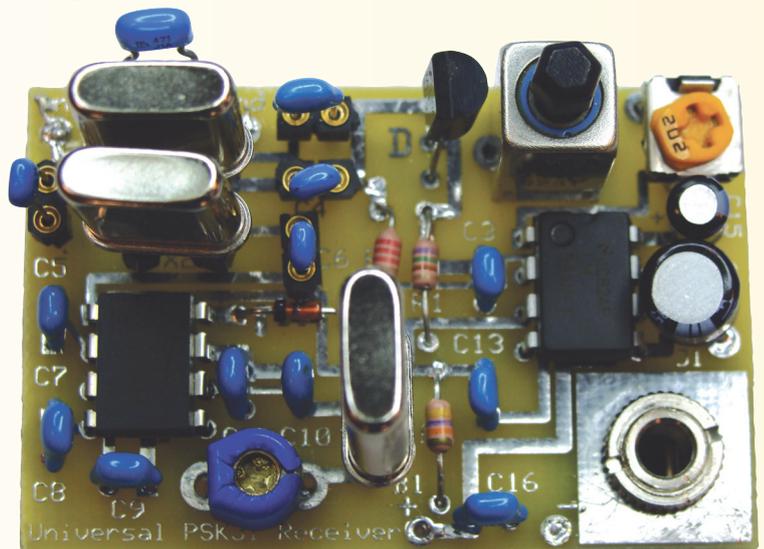


A UNIVERSAL DIRECT CONVERSION RECEIVER FOR PSK-31

Decode and read text message communications being sent over shortwave amateur radio frequencies.



by John Post

Although you may not be aware of it, the space that surrounds you is filled with bursts of text messages speeding to their destinations. No, we're not referring to messages produced by teenagers on their cell phones trying to link up at the mall, but rather messages on the shortwave bands that may contain emergency communications, announce a special event, or merely consist of friendly greetings exchanged between amateur radio operators located on two different continents. Read on to find out how to construct a simple receiver that allows you to "read the mail" using your personal computer.

Shortwave Text Messages

For decades, the shortwave radio frequencies have served as a medium for long-distance exchange of data, as well as voice communications. Data signals such as RTTY (radio teletype) and FAX (facsimile) – just to name a few of many that are in use – required expensive, specialized equipment to recover the encoded communications. Because of this, few people outside of the intended recipients could easily retrieve the information contained in these messages. The digital computing revolution has completely changed this situation! Now, almost any PC with a sound card is

capable of recovering this information using freely available software.

In this article, we'll focus on one particular "digital" mode, known as PSK-31 which was developed to facilitate text communications between amateur radio operators on shortwave frequencies. We'll also look at a simple direct conversion (DC) receiver design you can build. This receiver converts PSK-31 signals to audio frequencies that are digitized by your sound card and then processed digitally by your PC in order to recover the text messages. Although the focus of this article is on constructing the receiver, I'll also point you to some of the free software that you can download from the Internet for PCs running Windows to help you quickly get started "reading the mail" with PSK-31.

What is PSK-31?

The name PSK refers to the "phase shift keying" modulation technique which means that information is encoded simply by periodically shifting the phase of the transmitted audio tone in order to encode the information. This gives PSK a characteristic "warble" which you may hear online yourself at <http://aintel.bi.ehu.es/psk31.html>. The numerals 31 refer to the data bit rate in Hz (actually it's 31.25 Hz – an exact 1/256 sub-multiple of the 8 kHz sample rate commonly used in PC sound cards); a data rate that is equivalent to what a moderately good typist can type. Such a low data rate results in an extremely narrow bandwidth for the transmitted signal, and because noise is proportional to bandwidth, very low noise as well. Thus, acceptable signal to noise ratios (SNR) are possible even with signals that are barely audible to the operator.

PSK-31 encodes text information using a very efficient code called "varicode," developed by the designer of PSK-31, Peter Martinez G3PLX. Varicode follows the

Shortwave

Band (meters)	Frequency (kHz)	C1 (pF)	C2 (pF)	C4-C6 (pF)
160	1838.15	3,300	33,000	24 pF
80	3580.15*	680	6,800	18 pF
40	7080.15	150	1,500	18 pF
30	10142.15	150	1,500	10 pF
20	14070.15*	47	470	10 pF
17	18100.15*	43	330	10 pF
15	21080.15*	18	150	10 pF
12	24920.15	18	150	10 pF
10	28120.15	18	150	10 pF

Table 1. Recommended frequencies for PSK-31 activity along with suggested values for C1, C2, and C4-C6. (*Inexpensive crystals for these bands are available from Halted Specialties (www.halted.com). For the other bands, custom crystals can be ordered from International Crystal (www.icmfg.com).

example of Morse code so that shorter codes are assigned to letters of the alphabet that appear more frequently (like e) and longer codes are assigned for infrequently used letters (such as z). This minimizes the number of bits required to transmit a given amount of information and maximizes the code's efficiency.

Table 1 lists the frequencies where PSK-31 activities are concentrated. From my listening experience, the vast majority of activity takes place on 3.580 and 14.070 MHz in the 80 and 20 meter shortwave bands. Due to the limitations of propagation through the ionosphere, signals on the 80 meter band are strongest late at night – especially in the winter when nights are longer – while 20 meter propagation is best late during the day, especially in the summer when days are longer. A quick way of checking band conditions is to use a shortwave receiver to listen for the time station WWV or WWVH (which broadcasts on 2.5, 5.0, 10.0, 15.0, and 20.0 MHz) at the frequency nearest the one you are interested in.

The Receiver

Figure 1 presents the schematic for the DC receiver. Direct conversion receivers function by directly converting the desired RF signal to an audio frequency. This approach results in a relatively sensitive receiver that requires a

minimum number of components.

Again referring to Figure 1, capacitors C1, C2, along with inductor L1 form a bandpass filter that transforms the relatively low 50–75 ohm resistance presented by the antenna up to several thousand ohms to match the higher resistance seen at the gate of Q1. Q1 is a common-source JFET RF amplifier that provides up to 30 dB of gain between the antenna and the transistor's drain. The RF amplifier drives a two-element crystal (Cohn) filter (X1, X2, C4-C6) with a narrow bandpass response that is centered at the desired RF frequency. The

purpose of this filter is to reject undesired signals outside of the passband in order to avoid overloading the mixer.

Frequency conversion from RF to audio is accomplished using an SA602 integrated circuit (IC). Capacitors C10-C11 and the oscillator transistor internal to the SA602 form a Colpitts crystal local oscillator (LO) that oscillates at a frequency established by the crystal X3. Capacitor C12 allows minor adjustment in order to fine-tune the oscillator frequency. The mixer internal to the SA602 takes the difference between the RF and LO signals (which is at audio frequencies) and outputs this to an LM386 audio amplifier IC configured as a differential amplifier with 200 Hz–2 kHz bandpass response. The output of this amplifier is used either to drive a small headphone or speaker in order to verify operation of the receiver, or fed to the microphone input of a PC sound card in order to decode PSK-31. Variable resistor R4 allows adjustment of the volume of the received signal so that strong signals do not overload either the ears of the operator or the sound card of the PC.

This receiver is called a “universal” DC PSK-31 receiver because with an appropriate choice of crystals X1–X3 and capacitors C1, C2, and C4–C6, it will receive PSK-31 signals on any of the frequencies listed in Table 1. Table 1 also lists component values for four frequencies corresponding to the frequencies where crystals are

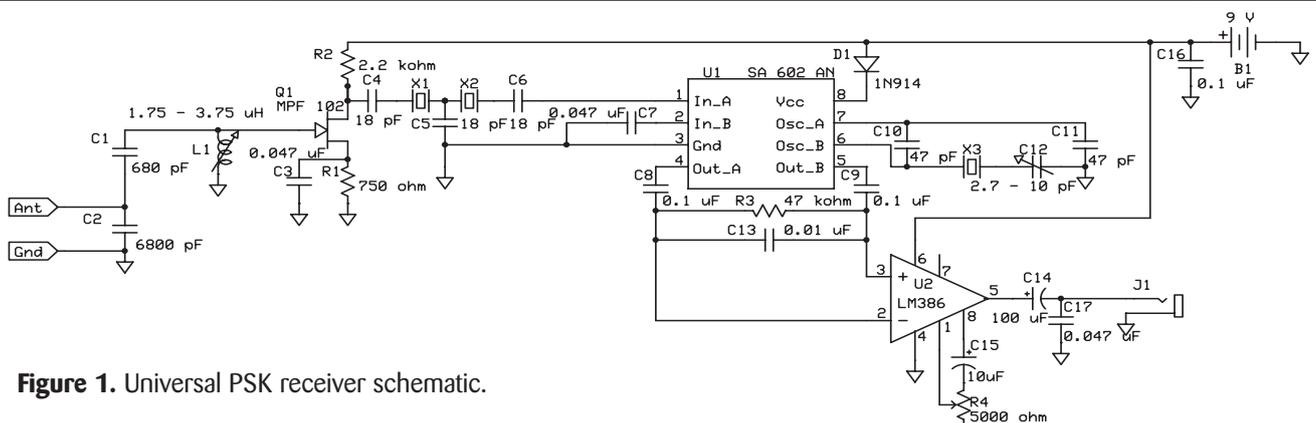


Figure 1. Universal PSK receiver schematic.

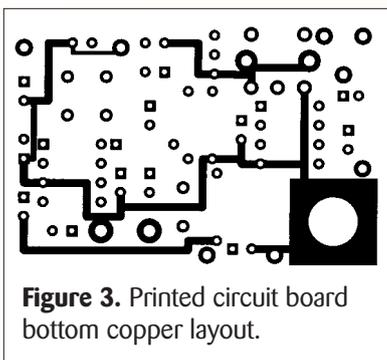


Figure 3. Printed circuit board bottom copper layout.

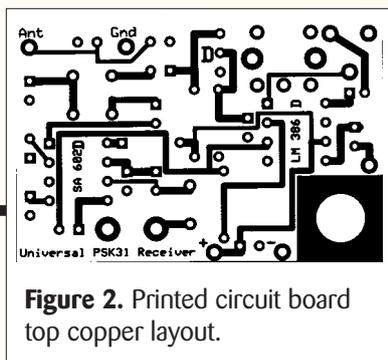


Figure 2. Printed circuit board top copper layout.

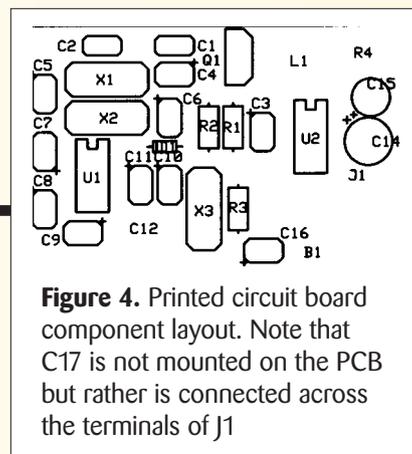


Figure 4. Printed circuit board component layout. Note that C17 is not mounted on the PCB but rather is connected across the terminals of J1

readily available. For other frequencies, the crystal frequency must be no more than about 0.06% below the desired PSK operating frequency to allow frequency adjustment using C11.

The inductor specified will work only for constructing an 80 meter receiver since its adjustment range is just 6%. In order to construct a receiver that will work on all bands listed in Table 1 (including 80 m), the inductor must adjust between 1.75-3.75 μ H. An acceptable inductor is available from www.danssmallpartsandkits.net.

Inexpensive crystals for 80 m are also available from Digi-Key. A source for suitable crystals for the 15 m, 17 m, and 20 m bands is www.halted.com. Finally, crystals for other frequencies can be special ordered (expensive!) from International Crystal (www.icmfg.com).

Construction, Testing, and Operation

The initial receiver prototype was constructed and tested by plugging the components into a proto board. Once the operation of the circuit was verified, a printed circuit board (PCB) was designed using the schematic capture and layout software provided by www.expresspcb.com. The board file can be downloaded from www.nutsvolts.com.

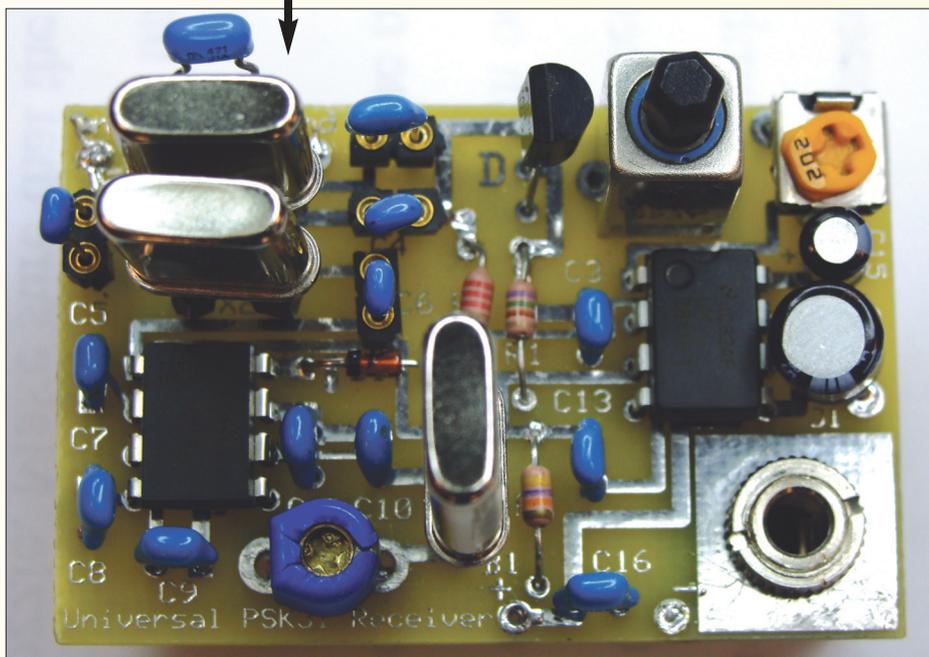
Figures 2-4 show the top copper layer, bottom copper layer, and

component layout, respectively, for the receiver, while

Figure 5 is a photograph of the finished product. In the PCB version of the receiver, sockets were installed to allow rapid switching of components C1, C2, C4-C6, and X1-X3 as necessary for bandswitching.

Once all components are installed, use a multi-meter to verify that the JFET and ICs power up when the battery

Figure 5. A printed circuit board implementation of the "universal" PSK-31 receiver. (The battery snap and antenna connector are not shown in this photo.)



DECODING SOFTWARE

Although installing and using PSK-31 software on your PC is not the subject of this article, it is not difficult to get started. There are many free software applications available for decoding digital signals. You should spend some time researching to determine which software package will work best for your particular combination of computer hardware and operating experience. Someone with modest experi-

ence installing and using new software should be able to install the software and learn enough to use it in an hour or so. Here are a few sites to get you started:

www.dxzone.com/catalog/Software/PSK31/
www.ac6v.com/software.htm#DIGITAL
www.qsl.net/wm2u/psk31.html
<http://aintel.bi.ehu.es/psk31.html>
www.qsl.net/hamscope/

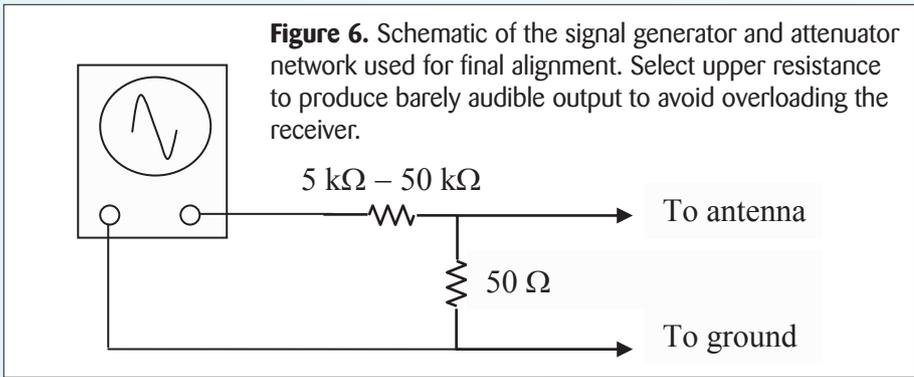


Figure 6. Schematic of the signal generator and attenuator network used for final alignment. Select upper resistance to produce barely audible output to avoid overloading the receiver.

is connected. You should measure approximately five volts at the drain terminal of Q1 and 1.5 volts at the gate and source terminals of Q1. If these voltages are not obtained, verify component values and connections for R1, R2, and L1 (remember that the inductor is a short at DC!). Next, verify that you have 8.3 volts at pin 8 of U1, and check that you have correctly installed D1 if no voltage is measured there. Finally, verify that you have nine volts at pin 6 of U2.

A rapid way of aligning the receiver is through the use of a signal generator and the resistive attenuator shown in **Figure 6**. Connect the receiver to the attenuator network, plug in a headphone or small speaker to the audio jack, and connect the battery. As you adjust the signal generator to the desired frequency, you should hear an audio tone from the speaker that changes in frequency as you adjust the signal generator. With the signal generator set to the frequency listed in the table, adjust C12 using a non-metallic tool until the audio tone decreases in frequency and then finally vanishes.

If the frequency of the tone won't decrease enough, try adding 10-15 pF of capacitance in parallel with C12 in order to lower the frequency of the LO. Also, your crystals will vary slightly in frequency so try swapping among them. Next, adjust L1 to maximize the clarity and volume of the received audio. The final step before decoding data is to connect the receiver to an antenna appropriate for the shortwave band of interest and listen for the distinctive warbling of PSK-31 signals when the shortwave bands are open.

If you don't have a signal generator available, connect the receiver to an antenna and then adjust L1 and C12 for best reception of the PSK-31 tones when the appropriate band is open.

Once your receiver is operating properly and you've installed PSK-31 decoding software on your PC (see sidebar), the final step is to connect the audio output of the receiver to the sound card of the PC using an audio patch cord with 1/8" phone plugs on each end. After you launch the software, you should be able to see the PSK signals on the PC's display and read the conversation in the text window. **Figure 7** is a screen capture of the Hamscope software using output from the receiver shown in **Figure 5**, configured for the 20 m band.

I hope you have as much fun building and using your Universal PSK Receiver as I have had with mine! You may contact me with any questions or comments at john.post@erau.edu. **NV**

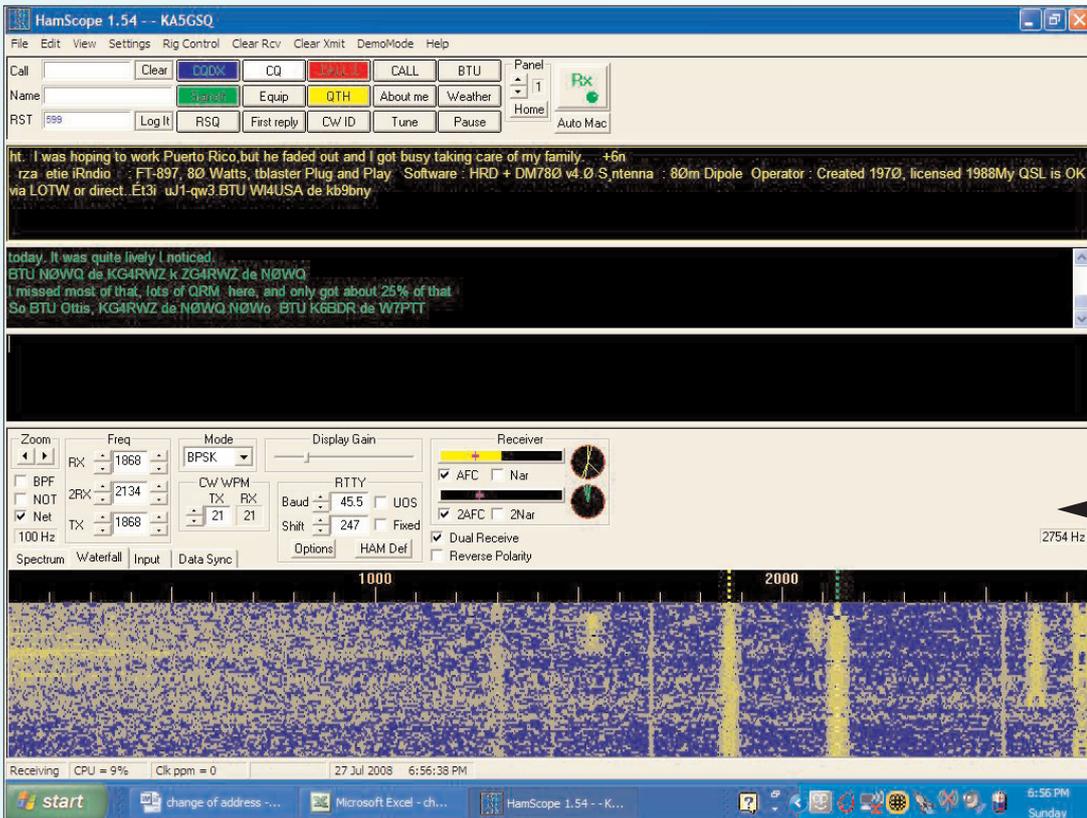


Figure 7. Screen capture of decoded PSK-31 signals produced by the receiver shown in Figure 5.

Parts List

<u>Item</u>	<u>Description</u>	<u>Digi-Key Part No.</u>
Resistors (1/4 Watt, 5%)		
R1	750 ohm	P750BACT-ND
R2	2.2K	P2.2KBACT-ND
R3	47K	P47KBACT-ND
R4	5K	D4AA53-ND
Capacitors (16 volts or higher)		
C1	680 pF ceramic*	490-3664-ND
C2	6,800 pF ceramic*	490-3854-ND
C3, C7, C17	0.047 μ F ceramic	490-3842-ND
C4, C5, C6	18 pF ceramic*	490-3632-ND
C8, C9, C16	0.1 μ F ceramic	490-3810-ND
C10, C11	47 pF ceramic	490-3657-ND
C12	2.7-10 pF trimmer	490-1971-ND
C13	0.01 μ F ceramic	490-3812-ND
C14	100 μ F electrolytic	P833-ND
C15	10 μ F electrolytic	P807-ND
Inductors (7MM IF can type)		
L1	3.3 μ H adjustable*%	TK3110-ND
Semiconductors		
D1	1N914 diode	1N914BCT-ND
Q1	MPF102 JFET	MPF1-02-ND
U1	SA 602 AN	568-1201-5-ND
U2	LM386	LM386-1-ND
Miscellaneous		
B1	9V battery	N145-ND
J1	1/8" phone jack	CP-3502MJ-ND
X1, X2, X3	3.579 MHz crystal*	X011-ND
	Sockets	A461-ND

* Digi-Key part is for 80 meters only. % for all band operation, use a 1.75-3.75 μ H adjustable inductor (search for "4 μ H 7MM SINGLE WINDING IF CAN" at (www.danssmallpartsandkits.net)).

A kit containing the printed circuit board, the variable inductor from Dan's, a phone jack, and assembly instructions is available for \$10. Contact the author at john.post@erau.edu to request the kit.

Sources

All parts for 80 m receiver
www.digikey.com

Crystals for 20 m, 17 m, and 15 m
www.halted.com

1.75-3.75 μ H adjustable inductor
www.danssmallpartsandkits.net

Crystals for additional frequencies
International Crystal (www.icmfg.com)

ExpressPCB file for PCB
www.nutsvolts.com/media-files/psk_receiver.pcb

Datasheets for ICs
www.onsemi.com/pub_link/Collateral/MPF102-D.PDF

www.datasheetcatalog.com/datasheets_pdf/S/A/6/0/SA602AN_01.shtml

www.datasheetcatalog.com/datasheets_pdf/L/M/3/8/LM386.shtml