3. A typical oscillator block diagram

![Diagram](image)

Frequency Selective Network

(1) When oscillation just starts to set up, we have

\[ V_{out}^{(1)} \] from noise. \[ U_i^{(1)} = \beta(s) V_{out}^{(1)} \] select frequency

\[ V_{out}^{(2)} = A(s) U_i^{(1)} \] amplify

\[ V_{out}^{(2)} = A(s) \beta(s) V_{out}^{(1)} \]

Obviously, we need \(|A(j\omega)\beta(j\omega)| > 1\) to set up

oscillation so that \(|V_{out}^{(2)}| > |V_{out}^{(1)}|\), and

further we have \[ V_{out}^{(n)} = A(s)\beta(s) V_{out}^{(n-1)} \]

\[ |V_{out}| \uparrow \]
(2) But we must control the amplitude also. This needs the circuit to be non-linear or

\[ A(j\omega) \beta(j\omega) \text{ is function of amplitude } |V_{\text{out}}| \]

\[ |V_{\text{out}}| \uparrow \quad |A(j\omega)\beta(j\omega)| \downarrow \]

until \[ |A(j\omega)\beta(j\omega)| = 1 \] to set up stable oscillation.

(3) When oscillation is set up (stable), we have

\[ V_{\text{out}} = A(s)\beta(s)\ V_{\text{out}} \]

\[ (L(s) - 1)\ V_{\text{out}} = 0 \quad , \quad L(s) = A(s)\beta(s) \]

Because \[ V_{\text{out}} \neq 0 \], we have

\[ L(s) = 1 \]

For the frequency of oscillation, this means

\[ L(j\omega_0) = A(j\omega_0)\beta(j\omega_0) = 1 \]

\[ \rightarrow \text{ Barkhausen Criterion} \]

\[ \Rightarrow (1) \omega_0 \quad (2) \text{ condition for oscillation to set up} \]
Example 1. (phase-shift oscillator)

\[ A(s) = -\frac{R_2}{R} \quad \text{inverting amplifier} \]

\[ B(s) = \left( \frac{R}{R + \frac{1}{5C}} \right)^3 \]

\[ L(s) = -\frac{R_2}{R} \frac{(SRC)^3}{(1 + SRC)^3} \]

\[ L(j\omega) = \frac{R_2}{R} \frac{(j\omega RC)(\omega RC)^2}{(1 - 3\omega^2 R^2 C^2) + j\omega RC \left[ 3 - \omega^2 R^2 C^2 \right]} \]

At oscillation, \[ L(j\omega) = 1 \Rightarrow R_2 (j\omega RC)(\omega RC)^2 = R \left[ (1 - 3\omega^2 R^2 C^2) + j\omega RC (3 - \omega^2 R^2 C^2) \right] \]
\[ 1 - 3\omega^2 R^2 C^2 = 0 \quad \Rightarrow \quad \omega_0 = \frac{1}{\sqrt{3} RC} \]

\[ L(j\omega_0) = \frac{R_2}{R} \frac{(\frac{1}{\sqrt{3} RC} R)^2}{3 - (\frac{1}{\sqrt{3} RC})^2 R^2 C^2} \]

\[ = \frac{R_2}{R} \frac{\frac{1}{3}}{3 - \frac{1}{3}} = \frac{R_2}{R} \frac{1}{8} = 1 \]

To set up oscillation \[ \frac{R_2}{R} \frac{1}{8} > 1 \] or \[ \frac{R_2}{R} > 8 \]

Can make \( R_2 \) to be \( R_2 \sqrt{2} \) when \( |V_{i+}| \uparrow \) until \( \frac{R_2}{R} = 0 \) at stable oscillation.