Engineer's notebook

Stable sinusoidal oscillator has multiple phased outputs

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This sine-wave oscillator design is useful as, among other things, a pure signal source for calibration. It provides gain-independent operation, is easy to adjust, and has a wide frequency range and stable amplitude What's more, the circuit is self-starting and provides multiple-phased outputs of equal amplitude.

As shown in Fig. 1, the feedback loop has two 90° phase shifters and a unity-gain inverter. Thus, the circuit meets the criteria for oscillation—a loop gain of 1 with a phase shift of 180°. Each 90° phase shift is provided by the delay equalizer circuits (A_2, A_3). These two circuits have a unity gain at all frequencies and a phase shift that is adjustable between 0° and −180°. It is these properties that make the oscillator's features notably superior to those of other designs.

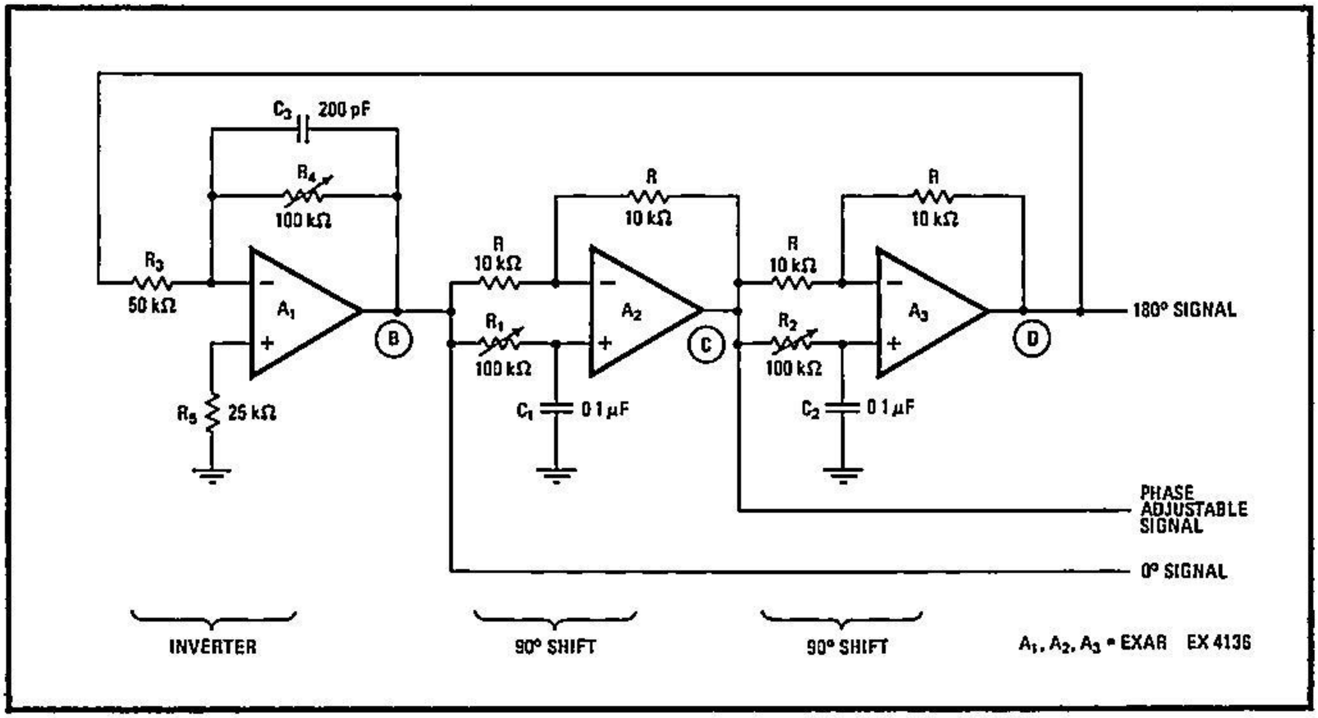
The transfer function of the equalizer circuit is $T(s) = V_{out}/V_{in} = (s-a)/(s+a)$, where $a = 1/R_1C_1$ At any frequency or pole/zero value, the absolute magnitude is always unity: $|T(s)| = |s-a|/|s+a| = (a^2+\omega^2)^{1/2}/(a^2+\omega^2)^{1/2} = 1$. Phase, $B(\omega)$, which is plotted in Fig. 2 is given by $B(\omega) = -2\tan^{-1}(\omega/a)$, where $a = 1/R_1C_1$. At $\omega = a$, the zero contributes −135° of phase shift and the pole contributes 45° of phase shift for a total phase shift of −90°.

The frequency of oscillation is completely determined by the two independent time constants, R_1C_1 and R_2C_2, and can be expressed exactly as $f = 1/[2\pi(R_1C_1R_2C_2)^{1/2}]$. If $R_1 = R_2$ and $C_1 = C_2$, then $f = 1/(2\pi R_1C_1)$.

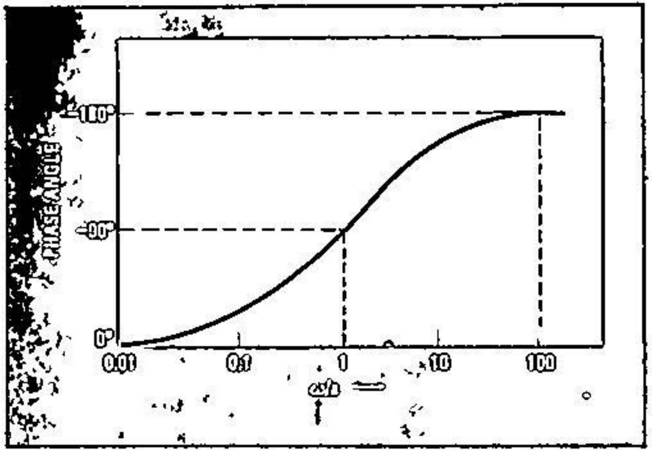
Since the frequency range of oscillation is totally independent of any gain factor, the amplitude stability and the amplitude of oscillation are completely decoupled from the frequency-determining adjustment of R_4. A wide frequency range is assured for this oscillator. The amplitude of oscillation is determined by the maximum voltage swing of the op amp

In the circuit of Fig. 1, C_1 and C_2 are equal; R_1 and R_2 are set equal; R_4 is adjusted for a total loop gain of 1 As the loop gain approaches unity, the pure sinusoidal oscillation begins. Further adjustment of R_4 permits the oscillation to be easily stabilized at its maximum amplitude and with no harmonic distortion. Adjustment of R_1 alters the phase relationship between the 0° and −180° signals. It also changes the frequency of the oscillator without disturbing the amplitude, amplitude stability, or oscillation criteria The placement of C_3 in the circuit prevents high-frequency parasitic oscillations from occurring in the operational amplifiers.

Oscillations over a large frequency range could be obtained by changing the value of C_1 and C_2 and varying R_1 and R_2 with a dual potentiometer For single-element



1. Phased out. An inverter (A_1) and two identical equalizer circuits (A_2, A_3) form a sinusoidal oscillator Three equal-amplitude signals are at 0°, 90°, and 180° phase angles, respectively The oscillator is self-starting and is capable of a wide range of frequencies.



2. Frequency equalizer. The oscillator circuit in Fig 1 provides unity gain independent of frequency The phase angle of the output varies from 0° to −180° with frequency, as shown above At the frequency of oscillation, $\omega = a$, the phase angle is −90°

control, R_1 and R_2 could be voltage-controlled resistances. Over a narrower range, frequency can be adequately varied by just adjusting R_1

The circuit is ideal for producing multiple signals with precise phase relationships of equal amplitude By cascading increasing numbers of delay equalizer stages, signals of any phase can be easily obtained. ☐

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