Circuit phase-locks function generators over 360°

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This circuit locks a low-cost function generator without a voltage-controlled-oscillator (VCO) input to a second inexpensive generator having such a phase-reference feature. A J-K flip-flop, two one-shots, two comparators, and an operational amplifier are linked in a feedback arrangement that includes the programmable generator as the VCO in a phase-locked loop (PLL). The resultant circuit provides a selectable phase shift between generator outputs over the range of 0° to 360°.

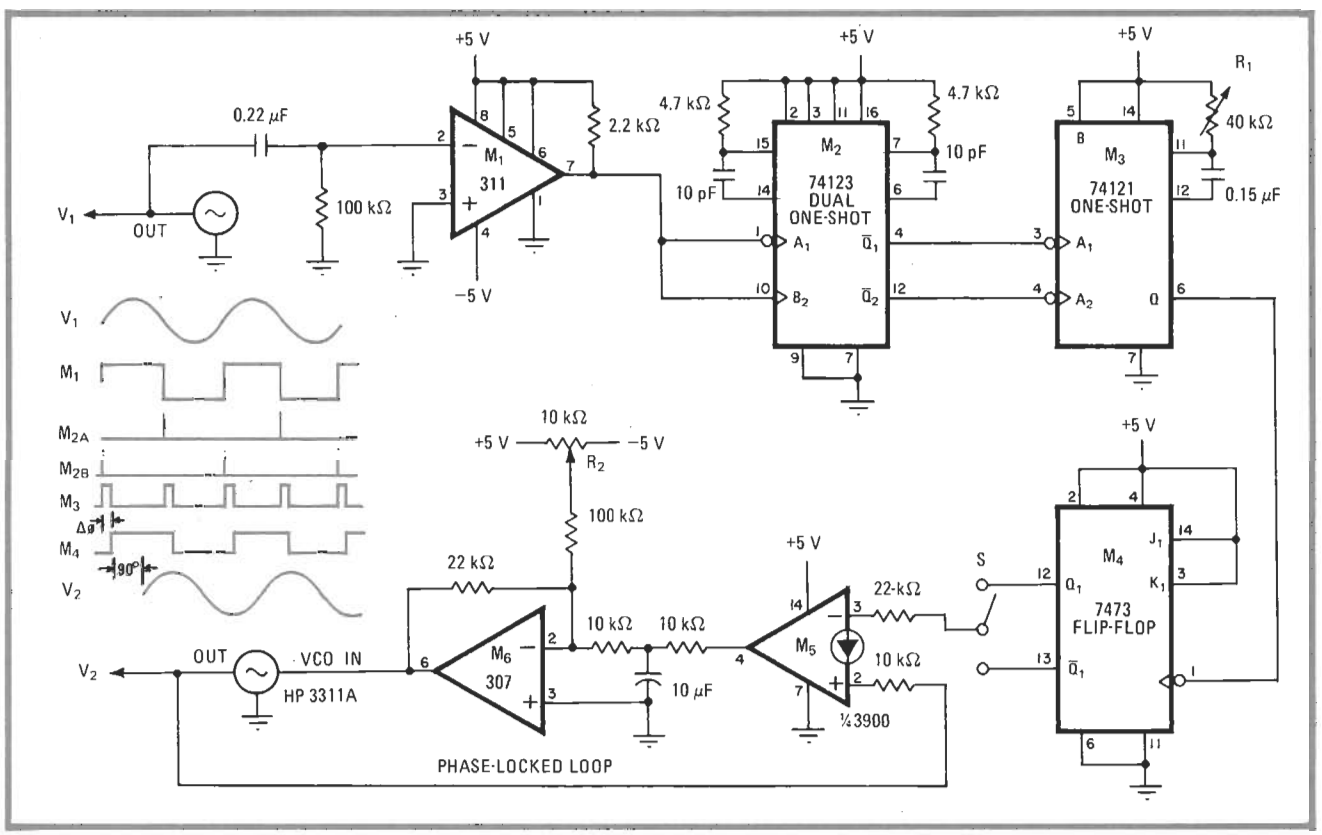
In operation, the output of the low-cost generator, v_1, passes through a high-pass filter to a zero-crossing detector that employs a 311 comparator (M_1), as shown. A dual monostable multivibrator and J-K flip-flop follow. Although these two devices can be eliminated, they enable the phase-locked loop to be operated at the center of its locking range for any phase shift. This arrangement ensures that two often desired phase angles, 0° and 180°, fall within the capture range of the PLL, so that if locking is lost, it will be automatically regained.

The outputs of the dual one-shot, M_2, wired so that each fires on opposite edges of the signal applied to its inputs (see timing diagram), are fed to the OR input of M_3, whose on time is selected by potentiometer R_1. Thus R_1 controls the amount of phase shift.

M_3 produces two pulses for each cycle of v_1 and triggers the J-K flip-flop, M_4, on each negative edge. The flip-flop thus produces a square wave with a frequency equal to v_1, but shifted in phase by up to 180°. An additional shift of 180° can be obtained by using switch S to connect the Q output of M_4 to the inverting input of the 3900 Norton amplifier.

The adjustable-phase square wave serves as a reference signal for the phase-locked loop, which is composed of the 3900, a low-pass filter, a buffer (307), and a VCO (the second function generator, a Hewlett-Packard 3311A). The input signal to the VCO is a negative dc voltage that is the inverted sum of the filtered output of the 3900 and the voltage selected by the offset control, R_2. By turning the generator's front-panel control or R_2, the free-running frequency of the loop can be adjusted.

Because the reference signal is a square wave, the PLL will lock onto either the fundamental of v_1 or its odd harmonics. Selection of a particular harmonic is made by adjusting the free-running frequency to the approximate value of the harmonic desired. Half-multiple harmonics ($\frac{1}{2}f_1$, $\frac{3}{2}f_1$, $\frac{5}{2}f_1$, etc.) can be produced at v_2 by breaking the $\overline{Q}_1$–A_1 connection between M_2 and M_3 and tying A_1 to +5 volts. Even harmonics can be obtained by using the remaining flip-flop in the 7473 as a divide-by-2 counter, and placing it between the output of the VCO and the 3900's noninverting input. □



Phase-locked. Comparators, one-shots, and flip-flop combine to provide stable locking of generators without phase-reference feature to those having a VCO input. R_1 and S are used to select phase of v_2 with respect to v_1; phase can be adjusted from 0° to 360°. M_2 and M_4 ensure that locking is regained if it is lost, and R_2 controls lock frequency, which may be set to integer or half-integer harmonics of v_1.