The Fourth Method: Generating and Detecting SSB Signals

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While looking for a simple system when building a new SSB transmitter, I found a nice audio phase shifter designed by HA5WH, in the *ARRL Handbook* (1986 edition, pp 18-9—Fig 1).

Omitting the op-amps, the outputs of the shifter (selected components within 1%) were four equal signals each 90 degrees out of phase.

I don't like RF phase shifters, expensive doubly balanced mixers and all other kinds of balancing. So I thought (based on the old frequency converter system with ac motor generators) using a dual-analog 1 to 4 multiplexer, the HEF4052B, must give good results. Because of switching effects, the usable operating frequency is not high, in this case, 90 kHz suppressed SSB carrier.

The SSB Exciter Diagram, Fig 2

The 11.59055-MHz crystal oscillator signal is first divided by 16 (HEF4029B) and then divided by eight in a second HEF4029B, driving the multiplexer. By counting up or down (changing the rotation direction of the multiplexer) LSB or USB is obtained.

The resistors around the HEF4029B limit the switching currents. A balanced-output LC filter on 90.55 kHz is connected to a balance mixer to eliminate switching spikes. The output of this mixer on 11.5 MHz is filtered by a simple crystal filter, removing unwanted mixing products at least 90 kHz away.

Results

With an output of 300 mV peak-to-peak on 11.5 MHz, 2-kHz test tone: The carrier suppression is better than 50 dB, other sideband suppression is better than 50 dB (<1 mV P-P).

Because of the high 300-2700 Hz audio level, 4 V P-P to inputs shifter, dc balancing of the buffer-op amps is not required.

The True SSB Detector Diagram, Fig 3

First, I had to find out if the audio phase shifter would work as an audio phase combiner.

An identical filter as combiner connected to the shifter in the exciter gives the following results:

By an input 4 × 900 mV P-P, 0°, 90°, 180° and

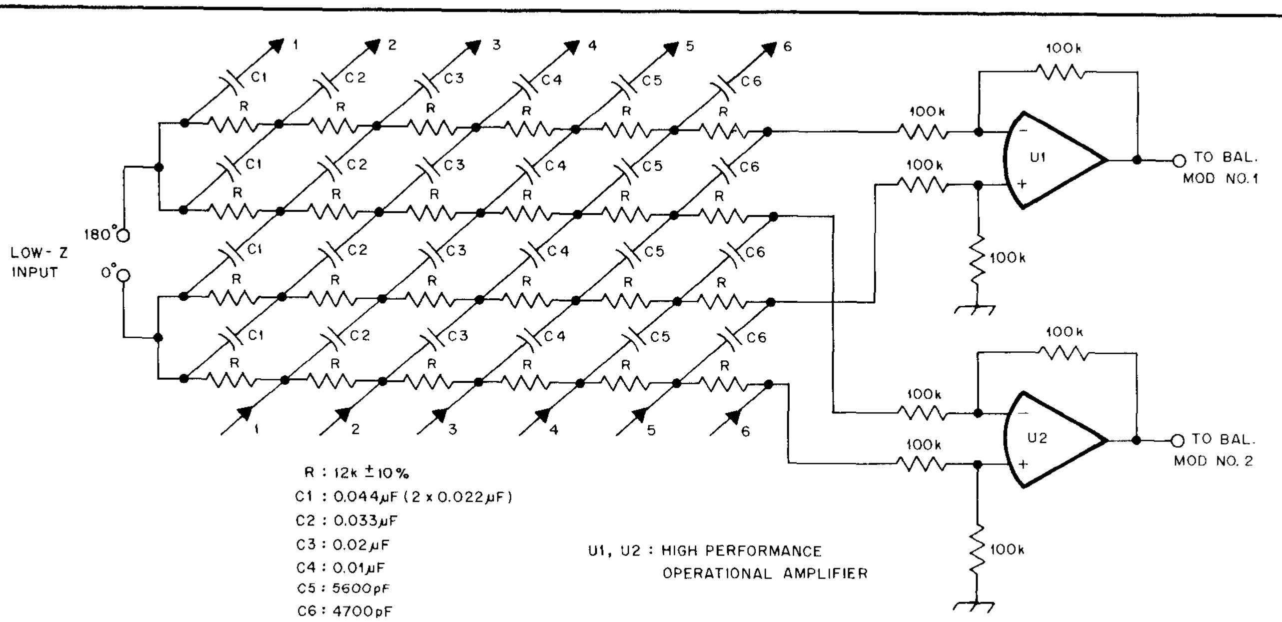


Fig 1—A high-performance audio phase shifter made from ordinary loose-tolerance components (designed by HA5WH), from the *ARRL Handbook*, 1986, p 18-9.

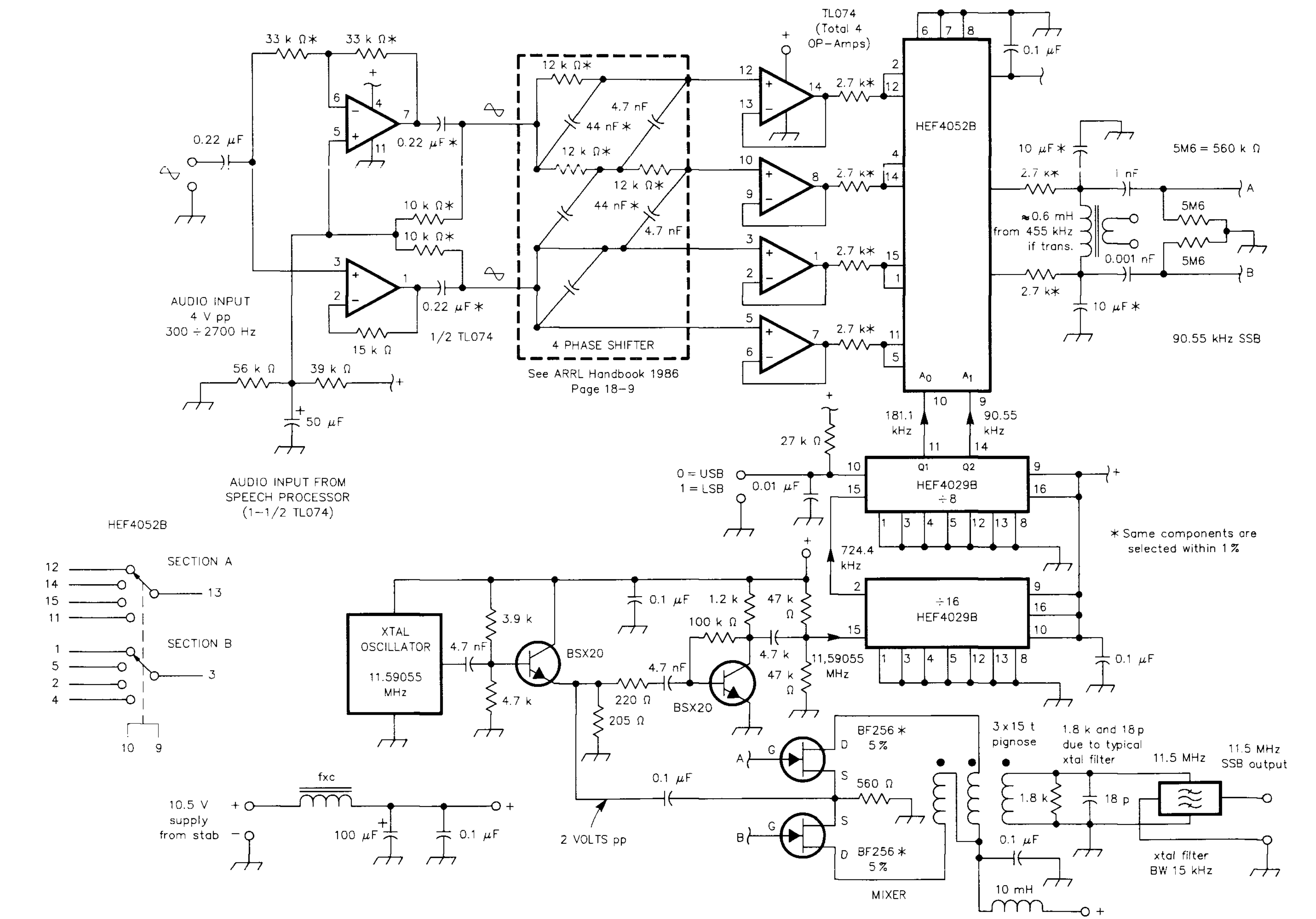


Fig 2—SSB Exciter (also see Fig 1)

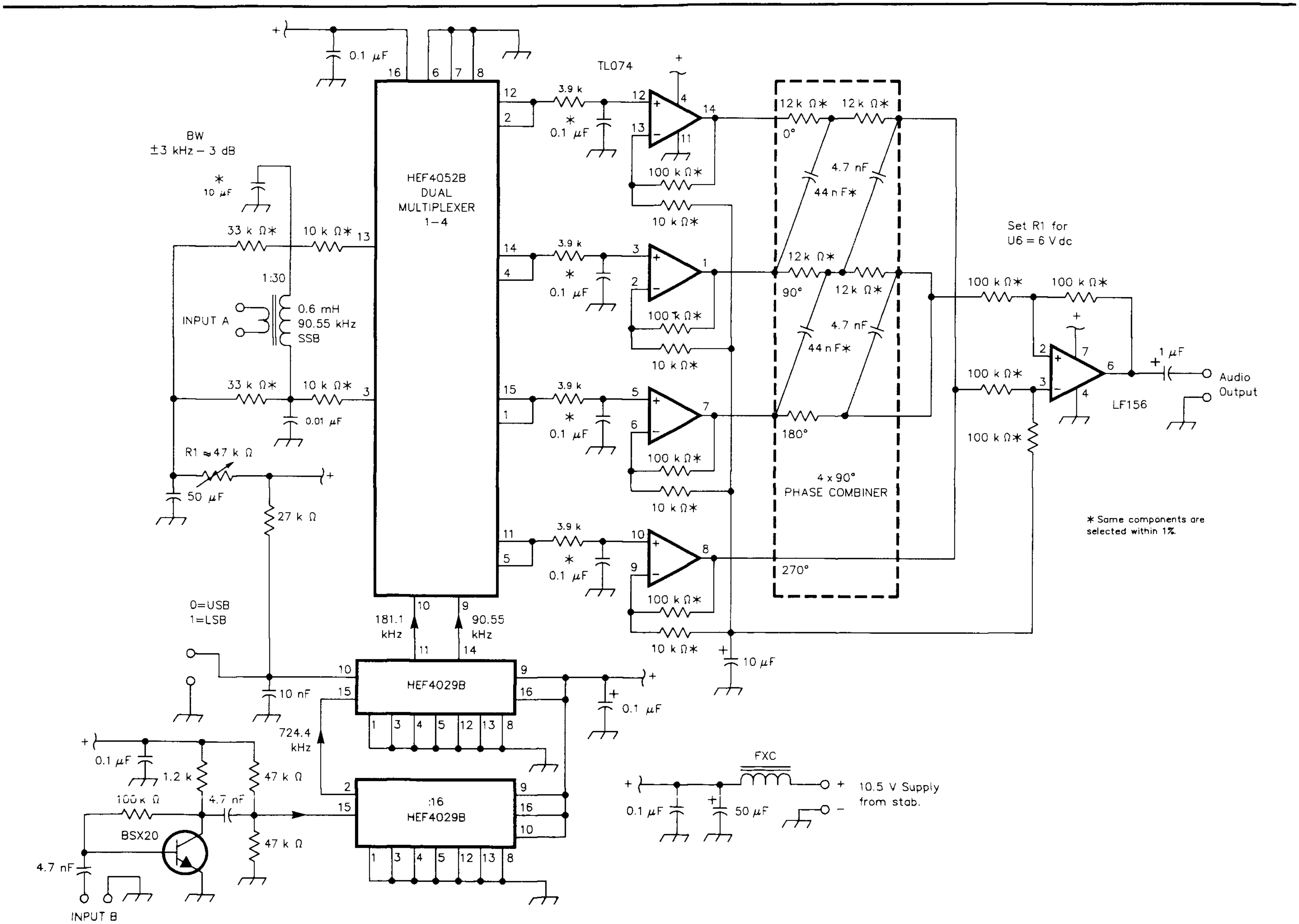


Fig 3—SSB Detector

270°, the output of the LF 156 is 600 mV P-P. By changing the 0° and 180° of the inputs, the output is noise only, less than mV P-P.

So the filter also works as a phase combiner.

The input to the detector, 90 kHz, is obtained by mixing (in a good double-balanced mixer) the 11.5-MHz IF and the crystal oscillator on 11.59055 MHz.

After the mixer, a gain-controlled 90-kHz amplifier is connected to input A. Input B received the signal from the crystal oscillator. Its unloaded output 2 V P-P; R_{int} = 50 Ω.

Results

Signal input on point 3 of the multiplexer is 120 mV P-P; 92.55 or 88.55 kHz.

Output LF 156: 700 mV P-P 2 kHz.

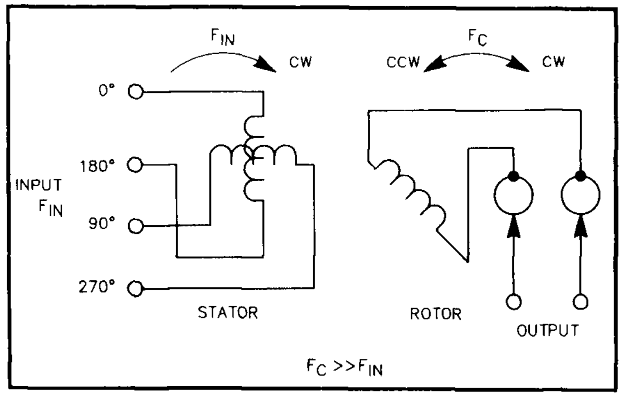
Sideband and carrier suppression: better than 50 dB. Switching spikes −15 dB (360 kHz) but an audio low-pass filter <2700 Hz will remove the spikes.

Playing with both systems together was a lot of fun. Much success to the next builders of this system.

SSB Exciter

The heart of the circuit is a combination of the dual-analog switch HEF4052B and the audio phase shifter designed by HA5WH.

Take a "selsyn" (one part of an electric axle, formerly used by radar systems). Its stator consists of two coils, 90° mechanically shifted. Its rotor consists of one coil and slip rings.



Feeding the stator by two electric signals 90° out of phase creates a clockwise-rotating field. If the rotor is at rest, the output has the same frequency as the input signals. By rotating the rotor CW, the output frequency is the sum: $f_c + f_{in}$. It is a linear system; no start of harmonics or mixing products. By rotating the rotor CW, the output frequency = $f_c - f_{in}$. Suppose: f_{in} = 300 − 2700 Hz audio, where f_c = carrier frequency (90.55 kHz). Depending on rotation direction of the rotor, we get USB or LSB only.

Replacing the selsyn by a rotating switch (HEF4052B), we get the same results, but because of the abrupt switching (or sampling), harmonics of f_c must be removed.

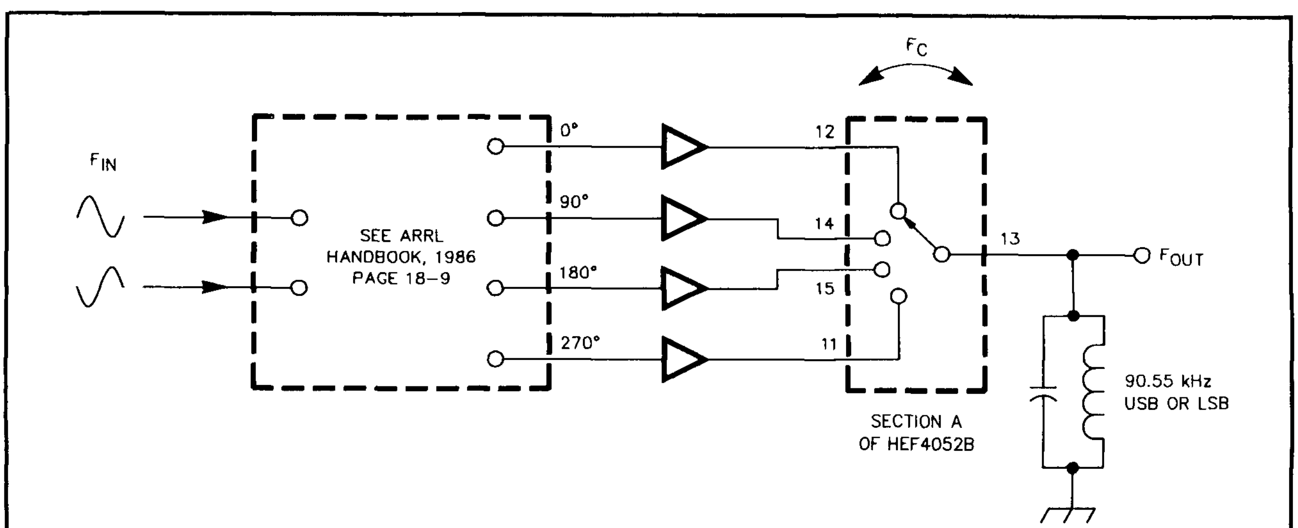
The four op-amps TL074 (only two are drawn) between the shifter and the switch act as buffers.

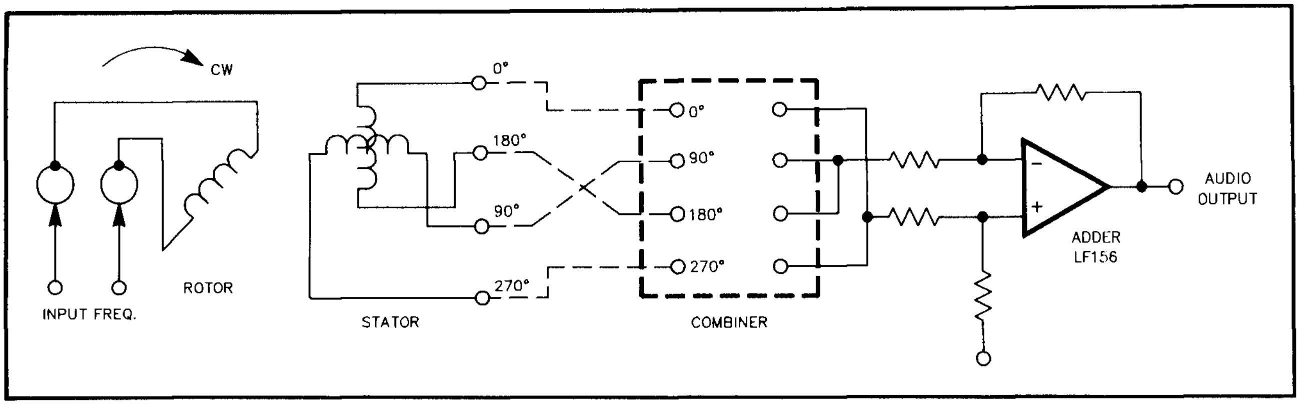
Both sections of HEF4052B are used in balance. As driver, the switch, a synchronous up/down counter HEF4029B, is used. By using the outputs Q1 = 11 and Q2 = 14, the counter divides by 8. USB or LSB is obtained by counting down or up (point 10).

The audio input to the phase splitter is obtained from a speech processor (AVC; clipping and filtering). There are many circuits in various handbooks, so I won't include details. Other circuitry depends on what we need. In my case, f_{out} must be 11.5-MHz SSB and the speed of the switch about 100 kHz. So:

$$f_{xtal} - \frac{f_{xtal}}{128} = 11.5 \text{ MHz or}$$

$$f_{xtal} = 11.5 \times \frac{128}{127} = 11.59055 \text{ MHz}$$





$f_{switch} = 11.59055 - 11.5 = 90.55$ kHz

128 = divided by 16 and divided by 8

SSB Detector

Back to the selsyn:

Situation:

A) rotor speed 100,000 c/s CW, input frequency 101,000 c/s } output stator 101,000 - 100,000 = 1 kHz CW

B) rotor speed 100,000 c/s CW, input frequency 99,000 c/s } output stator 100,000 - 99,000 - 1 kHz CW

Replacing the selsyn by the rotating switch, the results are the same, *but* the filter designed by HA5WH (Fig 1) shows a new combiner phenomenon.

In situation A, the two outputs of the combiner are maximum 1 kHz. In situation B, the two outputs of the combiner are minimum 1 kHz.

The op amp, as adder, brings the audio output from minimum to zero and from maximum to twice maximum. So, within the specs of the 300-2700 Hz combiner, only one sideband is received. By changing the switch rotation direction, the other sideband is received. A 300-2700 Hz audio filter removes all other frequencies below 100 and above 2700 Hz, along with the switching spikes and harmonics from the rotating switch. (See Fig 3.)

Input A, 90.55-kHz SSB is obtained from a mixer; 11.5-MHz SSB and 11.59055 MHz of a crystal oscillator. Input B comes from the same crystal oscillator; first divided by 16, then by 8.

The audio output is connected to a 300-2700 Hz audio filter (details appear in various handbooks).