RF Speech Clipper

Build this low distortion "Pile-Up Buster" to snag those DX contacts

The first step in building an RF speech clipper is modulating a carrier oscillator with the microphone audio into single sideband. Two popular techniques for doing this are the filter method and the phasing method[1]. The filter method produces suppressed carrier double sideband signals using a balanced modulator, one of which is then filtered to leave USB or LSB. Performance is dependent on carrier rejection using sharp cut-off filters. The phasing method generates two different double sideband signals and adds or subtracts them. The output of one balanced modulator is USB + LSB. The product of the second balanced modulator using phase shifted audio and carrier signals is USB - LSB. By simply adding or subtracting these sets of sidebands, the upper or lower sideband can be extracted. Performance is dependent on the audio phase shift (quadrature) network to maintain a constant 90° phase shift over the entire 300-3 KHz speech frequency spectrum.

The RF Speech Clipper is based on an excellent 1981 QST article by KC6T[2]. It uses the phasing method and has been updated with precision resistors and capacitors, audio EQ filters, an LED meter, and a new quadrature network that has been software optimized. The result should be a better sounding speech clipper with less distortion.

Circuit Description

A block diagram of the clipper showing the basic parts of the circuit is shown in Figure 1.

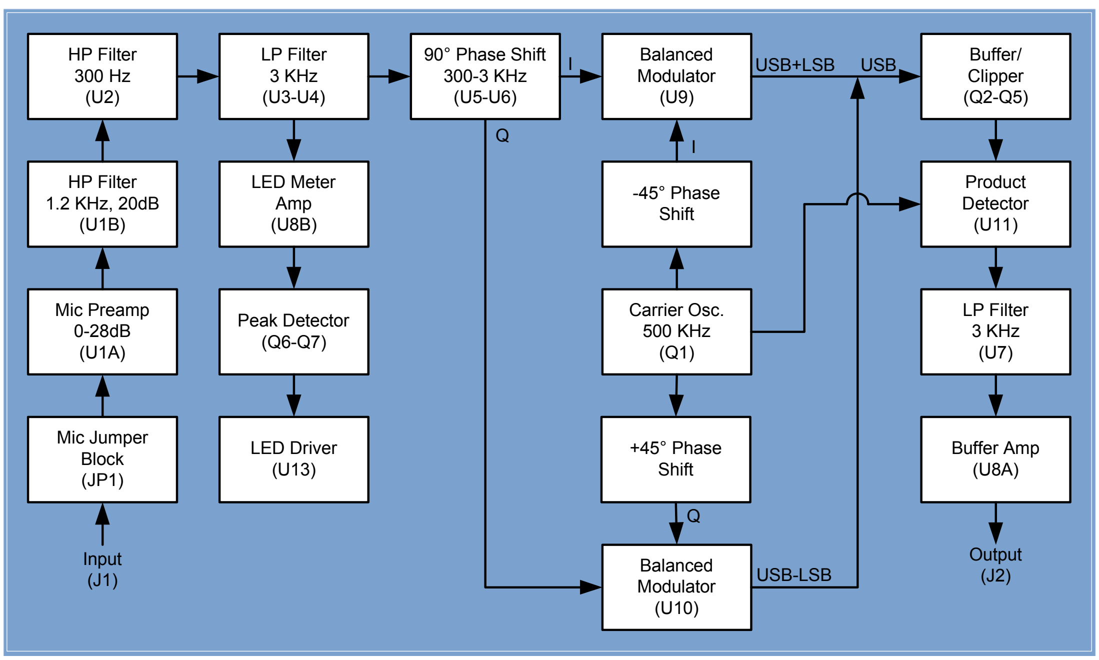

Figure 1

This processor differs from some designs that clip and demodulate a double sideband (DSB) signal versus a SSB signal. The RF clipping process itself generates intermodulation distortion products that spill over across the carrier frequency into the opposite sideband. When demodulating the clipped DSB signal these IMD products create low-frequency distortion in the audio[3].

The mic signal enters at J1, through mic jumper block JP1, bypass switch S1, and then to mic preamp (U1A) with up to 28 dB gain via the CLIPPING LEVEL pot. This feeds a two-pole Chebychev high pass filter with 20 dB gain (U1B). This high pass filter provides a 10 dB/octave treble boost to the microphone signal that levels out at 1.2 KHz. For today's flat response microphones this helps to reduce bass dominant voice signals so that the clipper will clip more speech consonants instead of mostly vowels. The end result is less distortion in the final signal[3]. All active filters were designed using FilterPro, a free software program from Texas Instruments[4]. FilterPro assumes that the filter's op amps are powered by dual supplies such as ±12V. Since I'm using a single supply I verified the op amp filter circuits using a SPICE-based analog simulation program called TINA-TI[5], another free program from Texas Instruments.

Next is a four pole Chebychev high pass filter (U2) to reduce the incoming audio below 300 Hz. The following eight-pole Chebychev low pass filter (U3-U4) restricts the signal above 3 KHz. These two filters combine to form a bandpass filter that reduces distortion in the subsequent networks.

The quadrature network (U5-U6) provides a 90° phase shift over the range of 300-3 KHz with 40 dB of opposite sideband rejection, and was designed with the use of Quadnet[6]. This free program allows the user to input the number of poles and frequency range. You then select either a constant capacitor or resistor value and tolerance and it computes the sideband rejection. This network generates the in-phase (I) and quadrature (Q) components of the audio signal.

A Clapp oscillator (Q1) is a standard design that provides the 500 KHz carrier frequency. The oscillation frequency is determined by the following equation (in Excel format):

f_0 = 1/(2π*SQRT(LC))
C = 1/(1/C33+1/C34+1/C35)
L = L1 = 100 µH
C33 = C34 = C35= 3000 pF
f_0 = 503,292 Hz

A simple IQ generator shifts the carrier phases by ± 45°. This RC-CR network works well for single frequencies[7]. R38 and C37 form the RC network, and C38 and R39 form the CR network. These networks provide a 90° phase shift for the balanced modulators (U9-U10), and are essentially low pass and high pass filters with cutoff frequencies near the carrier frequency. The product detector (U11) receives the non-phase shifted carrier signal.

The balanced modulators and product detector are set up for single supply operation[8]. The output voltage is a product of the input signal and the carrier. When U9 and U10 outputs are combined, the resulting signal is upper sideband: (USB+LSB) + (USB-LSB) = USB. This USB signal is buffered (Q2-Q3), and then clipped by super diodes (Q4-Q5). A super diode is formed when the base and collector of a transistor are connected so that the device exhibits a steep knee in the forward transfer characteristics.

The product detector (U11) performs demodulation of the clipped USB signal. The output is fed to a four-pole 3 KHz low pass filter (U7), and buffer (U8A). The output of the buffer goes to the OUTPUT LEVEL control, through bypass switch S1, mic jumper block JP1, and then to the MIC OUT jack.

The audio signal from U4-7 is fed to a meter amp (U8B) and then a peak detector[9] (Q6-Q7). The meter amp input capacitor C64 rolls off frequencies below 482 Hz to keep the LED meter from indicating too much low frequency information. The output of the peak detector is sent to U12 which drives ten LEDs to indicate the approximate level of RF processing in dB. The gain of U8B is set so that the 3dB LED lights at the onset of clipping, as monitored at TP2. The use of active filters before and after USB clipping permits as much as 30dB of clipping before distortion renders the signal unusable.

Figure 2 depicts the audio frequency response of the clipper (CLIPPING LEVEL set at midpoint), and was generated using TINA-TI. The low frequency roll-off slope below 300 Hz is 48dB/octave. The slope from 300Hz to 1.2 KHz is 10dB/octave, and is relatively flat from 1.2 KHz to 3 KHz. The high frequency roll-off slope above 3 KHz is 60dB/octave.

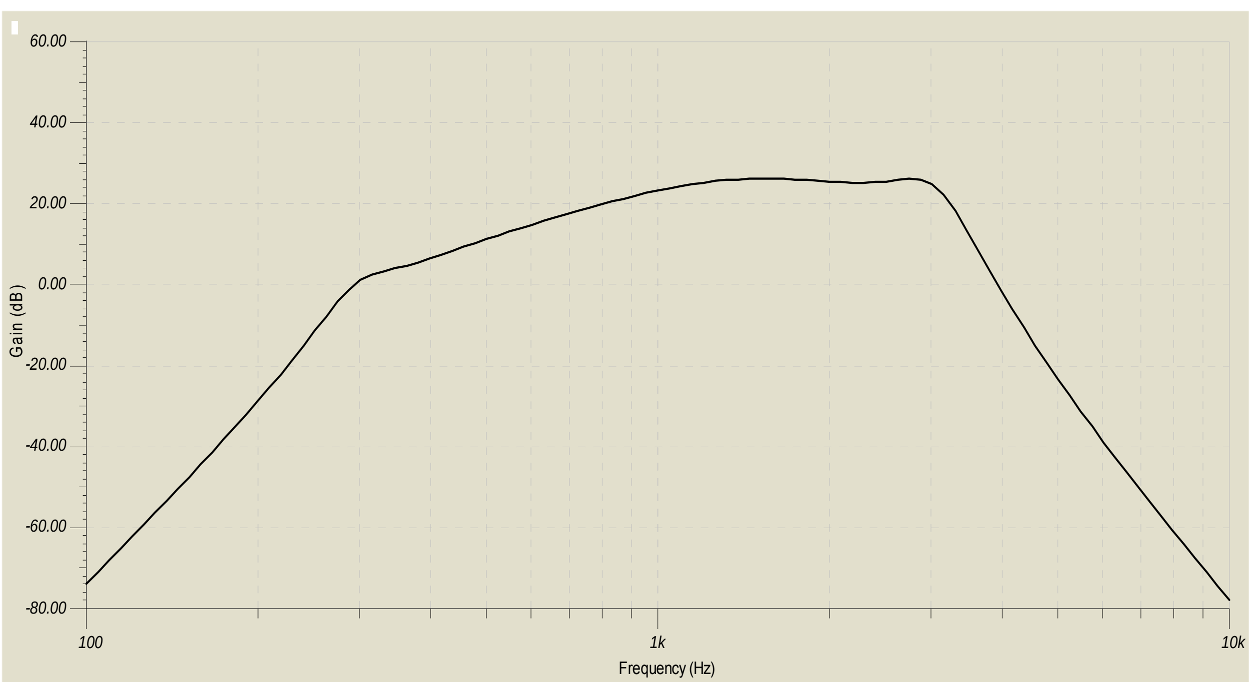

Figure 2

Problems will arise if the RF Speech Clipper circuit is powered from the same 12VDC power supply that supplies the transceiver because the microphone ground is connected to the circuit ground. To reduce noise and prevent ground loops, most modern transceivers keep microphone ground isolated from PTT ground until these signals are inside the radio. A 600Ω 1:1 audio isolation transformer on the mic input would eliminate the problem, but most reasonably priced transformers are limited in frequency response, add distortion, and have some insertion loss. Most "wall wart" supplies introduce noise and hum so I built a high quality linear supply inside of a wall wart enclosure.

I/O and Controls

J1 and J2 are RJ-45 mic input and output jacks, respectively. J4 provides an additional mic input for 3.5mm connectors. Jumper block JP1 allows the user to place jumpers to match the mic wiring for most transceivers. Jumper block JP2 applies mic bias voltage as needed for electret mics. LED D3 indicates power, and S1 switches the RF Speech Clipper in and out. R1 is the CLIPPING LEVEL control and sets the input gain, while R84 controls the OUTPUT LEVEL. In use, the OUTPUT LEVEL should be adjusted to provide the same signal amplitude as when the RF Speech Clipper is switched out. The LED meter monitors the audio signal from the output of U4 and displays a 30 dB range, providing feedback on the approximate amount of RF clipping.

Construction

A prototype PC board (PCB) was ordered from ExpressPCB[10]. At the two board minimum, the cost per "standard service" board (no solder mask or silkscreen) is $66. Email me and I will collect names and compile groups of 10 or more to get the PCB cost down. These PCBs will be "production service" boards which feature a solder mask and component silkscreen.

All components are through-hole and mount on the PCB. This eliminates external wiring and makes testing and troubleshooting easier. The PCB ground plane isolates and shields the 500 KHz carrier from the rest of the circuitry. All trimmer pots have been eliminated, allowing the user to build this unit without any test equipment. The PCB is double sided with plated-thru holes and slides into the bottom slots of the extruded aluminum enclosure. The color of the enclosure and control knobs can be selected by the builder with a choice of clear or black anodized aluminum. Also available for the enclosure are red, yellow, translucent red and translucent blue bezels. As with most projects, the prototype PCB and enclosure total to about half of the building cost.

Mount all 215 components on the component side of the PCB, installing the smaller components first. I cleaned the solder flux from the board using a 50-50 mix of acetone and isopropyl alcohol and a toothbrush.

To complete the RF Speech Clipper, print the panel drilling templates (page 3 of 5) by setting the Adobe Acrobat page scaling to "none". Ensure that the box at the top of the printed page measures exactly 7 inches. Measure and mark the panel center lines with a pencil. Cut the templates out and glue-stick them to the panel, aligning the center lines. Center punch and drill all holes and use a small file for the rectangular holes. Apply a coat of Krylon flat black spray paint to the panels to cover the hole edges. Bake the panels in an oven at 300°F for 15 minutes. Apply labels using dry transfer lettering or a label writer. Spray several light coats of flat lacquer over dry transfer lettering for protection. Use black text on the natural aluminum enclosure or white text on the black enclosure. Install the enclosure top plate and the front and rear bezels and panels. Add the rear panel ground screw (and internal washers as needed), mounting feet, jack nut, control knobs, and stick-on feet.

The power supply is built on perf board using point to point wiring of component leads when possible. Voltage regulator (U13) does not require a heat sink because the circuit only draws about 100mA.

Cables and Setup

Yaesu FT-817/857/897 and Kenwood TS-480 owners can plug the rig's standard microphone directly into the RF Speech Clipper. Connection to the radio is made using a standard CAT-5 cable. Adapters for other microphones and radios can be fabricated with a short CAT-5 cable cut in half and the appropriate connectors attached on each end. Round 8-pin Foster male and female cable connectors are listed in the parts list. For the MIC INPUT, wire a Foster male cable connector (pins 1-8) to one half of the CAT-5 cable (pins 1-8). For the MIC OUTPUT, wire the other half of the CAT-5 cable to a Foster female cable connector (pins 1-8). Configure the mic jumpers on JP1 and JP2 according to your radio manual and Table 1.

Microphone Configuration Chart										
Radio	**Model**	**JP1**								**JP2**
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
Icom	IC-703,706	J	J	9	10	J	J	J	J	On
	IC-718, 725, 735, 746, 756, 7200, 7600, 7700, 7800	9	J	J	J	J	J	10	J	On
Kenwood	TS-50, 570, 850, 870, 2000	9	J	J	J	J	J	10	J	Off
	TS-480	J	J	J	J	10	9	J	J	Off
Elecraft	K2/K3	9	J	J	J	J	J	10	J	Off
Ten-Tec	Omni VII, Orion II	J	J	J	J	J	J	10	9	Off
Yaesu	FT-450, 817, 857, 897	J	J	J	10	9	J	J	J	Off
	FT-847, 920, 950, 2000	J	J	J	J	J	J	10	9	Off

Table 1

Referring to Table 1, there are six 1X2 shorting jumper blocks ("J") placed straight across the indicated header pins 1-8 on JP1. JP1 pins 9 and 10 are configured using 3-inch wire jumpers. These wire jumpers connect the mic and mic ground signals to the input and output jacks. The JP2 column is also a 1X2 shorting jumper placed across pins 1 and 2 (On) or pins 2 and 3 (Off).

Results

Initial testing was done with the RF Speech Clipper connected to a Yaesu FT-857 as the transmitter and a Kenwood TS-480SAT as the receiver. The FT-857 was set to 5W and the output was connected to a dummy load to simulate a weak signal. Further testing with NG4T on 2m SSB was the next test and proved very successful. The provided video demonstrates various settings of the RF Speech Clipper. I was very pleased with the sound of the unit at clipping levels up to and including 30 dB. Compared to the non-clipped signal, the received sound was considerably louder and envelope limited while maintaining a natural tone with little audible distortion. The clipped microphone signal sounds like it has less low end due to the 10dB/octave boost from 300 to 1.2 KHz.

The RF Speech Clipper can increase average received SSB power output by up to 6 dB, which equates to a power increase of four. As with all speech processors, less is best.

All files and project details are available at www.kg4jjh.com. Good DX and I hope to see you on the air!

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References

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