2
Basic Oscillator Theory

In undertaking the design of a crystal oscillator, an understanding of basic oscillator principles is not only desirable but essential. Therefore, a brief explanation of the operation of a crystal oscillator is given here. Basically, a crystal oscillator can be thought of as a closed loop system composed of an amplifier and a feedback network containing the crystal. Amplitude of oscillation builds up to the point where nonlinearities decrease the loop gain to unity. The frequency adjusts itself so that the total phase shift around the loop is 0 or 360 degrees. The crystal, which has a large reactance-frequency slope, is located in the feedback network at a point where it has the maximum influence on the frequency of oscillation. A crystal oscillator is unique in that the impedance of the crystal changes so rapidly with frequency that all other circuit components can be considered to be of constant reactance, this reactance being calculated at the nominal frequency of the crystal. The frequency of oscillation will adjust itself so that the crystal presents a reactance to the circuit which will satisfy the phase requirement. If the circuit is such that a loop gain greater than unity does not exist at a frequency where the phase requirement can be met, oscillation will not occur.

The application of these principles to oscillator design usually is difficult because many factors play an important part in the operation. As a result, the design of transistorized crystal oscillators is often a "cut and try" procedure.

Methods have been developed for predicting the amplitude of oscillation based on the small-signal loop gain. The reduction in gain for a transistor operating at large signal values is predictable and has been plotted as a function of the ac base-to-emitter voltage. Since it is known that the loop gain after equilibrium has been reached will be unity, the reduction factor is numerically equal to the small-signal loop gain. Using this value, the amplitude of oscillation can be predicted from the graphs.