noise blanker design

A discussion of the design requirements for noise blankers which will effectively eliminate high amplitude, low repetition rate noise

The principles of noise blanking are not new. The first description of the idea was published by Lamb[1] in 1936; however, there are subtle design considerations that have been overlooked in some previously published designs. This article will try to explain some of these considerations and the trade-offs that accompany a practical design. In addition, a brief description of a working circuit, used in one of my receivers, is given. First, however, you have to understand what noise blanking can and cannot do.

Under most conditions, noise blanking can minimize the effects of short duration, high amplitude, low repetition rate noise on a desired signal. Examples are some automobile ignition noise, certain electrical arcing noise due to power lines, and make or break switching.

Noise, with the opposite characteristics, long duration, low amplitude and high repetition rate, is difficult to control. This category includes lightning crashes, brush arcing, some powerline noise, and receiver generated thermal noise. These types of noise, as well as most others, are best dealt with at the source, if possible, or by minimizing them with other techniques such as lower noise amplifiers and directive antennas. (An article by Nelson[2] is an excellent source of information on noise sources.)

The reason a noise blanker is ineffective on lower amplitude and long duration pulses can best be understood by remembering that it operates by first sensing the presence of a noise pulse and then silencing the receiver for the duration of that pulse. The sensing operation requires discrimination between the signal and noise. Obviously, the greater the ratio between the two, the easier discrimination becomes. Silencing of the receiver is only permissible if the duration does not become so excessive that intelligibility suffers.

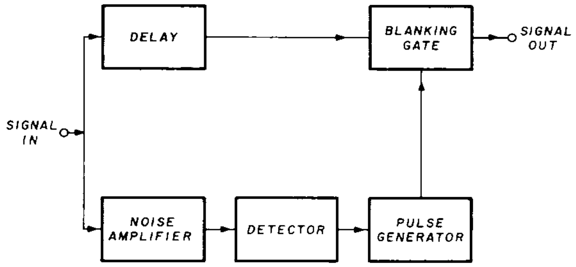

fig. 1. Block diagram of a typical noise blanking circuit. The signal is split into two paths, the noise or control signal plus the original communications signal. The delay is introduced to ensure that the two signals arrive at the blanking gate simultaneously.

basic circuit

Now that the limitations are understood, let's examine a typical system. As shown in **fig. 1**, the incoming path is split into two channels. One channel is referred to as the main channel; the other, the noise channel. (The noise channel also contains signal, but the terminology is by convention.)

By Wes Stewart, K7CVT, 1801 East Canada Street, Tuscon, Arizona 85706

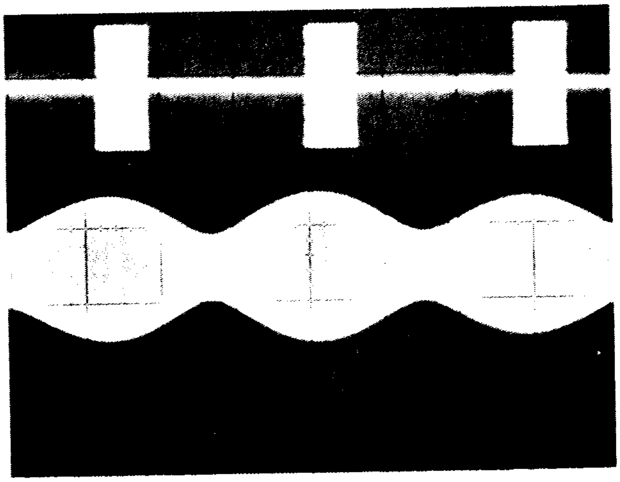

fig. 2. Example of the effects of applying a noise pulse to a relatively narrow i-f filter. The upper trace shows an applied pulse while the bottom shows the output from the filter. Both traces were recorded at identical sweep speeds.

The main channel is sometimes delayed, then passed through a gate and on to the rest of the receiver. In the noise channel, the noise and signal are amplified, and the noise impulses detected with the detector output are used to trigger the pulse generator. The pulse generator forms a signal of proper amplitude and polarity to cut off the gate for the duration of the noise impulse.

With the fundamentals behind us, look at some of the finer points. First of all, you must decide where, in the receiver, to place the blanker. For one thing, the blanking must be done prior to the narrow bandwidth i-f filter. The reason for this can be seen by examining **fig. 2**. The top trace of the photograph shows a simulated noise impulse which was applied to a mechanical filter with a 2-kHz bandwidth; the bottom trace is the output from the filter. While this is an extreme example of pulse stretching due to filter ringing, it shows the necessity of blanking at a point of wider bandwidth. However, it must be done before strong out-of-band signals become a problem. I have found a bandwidth of 50 to 100 kHz to be a reasonable compromise.

Another factor to be considered is amplifier overload. If you wait until the signal has passed through several amplifiers before blanking, the amplitude of the noise impulses may be high enough to have already overloaded one or more stages. The effects of nonlinear amplifiers are well known and need no further discussion.

So far, everything seems to indicate blanking very near the antenna. But, before going any further, take a look at the requirements for some of the other circuitry.

Noise amplifier. The input must be amplified to a level high enough to operate the threshold detector. Since the threshold point is generally in the range of

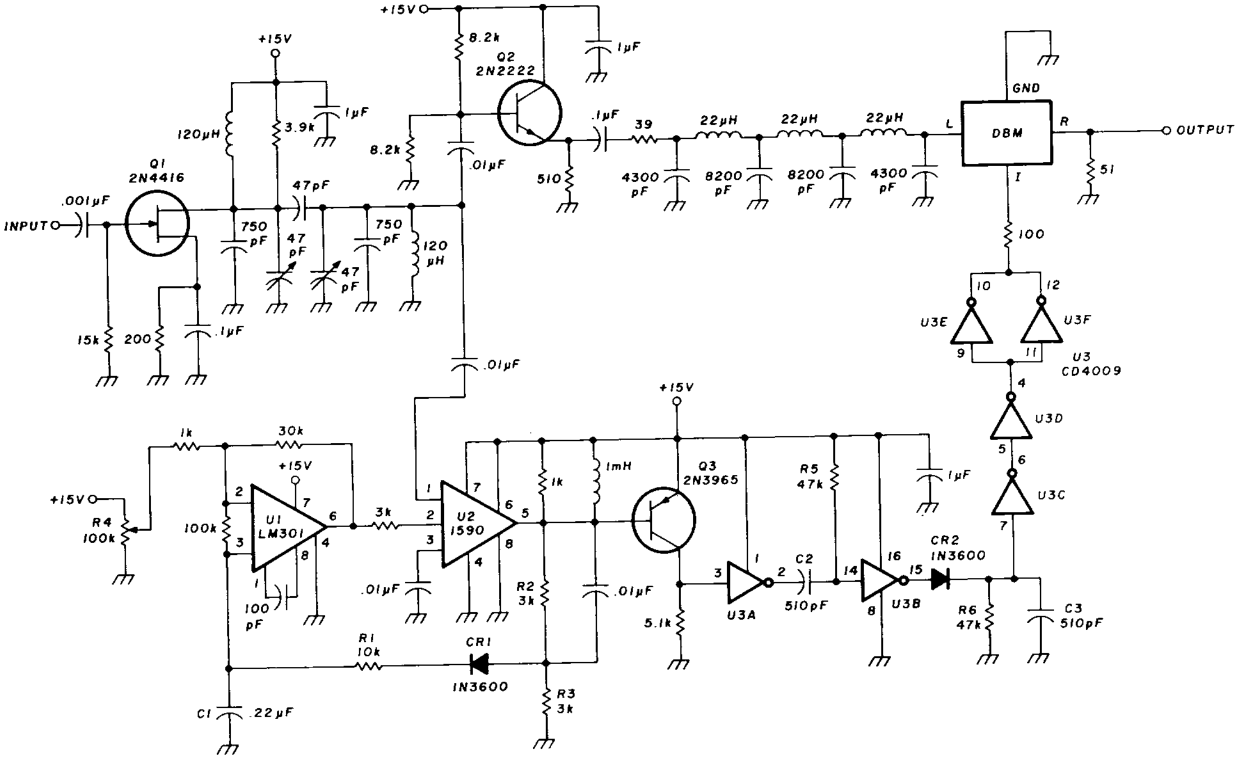

fig. 3. The final design of the noise blanker as applied to the author's receiver.

0.5 to 1 volt, the required gain may be extremely high if the input is small. This suggests placing the blanker at a point of high signal level. Again, there are two conflicting requirements and compromise is necessary. Also, for reasons of simplicity, the noise amplifier should be fixed-tuned which means it must be placed somewhere between the mixer and the narrow i-f filter. The bandwidth of the amplifier must, of course, be great enough to accurately follow pulse rise-time and minimize delay. If, as in my case, agc is used to obtain automatic threshold adjustment, the amplifier should maintain all its desirable characteristics with agc applied.

Detector. The ideal detector would have a very definite threshold below which it has no output and above which it has a large output. The response time must be very fast. There are many regenerative types of circuitry that would work, but I have found the simple transistor design used in the sample design (**fig. 3**) to be adequate.

Pulse generator. The function of the pulse generator was outlined earlier. Since the requirements will depend on the type of gate used, one circuit will not satisfy every need. A design that may come close is the retriggerable, one-shot multivibrator using CMOS ICs.[3] The retriggering action inhibits the gate for the duration of the noise pulse and then recovers very quickly. Risetime is relatively fast, but not so fast as to cause excessive transients and ringing. The voltage swing (0 to +15V) is high enough to operate most blanking gates. If required, CMOS gates may be paralleled for additional current capability.

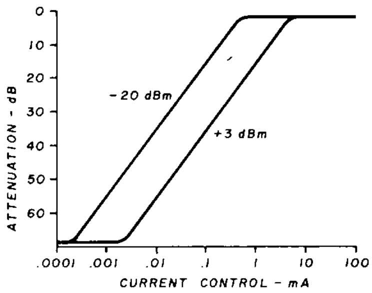

fig. 4. A double-balanced mixer can be used as a current-controlled attenuator. This example shows the required current for two different applied power levels.

Delay network. Since it takes a finite amount of time to amplify, detect, and form a pulse, a commensurate time delay should be introduced in the main channel to insure coincidence between the noise impulse and the blanking pulse. This delay is admittedly hard to come by at the higher frequencies and is left out in many designs. For lower frequencies the phase shift, through lowpass filters, is a reasonable method of introducing an apparent time delay. The amount of delay, t_d, can be calculated from:

$$t_d = \frac{\theta}{360 \cdot f}$$

where

θ = the phase shift in degrees
f = the frequency of operation.

Blanking gate. Last, but perhaps most important, is the selection of a suitable gate. The characteristics of an ideal gate are: zero insertion loss when on, infinite insertion loss when off, and no feedthrough of any switching transients to the output. This last point is extremely important. Some switching circuits, while doing a good job of cutting off the signal, can generate transients of larger amplitude than the original noise pulse!

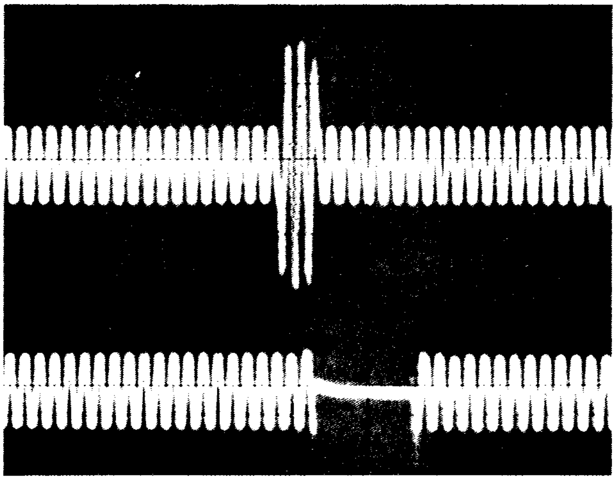

fig. 5. The bottom trace of this photograph shows the output from the gate after a noise pulse has been blanked. The original pulse (top trace) had a 10 dB noise-to-signal ratio.

I have tried many different types of gates, series and shunt diode bridges, switching fets, bipolar transistor switches, and even a double-balanced mixer (DBM) operated as a current-controlled attenuator. After evaluating all of the different possibilities, I settled on the DBM because of its good performance and simplicity. For those not familiar with this application of the DBM, **fig. 4** is a plot of attenuation vs control current at two different signal power levels.

practical circuit details

Fig. 3 is the complete circuit diagram of my blanker design. This particular circuit is installed in a modified Collins ARR-41 receiver. It is inserted

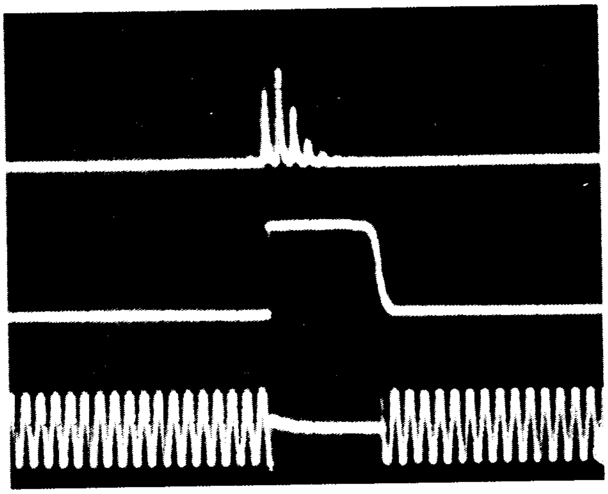

fig. 6. Additional points in the blanker are shown in this photograph. The upper trace is the collector of Q3 while the middle trace is the output of the one-shot multivibrator. The bottom trace is the same input as in fig. 5.

between the plate of the second mixer and the first i-f amplifier. The i-f is at 500 kHz and the signal level is a few millivolts.

In this circuit Q1 and its double-tuned drain circuit comprise a low-gain bandpass amplifier that removes the remaining local oscillator signal while setting the bandwidth at about 50 kHz. At this point, the signal is split into the two channels. In the main channel, Q2, an emitter follower, drives the 50-ohm lowpass delay network. The output from this network passes through the gate (DBM) on to the remainder of the receiver. This particular delay network is a seven-pole Butterworth lowpass filter with a 700-kHz cutoff frequency. The phase shift is about 200 degrees at 500 kHz; therefore, the delay is about 1.1 μs.

In the noise channel, U2, a MC1590 operating as a video amplifier, is the noise amplifier. It drives Q3, the pulse detector, and CR1, the agc detector. The agc time-constant, set by R1 and C1, is long enough to be unaffected by short noise pulses but will follow the average signal level. The anode of CR1 is biased at one half the supply voltage by R2 and R3. An operational amplifier, U1, amplifies the agc and controls the gain of U2. R4 applies an offset voltage to the input of U1. This has the effect of setting the point at which CR1 begins to conduct, since both inputs of the op amp are at the same potential. R4, therefore, becomes the threshold adjustment. Once set, it should not require further adjustment unless it is necessary to disable the blanker in the presence of a strong adjacent channel signal.

Detection takes place in Q3 and the resulting positive pulses are applied to buffer U3A. The output of U3A triggers the one-shot comprised of R5, R6, C2, C3, CR2, and gates U3B and U3C. The remaining gates of U3 are used to develop the proper phase and current amplitude to operate the blanking gate.

circuit performance

Figs. 5, 6 and **7** demonstrate the performance that can be achieved with the circuit of **fig. 3**. The top trace of **fig. 5** shows a signal with a simulated noise spike, of 10 dB greater amplitude. The bottom trace is the same signal at the output of the blanking gate.

Fig. 6, made under the same conditions as above, shows, on the top trace, the detected output of Q3. The middle trace is the output of the one-shot as seen at pin 4 of U3D. The bottom trace is the blanker output. The only change in **fig. 7** from **fig. 5** was to increase the noise to signal ratio to 40 dB and reduce the top trace vertical sensitivity to 500 mV per division. Almost total elimination of the noise at the output is clearly evident.

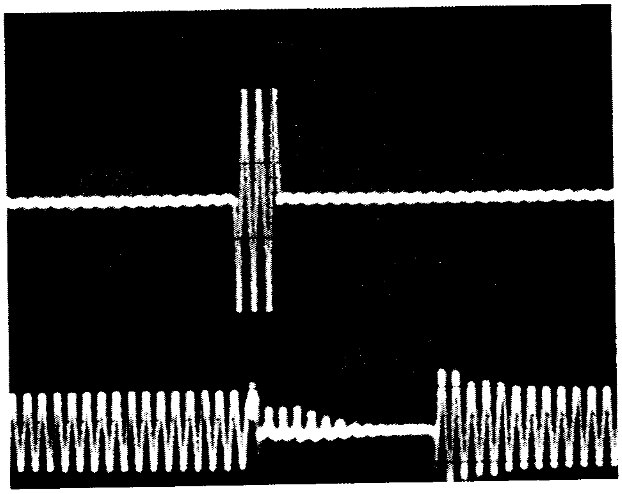

fig. 7. Example where the noise-to-signal ratio has been increased to 40 dB. The bottom trace shows almost complete elimination of the noise pulse at the output of the blanking gate.

problems. It is but one technique among other more sophisticated ones, such as coherent detection, adaptive filtering, and auto-correlation, that should be considered when attempting to communicate in the presence of noise.

references

1. J. J. Lamb, "A Noise Silencing I.F. Circuit for Superhet Receivers," *QST*, February, 1936, page 11.

2. W. R. Nelson, "Electrical Interference," *QST*, April, 1966, page 11; May, 1966, page 39.

3. J. A. Dean and J. P. Rupley, "Astable and Monostable Oscillators Using RCA Cos/Mos Digital Integrated Circuits," *Applications Note ICAN-6267*, RCA Solid State Division, Somerville, New Jersey.

ham radio