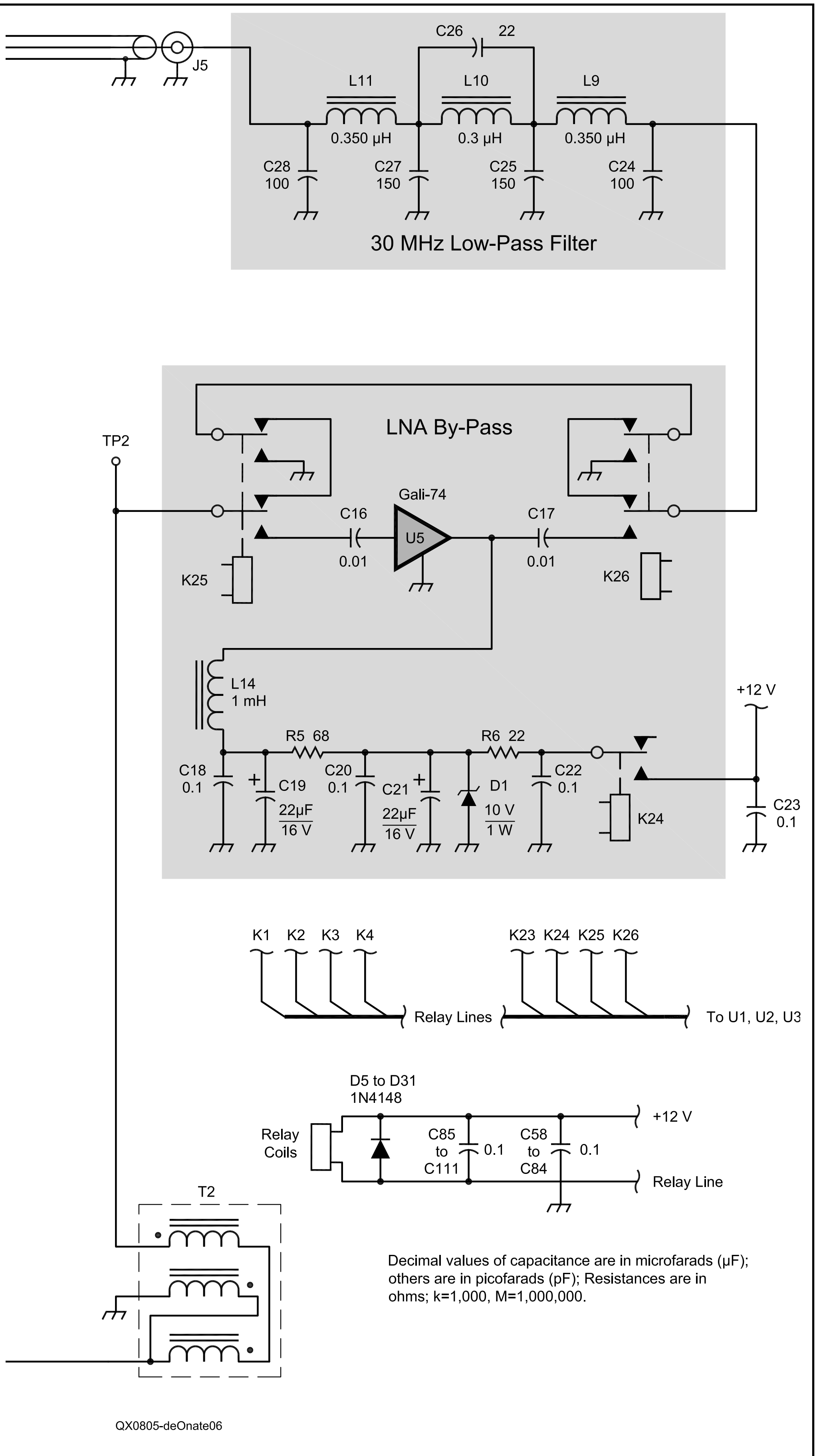


Figure 6 — The schematic diagram of the SCR-Preselector main circuit board.

L8 shapes a sharp BCB HPF of ten elements. T80-2 powdered iron toroidal cores are used to achieve large Q values. Other characteristics are the low pass band insertion loss — less than 1 db — and the flat pass band response.

The characteristic impedance of the circuit, 50 Ω, is converted to a typical low level for the series band pass filter by means of T1, a wide bandwidth UNUN transformer arranged to improve the filter high-frequency response.[5]

A set of eight capacitors, C1 to C8, and relays K11 to K18, form the "switching capacitor" section or "variable capacitor emulator" that is connected to relays K1 to K5. Together with K6 to K10 and L1 to L5, the switched capacitors shape the five overlapped band pass filters. Only one set of relays and one inductor are connected at a time, such as K1-L1-K6.

Notice that the band inductors that are not selected are connected to ground to avoid unwanted resonances. Large cores — T106 powdered iron — are used to avoid saturation. Saturated cores produce intermodulation distortion (IMD) with large signals. Some designers use the saying, "*The more iron in circuit, the merrier*." On the other hand, high Q values of more than 300 at the resonant frequency are reached, as measured with an HP 4342A Q-meter.

The resonant circuits with different values were designed with the filter design program, *Elsie*, written by Jim Tonne, WB6BLD.[6] This is an excellent piece of software. I was able to evaluate the filters in real time using *WinDipoles*.[7] I followed this methodology for the entire project.

All this work revealed good selectivity, but some attenuation — an average of 3 dB on bands of interest. Sensitivity and selectivity are not friends. That is not a difficulty, because who wants sensitivity in noisy and crowded bands? On the other hand a good preamplifier complemented with a step attenuator offers a good option for keeping gain and noise at optimum point to feed the mixer. That is the mission of the next stage, amplification, if needed.

The amplifier stage is built around U5, a low noise amplifier with high IP3 of 38 dBm, polarized to 4.8 V dc and decoupled. K24 provides operating voltage when the amplifier is selected. Signals are routed to or bypassed around the amplifier by relays K25 and K26.

After the amplifier, the signal goes towards C24 to C28 and L9 to L11, which form a sharp eight element low pass filter

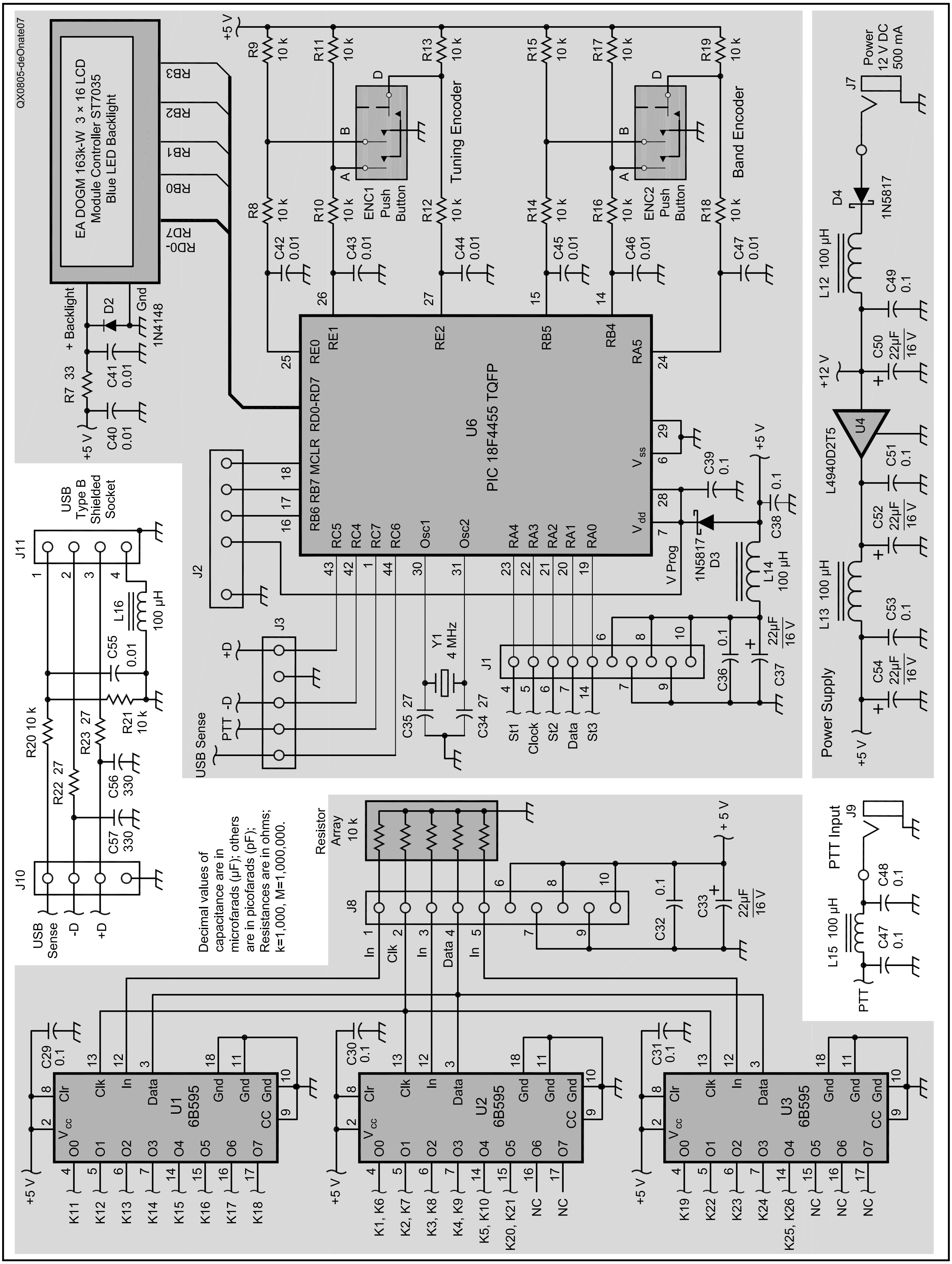


Figure 7 — This schematic diagram shows the SCR-Preselector power drivers and front panel module.

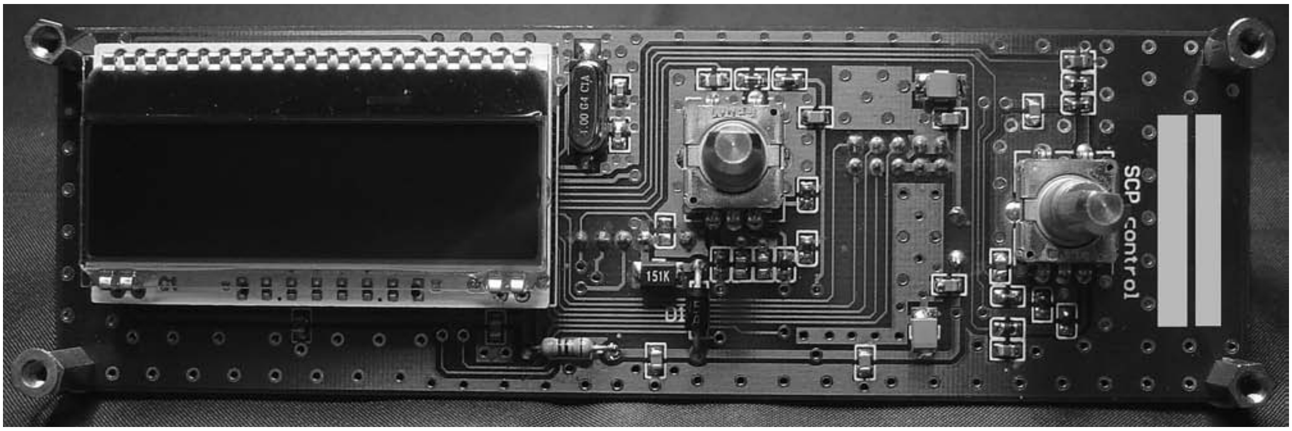


Figure 8 — The front panel module circuit board is shown in this photo. The PIC microcontroller is located below the LCD. The band encoder and tuning encoder switches are visible near the center and near the right edge of the photo.

with a cut-off frequency of 30 MHz. This filter has a Chebyshev topology, with a touch of Cauer response to improve its stop-band rejection but maintaining an acceptable pass-band return loss, greater than 20 dB. The LPF output at J5 connects through an internal coaxial link, with J4 and is then routed to J6, the preselector output, via K21. If bypass mode is activated, U5 is switched off and J4 is shorted to ground for protection purpose.

In Figure 7, the eight bit serial power driver shift registers, U1, U2 and U3 interface the relays on the main board with the microcontroller. Data, clock and strobe control signals are connected to the front panel control module via J8. These signals are pulled down with Resistor Array 1. Data signals are clocked to them and each one is latched independently by means of its strobe line. Power drivers can be commanded from any external compatible logic control, because of their simple codification.

J7 is the external power supply connector. It is followed by reverse-polarity protection and decoupling. A 5 V regulator, U4, feeds the logic control through J8.

Front Panel Control Module

The circuit board for the control module of the SCR-Preselector is located behind the front panel. The Schematic diagram is included in Figure 7. The user operates in Standalone Mode by means of two rotary mechanical encoders with push-on switches, ENC1 and ENC2. You can see those controls in the center and on the right side of Figure 8. Both have 20 pulses per revolution and a series of polarized RC filters on each pin to eliminate the noise generated by the bounce of its switches. This application does not require the fine precision that a VFO tuning control would require, so optical encoders were not used.

The 3 line × 16 character LCD module is driven in parallel mode. The polarization protection circuit, R7 and D2 feeds the operating voltage to the backlight LED.

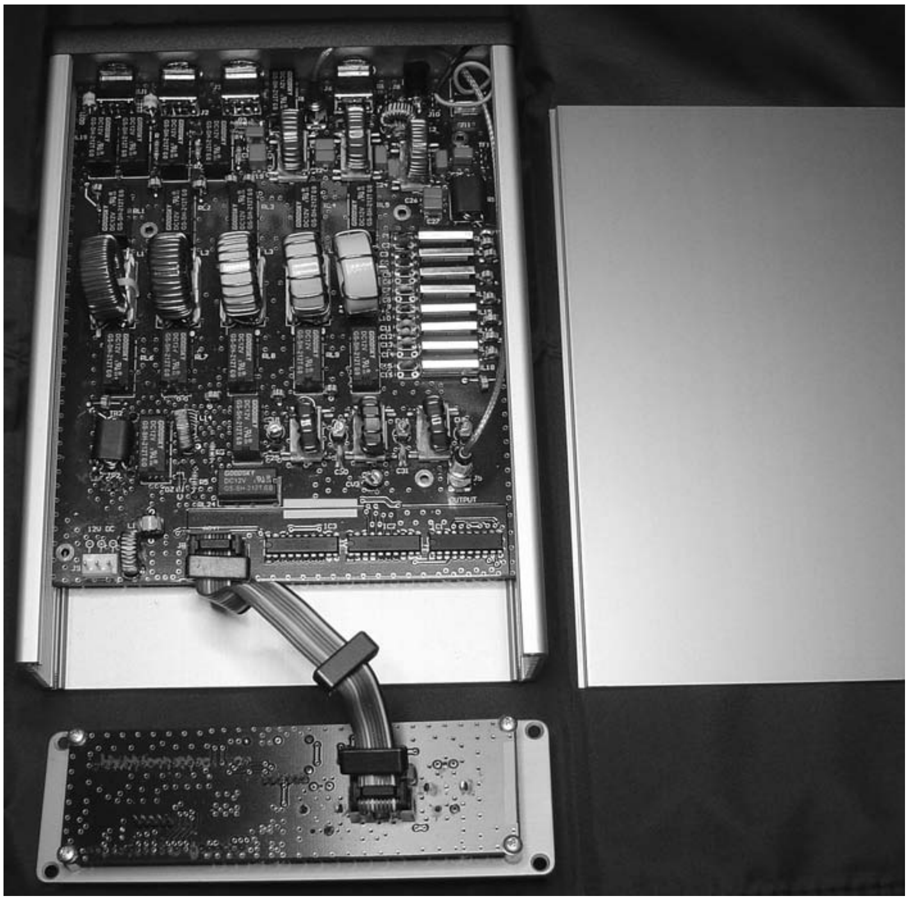


Figure 9 — A photo of the completed SCR-Preselector, with the front panel and cover removed.

Because of its TQFP package, the PIC microcontroller must be programmed in circuit. For this, an ICSP service connector is included, as J2. Another connector, J3, routes external signals, USB sense, PTT activated and USB data differential lines. A 4MHz quartz crystal is used for the main oscillator. The internal PLL multiplier converts this to the 96 MHz USB clock and 48 MHz CPU clock frequencies. No external reset or supervision circuits are needed because they are embedded in the microcontroller. J1 routes the signals to control the power drivers to J8 on the main circuit board. The 5 V dc supply from U4 is fed to pins 6 to 10 of J1, to power the module. This supply is strongly decoupled with capacitors and L14, to eliminate the noise generated from the PIC microcontroller.

Construction

No project can be considered complete without dressing a good case around it. So I chose a Hammond Instrument enclosure, model1455T2201. These enclosures are very good for projects, because they have removable front/back panels, and a sliding top cover. See Figure 9. The internal slots make it very easy to slide a 0.062 inch (1.6 mm), standard thickness circuit board into the slots, and no screws are required. If another enclosure is selected, the main board arranges several through holes to mount spacers. The board is fixed on the rear panel by means of the hardware supplied with the BNC right angle sockets.

Firmware, Software

The firmware (object code) on the PIC microcontroller was written in Assembler and *C* languages, under *MPLAB* and *C18* compiler.[8] The software program and driver on the computer side were developed under *Visual Studio.NET* from Microsoft. The program is an executable file that runs under *Windows XP* or *Vista32*. Figure 10 shows the computer screen with the Rocky 3.4 SDR software, the Realtek soundcard audio control software and the SCR-Preselector software all running. The SCR-Preselector software doesn't need to be installed; only the USB driver does. The software does need the Framework installed, however. This is a software component that comes with *Windows* update. The software was tested on several computers, and the final version ran without bugs.

The program offers to the operator the following features on the computer and standalone operating modes:

Selection of one of the five bands; bypass mode; four attenuator positions; Preamplifier ON/OFF; Antenna selection switch; tuning steps ×1, ×2, ×5 and ×10; tuning knob and five memories for each band. Each memory keeps all present configurations. When the program starts, it attempts to connect to the SCR-Preselector. If it is not connected, an error message appears for three times, followed by the GUI being configured in default status — Bypass. Selecting any band, the program leaves this state. Tuning is accomplished either by rotating the wheel mouse or through left-right arrow keys. The memory feature is activated by clicking on the MEM button. There are five red "LEDs" on the display, marked 1 through 5, that flash; when you press any of them, all present configurations are stored in that memory location. The selected "LED" number remains on. Up to five presets per band can be memorized. To erase a memory, simply click two times on the red LED selected will clear that position.

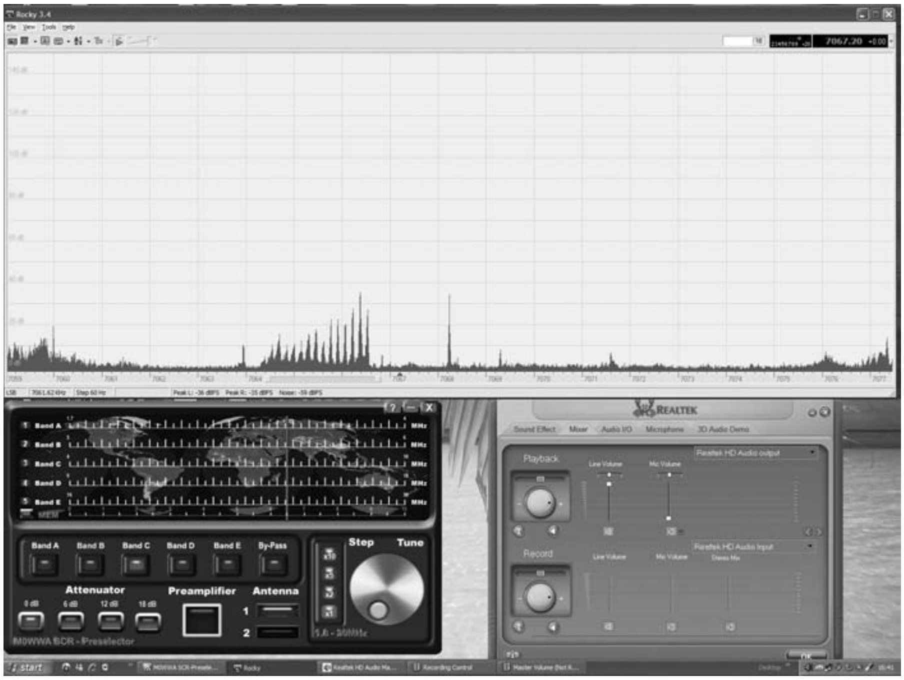


Figure 10 — This screen shot shows the SCR-Preselector control software working together with the Rocky 3.4 Softrock receiver control program and the Realtek sound card control software.

Explaining all of the software and hardware options involved on this project in detail would take too many pages, we offer you further information regarding this project on our little corner on Internet, at: **www.m0wwa.co.uk/**.

Notes

[1]Leif Åsbrink, SM5BSZ, "IMD in Digital Receivers," *QEX*, Nov/Dec 2006, pp 18-22.

[2]Jeffrey Pawlan, WA6KBL, **www.pawlan.com/wa6kbl.html**..

[3]Minicircuits, Gali-74 Datasheet, **www.minicircuits.com/products/amplifiers_monolithic.html**.

[4]Microchip, PIC18F2455/2550/4455/4550 Data sheet, **ww1.microchip.com/downloads/en/DeviceDoc/39632D.pdf**.

[5]Jerry Sevick, W2FMI, *Transmission Line Transformers*, Chapter 6, "Unbalanced to Unbalanced Transformer Designs," SciTech Publishing, Raleigh, NC, 4th Edition, 2006. *Transmission Line Transformers* is available from your local ARRL dealer, or from the ARRL Bookstore. Telephone toll-free in the US 888-277-5289, or call 860-594-0355, fax 860-594-0303; **www.arrl.org/shop**; **pubsales@arrl.org**.

[6]Jim Tonne, WB6BLD, **tonnesoftware.com/index.html**.

[7]Heros Technology Ltd., *WinDipoles*, **www.herostechnology.co.uk/herostech/pages/software.html**.

[8]Microchip, Development tools, **www.microchip.com/stellent/idcplg?IdcService=SS_GET_PAGE&nodeId=64**.

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