Outputs of op-amp networks have fixed phase difference

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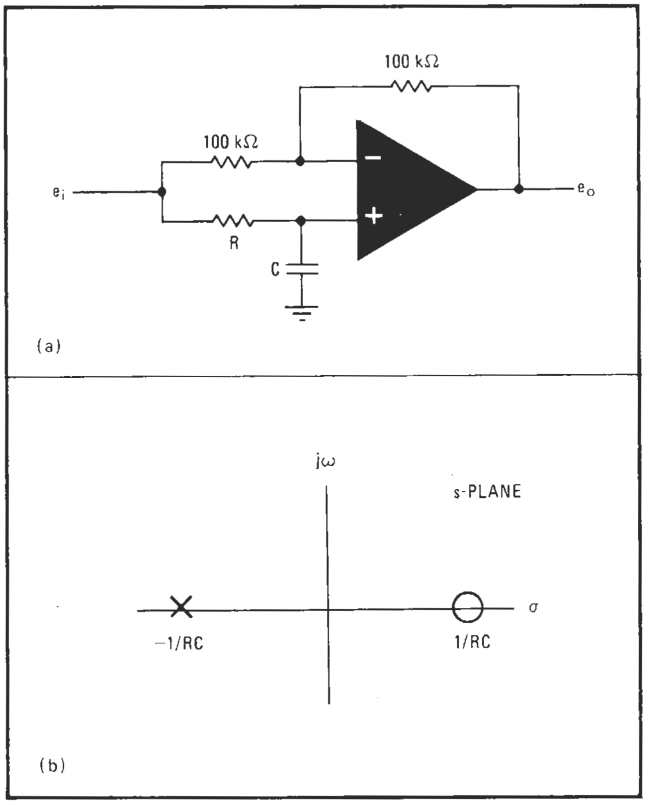
In the phasing method of single-sideband generation, two modulating signals are derived from the audio input. The two signals must have equal amplitudes, but must differ in phase by 90° at all frequencies in the audio band. A differential-phase-shift system that provides these two signals can be made from resistors, capacitors, and operational amplifiers.

The basic section of the constant-phase-shift system is the op-amp circuit shown in Fig. 1. The transfer function of this circuit is

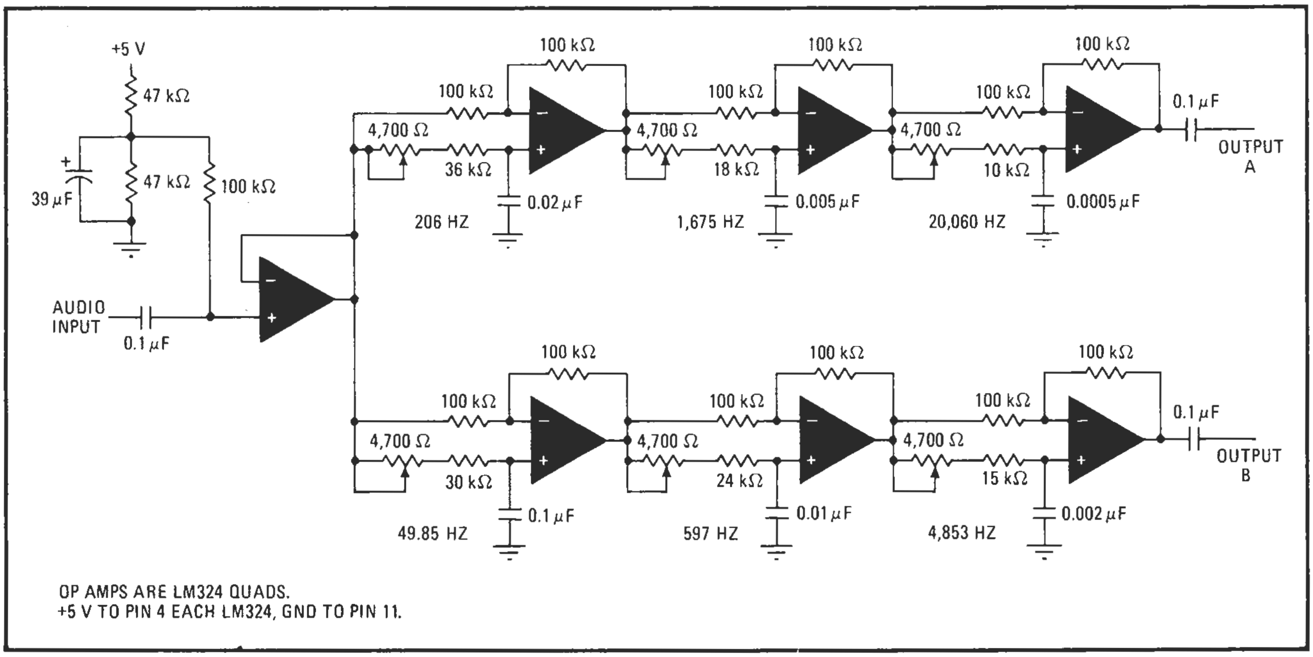
$$e_o/e_i = (1 - j\omega RC)/(1 + j\omega RC) = 1 \underline{/-2 \arctan \omega RC}$$

Thus the gain is always unity, and the phase shift decreases from 0 to –180° as frequency increases from zero to infinity. The shape of the phase-shift curve depends upon the time constant RC, i.e., upon the locations of the singularities in the s-plane plot that is included in Fig. 1.

If three of these basic sections are cascaded, the over-all gain remains constant at unity, and the over-all phase shift through the network falls from 0 to -540° at



1. Basic section. Op amp connected as shown (a) is a unity-gain phase shifter. Singularities of circuit are shown (b) in s-plane plot. Phase shift ranges from 0 at dc to –180° at infinite frequency; however, gain is unity at all frequencies.



2. Quadrature. Differential phase shifter converts audio-frequency input signal to two outputs, 90° out of phase, for SSB modulation. Simple transformerless circuit uses quad op amps driven by a single-ended 5-volt supply. The individual sections are adjusted for 90° phase shift at the frequencies indicated on the figure; the two outputs are then in quadrature to within 2° from 100 Hz to 10 kHz.

a rate that is determined by the three RC products.

Two such phase-shift networks, fed from a common input (as shown in Fig. 2), can be designed so that the phase shift through one lags behind the phase shift through the other by 90° over a substantial frequency range. The time constants are chosen so that the singularities of the two networks interlace.

The all-pass system in Fig. 2 provides two equal-amplitude outputs that differ in phase by (90 ± 2)° over the frequency interval from 100 hertz to 10 kilohertz. The various R and C values were calculated from the table published by S.D. Bedrosion, "Normalized Design of 90 Degree Phase Difference Networks," IRE Transactions on Circuit Theory, June 1960, pp. 128–136. In each section, $RC = 1/2\pi f$, where f is the 90° frequency for that section as shown in Fig. 2. An exception is the 20,060-Hz stage, where R was decreased to compensate for the inherent phase shift in the op amp.

Each section of each network should be individually adjusted to an exactly 90° phase shift at the indicated frequency. This adjustment can be made by connecting the input and output of that section to the horizontal and vertical inputs of an oscilloscope, and then varying the 4,700-ohm potentiometer until the Lissajous figure is a circle. Alternatively, a phasemeter can be used.

Each op amp is one quarter of an LM324 quad amplifier. The input biasing network allows operation from a single 5-volt supply. □