NASA TECH BRIEF
Goddard Space Flight Center

Ankylosis-Stabilized Oscillator

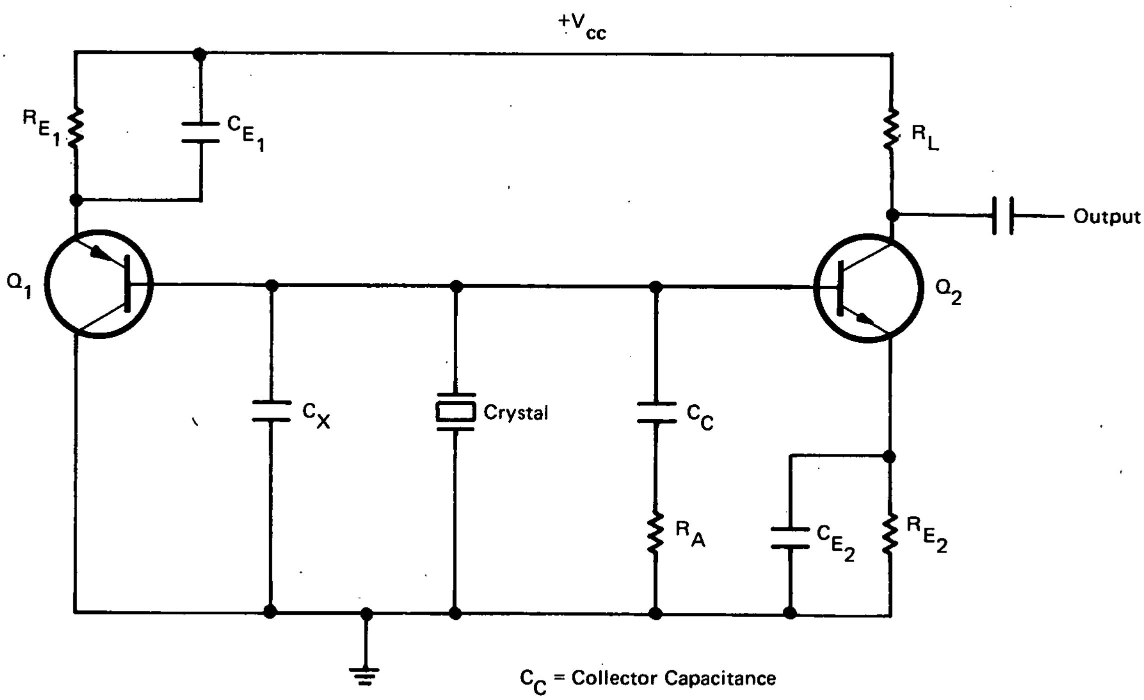
Highly stable oscillators come hand in hand with high costs. One oscillator design, however, has indicated both long- and short-term stability at a reasonably low price.

This circuit (see figure) has exhibited short-term stability ranging from 1×10^{-9} to 2×10^{-10} for 30 to 90 seconds. Yet, its long-term stability has not been better than 1×10^{-8} for periods greater than 15 minutes. The reason for this problem is explained by the equations below.

A relative change in the reflected capacitance, C, that appears across the crystal in the base circuit is given by

$$\frac{dC}{C} = \frac{2df_o}{f_o} - \frac{2df_\alpha}{f_\alpha} \qquad (1)$$

where f_o is the frequency of oscillation and f_α is the cut-off frequency. If the relative change in the reflected capacitance has the same direction (sign) as the relative



C_C = Collector Capacitance
R_E and C_E = Emitter Resistance and Capacitance, Respectively.

Stable Oscillator Circuit

(continued overleaf)

change in the frequency of oscillation (df_o/f_o), then the tendency to change frequency is opposed. However, if the direction is opposite, the reflected capacitance will cause the frequency change to shift continually in the same direction. Hence, long-term stability cannot be secured. This is exactly what occurs when the frictional condition (ankylosis) is considered as a function of frequency of oscillation, f_o, and cutoff frequency, f_α.

Since the base is loaded by a constant resistance, and the reflected negative resistance must equal this value as a function of f_o and f_α, the relative changes in f_o and f_α can be determined by setting

$$\frac{2df_o}{f_o} = \frac{df_\alpha}{f_\alpha} \qquad (2)$$

This substituted into equation (1) yields

$$\frac{dC}{C} = \frac{2df_o}{f_o} - \frac{4df_o}{f_o} = -\frac{2df_o}{f_o} \qquad (3)$$

which shows the long-term instability, as the relative change of reflected capacitance aids the change in frequency. The mechanism by which the reflected negative resistance is altered as a function of frequency which precipitates a change in f_α, as stated in equation (2), is the change in the amplitude of the oscillations and the degree of limiting incurred. The f_α changes as the dC level changes, so that equation (2) is maintained.

The question of importance is the synthesis of a circuit that embodies the required features of the oscillator and yet circumvents the inherent limitation of the basic circuit. One useful approach is to bias the transistor in a region where the change in f_α is compensated for a given change in quiescent current. There are two regions where this condition is met: (1) a high-current low-voltage region and (2) a low-current high-voltage region. In general, the low-current case is preferable. This is the reason for the inclusion of the C_x component (see figure), as the primary function of the emitter capacitor is the generation of negative resistance.

The synthesized circuit embodies all of the desired features of the oscillator, particularly the long-term stability. This is accomplished by canceling (or reducing) the change in f_α, df_α in transistor Q_1. An increase in quiescent current in one transistor is accompanied by an equal decrease in the other. Another feature of this mechanism is the reduction of self-modulation, a source of harmonic generation. Since the amplitude of oscillation is large, the f_α is varied in proportion to the amplitude and frequency of oscillation. While one transistor is experiencing a positive alternation (increasing the instantaneous current through the transistor), the other is experiencing a negative alternation (decreasing the instantaneous current). The net effect is a reduction in self-modulation.

Note:

No further documentation is available. Specific questions, however, may be directed to:

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Patent status:

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning non-exclusive or exclusive license for its commercial development should be addressed to:

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