Low-distortion oscillator uses state-variable filter

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The state-variable filter, which in any case excels as a flexible active-filter design block, can also be made to oscillate with only a little additional circuit complexity With high-performance quad op amps now readily available, a single integrated circuit makes a ultra-low-distortion sine-wave oscillator with a output frequency of up to 5 kilohertz and three output phases for driving servo or instrumentation systems

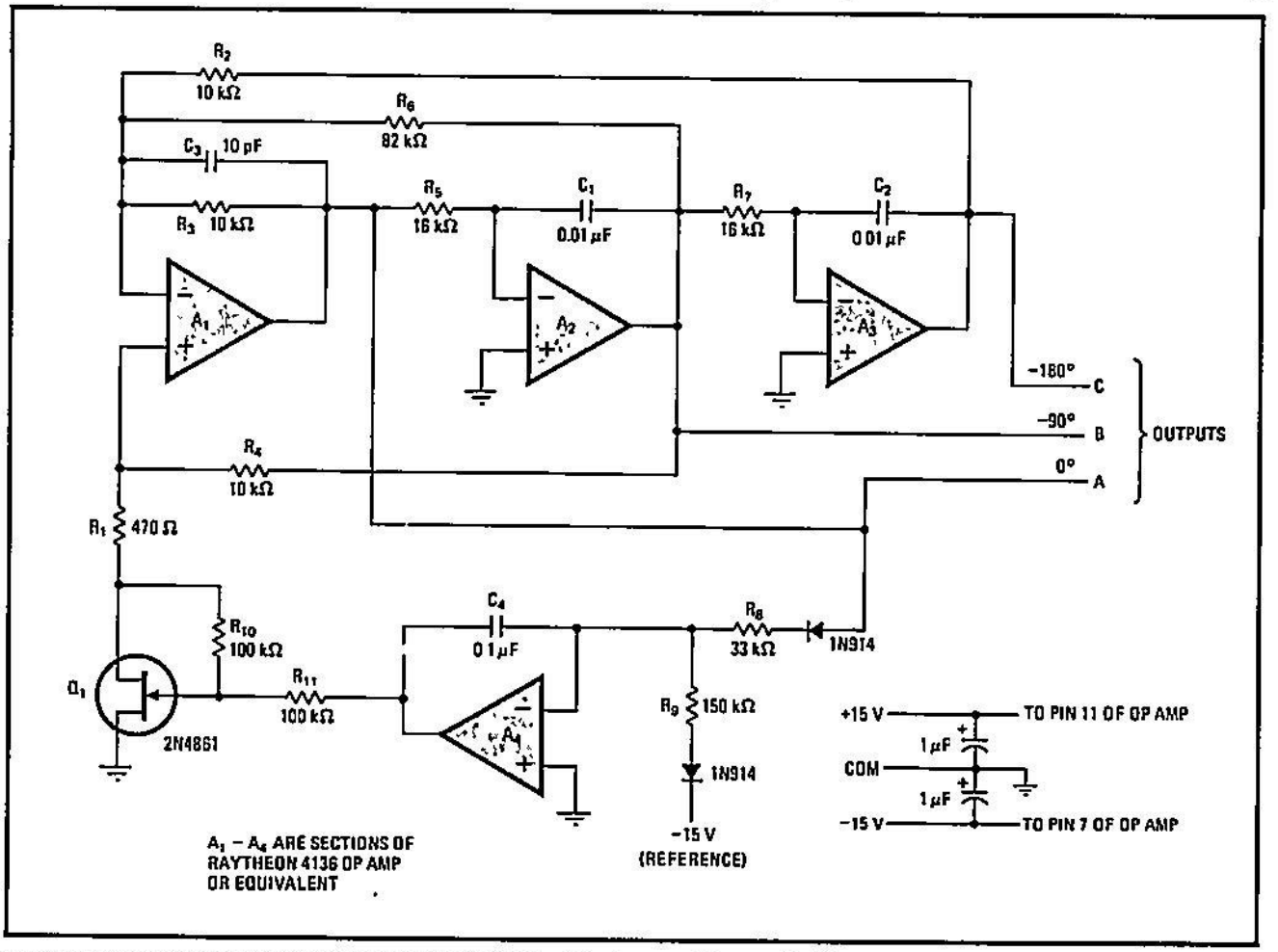
The schematic diagram shows the circuit of the oscillator Operational amplifiers A_1, A_2, and A_3 comprise the state-variable filter, with its normal negative feedback path via R_4, positive feedback to sustain oscillation is provided by R_6. The oscillation frequency is given by

$$f = 1/2\pi RC$$

where R is the value of equal resistors R_5 and R_7 and C is the value of equal capacitors C_1 and C_2. For the circuit shown, f is 1 kilohertz.

As in other sine-wave oscillators, the positive and negative feedback paths must be carefully balanced to attain—and sustain—low-distortion operation. The balance is achieved by use of some type of automatic gain control; in this circuit the mechanism is the variable channel resistance of field-effect transistor Q_1.

The agc circuit in itself comprises an active loop that serves several important purposes. The integrator A_4 filters and smoothes the rectified output to provide a dc control voltage for the gate of Q_1 Low ripple on this control voltage is necessary to prevent modulation distortion on the output. The high dc gain of the integrator automatically adjusts the loop to the required dc bias for Q_1 in spite of parameter variations, thus eliminating



State-variable oscillator. Addition of regenerative feedback via R_6 changes state-variable filter into sine-wave oscillator with three phases of output Filter uses three of the amplifiers in a quad op amp IC, the fourth amplifier is part of agc loop that ensures ultra-low distortion

the necessity for device selection The output voltage is regulated to a value that causes the average current in R_8 to be equal to that in R_9 Thus R_9 and the -15-V supply serve as a reference, and the age loop tracks this reference to maintain the output peak voltage at about 10 V.

Resistors R_{10} and R_{11} provide a local feedback path around Q_1, to reduce distortion drastically below the straightforward connection The high values of feedback resistance (100 kilohms) in relation to Q_1's "on" resistance (nominally 100 ohms) prevent undesirable interaction of the ac and dc signals

In operation, the total harmonic distortion at the A output is on the order of 0 02%, and distortion in the B and C outputs is considerably less because of the low-pass filtering in the A_2 and A_3 integrator circuits All outputs appear at the same level, with the phase relations shown

The prototype of this circuit uses a Raytheon 4136 quad op amp, which has a 3-megahertz bandwidth The Harris 4741, with similar ac characteristics, is another suitable unit The Motorola 3403 and National 348, both 1-MHz devices, provide ultra-low-distortion performance at frequencies up to 2 kHz The main asset of a quad device for this circuit is its cost-effectiveness—the entire circuit can be built for $10 or less □