12.15 Conditional Stability in Feedback Loops

A feedback loop may be stable under normal operating conditions when it is up and running, but can be shocked into continuous oscillation at turnon or by a line input transient. This odd situation, called *conditional stability,* can be understood from Fig. 12.17*a* and 12.17*b*.

Figure 12.17*a*and 12.17*b* contains plots of total open-loop phase shift and total open-loop gain versus frequency, respectively. Conditional stability may arise if there are two frequencies (points *A* and *C*) at which the total open-loop phase shift reaches 360° as in Fig. 12.17*a*.

Recall that the criterion for oscillation is that at the frequency where the total open-loop gain is unity or 0 dB, the total open-loop

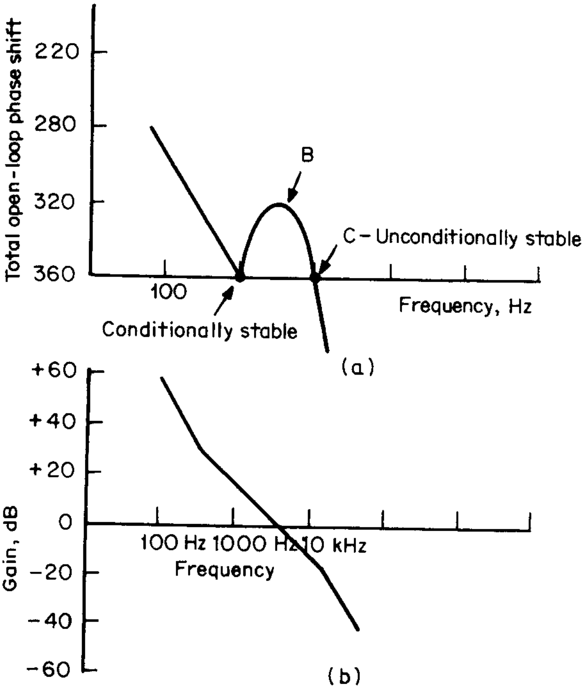

Figure 12.17 A loop may be conditionally stable if there are two frequencies where the total open-loop phase shift is 360°. Loop is conditionally stable at point *A* as a momentary drop in gain to 0 dB such as may occur at initial turnon may result in the conditions for oscillation, i.e., 360° total open-loop phase shift and 0 dB gain. Once oscillation breaks out, it will continue. Circuit is unconditionally stable at *B* as momentary increases in gain are very unlikely.

phase shift is 360°. The loop is still stable if the total open-loop phase shift is 360° at a given frequency but the total open-loop gain at that frequency is greater than 1.

This may be difficult to grasp, as it would appear that if at some frequency the echo of a signal coming around the loop is exactly in phase with the original signal but larger in amplitude, it would grow larger in amplitude each time around the loop. It would thus build up to a level where the losses would be such to limit the oscillation to some high level and remain in oscillation. This does not occur, as can be demonstrated mathematically. But for the purposes herein, it will simply be accepted that oscillations do not occur if the total open-loop gain is greater than unity at the frequency where the total open-loop phase shift is 360°.

Thus in Fig. 12.17*a*, the loop is unconditionally stable at *B* as there the open-loop gain is unity but the open-loop phase shift is less than 360° by about 40°—i.e., there is a phase margin at point *B*. The loop is also stable at point *C* as there the open-loop phase shift is 360° but gain is less than unity—i.e., there is gain margin at point *C*. But at point *A* the loop is conditionally stable. Although the total open-loop phase shift is 360°, the gain is greater than unity (about +16 dB) and, as stated, the loop is stable for those conditions.

However, if under certain conditions—say, at initial turnon when the circuit has not yet come to equilibrium and open-loop gain momentarily drops 16 dB at the frequency of point *A*—the condition for oscillation exists. Gain is unity and phase shift is 360°. The circuit will break into oscillation and remain oscillatory. Point *C* is not a likely location for such conditional oscillation as it is not possible for gain to increase momentarily.

If conditional stability exists (most likely at initial turnon), it is likely to occur at the corner frequency of the output *LC* filter under conditions of light load. It is seen in Fig. 12.3*a* and 12.3*b* that a lightly loaded *LC* filter has a large resonant bump in gain and very fast phase shifts at its corner frequency. The large phase shifts can result in a total of 360° at the *LC* corner frequency. If total open-loop gain (which is not easily predictable during the turnon transient may be unity or may momentarily be unity—the loop may break into oscillation.

It is rather difficult to calculate whether this may occur. The safest way to avoid this possibility is to provide a phase boost at the *LC* corner frequency by introducing a zero there to cancel some of the phase lag in the loop. This can be done easily by adding a capacitor in shunt with the upper resistor in the output voltage sampling network (Fig. 12.12).