Contents

- Basic principles of sinusoid oscillators
- Oscillators using Op amp and RC
- Bistable Multivibrators
- Square and triangular wave generators
Why Signal Generators?

- Timing clock for computers and control systems
- Information carriers for communication systems
- Testing and characterizing electronic devices and circuits
What Signal Generators?

- Signals are usually periodic.
- For examples
  - Sinusoidal signals --- the basic and most widely used signals
  - Square waves
  - Triangular waves
  - Pulses
There are two approaches to generate signals:

- Linear oscillators
  an amplifier plus a frequency selective positive feedback network

- Nonlinear oscillators using multivibrators
Principles of Sinusoidal Generators

- Amplifier A
- Frequency selective network B
The system is described by the following equation:

\[ Y(s) = A(s)[X(s) + Y(s)B(s)] \]

Therefore

\[ T(s) = \frac{Y(S)}{X(S)} = \frac{A(S)}{1 - A(s)B(s)} \]
The output is given by

\[ Y(s) = T(s)X(s) \]

It is desired that the system generate sinusoidal signal with frequency \( \omega_0 \) when there is no input \( X(s)=0 \). This implies that the transmission function is infinity at \( \omega_0 \)

\[
T(j\omega_0) = \frac{A(j\omega_0)}{1 - A(j\omega_0)B(j\omega_0)} \rightarrow \infty
\]

or

\[
1 - A(j\omega_0)B(j\omega_0) = 0 \Rightarrow A(j\omega_0)B(j\omega_0) = 1
\]
The condition is called the **Barkhausen criterion**

\[ A(j\omega_0)B(j\omega_0) = 1 \quad \implies \quad \left| A(j\omega_0)\right|\left| B(j\omega_0)\right| e^{j[\phi_A(j\omega_0)+\phi_B(j\omega_0)]} = 1 \]

- The phase of the loop gain is zero
  \[ \phi_A(j\omega_0) + \phi_B(j\omega_0) = 0 \]
- The magnitude of the loop gain is unity
  \[ \left| A(j\omega_0)\right|\left| B(j\omega_0)\right| = 1 \]
How to get a more pure sinusoidal wave?

\[ \phi_A(j\omega_0) + \phi_B(j\omega_0) = 0 \]

\[ |A(j\omega_0)||B(j\omega_0)| = 1 \]
Nonlinear Amplitude Control

- Initially $|AB|$ should be slightly greater than 1, so that oscillation magnitude will grow when power is turned on; when the magnitude reaches the desired level, the loop gain to be reduced to exactly unity;
- In other word, the loop gain should be non-linearly dependent on the output magnitude. This can be achieved by inserting a nonlinear network into the feedback path;
- A popular nonlinear network is limiter circuit;
- The nonlinear network will cause some distortion to the waveform. The distortion will be eliminated by frequency selective network in the feedback loop.
Principles of Signal Generators

(a)

Slope \( \frac{R_1}{R_2} \)

(b)

Slope \( \frac{R_1}{R_1} \)

(c)

Slope \( \frac{R_3}{R_1} \)

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Op Amp - RC Oscillator Circuit
Op Amp - RC Oscillator Circuit

\[ L(s) = A(s)B(s) = \left(1 + \frac{R_2}{R_1}\right) \frac{Z_p}{Z_p + Z_s} = \frac{1 + R_2 / R_1}{3 + sCR + 1 / sCR} \]

\[ L(j\omega) = \frac{1 + R_2 / R_1}{3 + j(\omega CR - 1 / \omega CR)} \]

Firstly, the phase should be zero:

\[ \omega_0 CR = \frac{1}{\omega_0 CR} \]

Then, loop gain be 1, therefore:

\[ R_2 / R_1 = 2 \]
Op Amp - RC Oscillator Circuit:
Wien-Bridge
The resistance between a and b decreases with the voltage across them.
The circuit will oscillate at the frequency for which the phase shift of the RC network is 180 degree.

Three is the minimum number of RC sections capable of producing 180 degree phase shift for any high frequency.
Phase Shifter Oscillator
The Quadrature Oscillator

\[ L(s) = \frac{V_{02}}{V_x} = -\frac{1}{s^2C^2R^2} \]

\[ \omega_0 = \frac{1}{CR} \]
Active Filter Tuned Oscillator
Active Filter Tuned Oscillator
A bistable circuit has two stable output states: Positive saturation or negative saturation.

A physical analogy for the operation of the bistable circuit.
When $v_i$ increases

When $v_i$ decreases
Bistable Multivibrators

The output will remain either as L+ or L+ when \(-V_{TH} < V_i < V_{TH}\).

When the output is L+, a input voltage higher than \(V_{TH}\) will force the output to L-;

When the output is L-, a input voltage lower than \(-V_{TH}\) will force the output to L+;

Therefore the state can be changed by pulse signals with amplitude larger than the \(V_{TH}\).
Bistable Multivibrators

Triggering signal

Output signal
Bistable Multivibrators

Noninverting Transfer Characteristics
Square Wave Generator
Using Astable Multivibrators

Fig. 12.24
Square Wave Generator
Using Astable Multivibrators
Triangular Wave Generator
Using Astable Multivibrators
Monostable Multivibrator: Pulse Generator

- Aim: To generate a pulse with known height and width in response to a trigger signal.
Monostable Multivibrator: Pulse Generator
Monostable Multivibrator: Pulse Generator

- **Operation mechanism:** \( \beta = \frac{R_1}{(R_1 + R_2)} \)

- **What are the steady states (select R4>>R1)?**
  - Assume \( V_A = L_+ \). \( V_c = \beta L_+ \). D1 is conducting. D2 is also conducting and so \( V_B = 0.7v \). We can R1 and R2 and R3, such that \( V_c \) is lower than \( V_B \). Hence this can be a stable state.
  
  - When \( V_A = L_- \), D2 is cut off and so \( V_c = \beta L_- \). D1 is cut off and C1 will discharge through R3 and therefore \( V_B \) will decrease toward \( V_b = L_- \). When \( V_B < V_c \), the op-amp change the state.

- Therefore the circuit only has one stable state.
Operation mechanism:

- Suppose $V_A = L+$, and a negative-going step applied at triggering input;
- $V$ will follow the drop and $D2$ will conduct and $V_C$ will be pulled down. If the triggering low edge is low enough $V_C$ can be lower than $V_B$, and this will make $V_A = L-$;
- When $V_A = L-$, $D2$ is cut off and so $V_C = bL-$. $D1$ is cut off and $C1$ will discharge through $R3$ and therefore $V_B$ will decrease toward $V_b = L-$. When $V_B < V_C$, the op-amp change the state.
- The duration when $V_A$ stays in $L-$ will depend on the discharging time constant $C1R3$. 

$$\beta = \frac{R_1}{(R_1 + R_2)}$$
What is the width of the pulse?

- The initial $V_B$ is $V_{D1}$ (0.7v). When $V_A=L_-$, the steady state for $C1$ to discharge via $R3$ is $L_-$, and therefore

$$V_B = L_- -(L_- - V_{D1})e^{-t/(C_1R_3)}$$

- The op amp will flip when $V_B > V_C$

$$V_B(T) = \beta L_- = L_- -(L_- - V_{D1})e^{-T/(C_1R_3)}$$

$$T = C_1R_3 \ln \left( \frac{V_{D1} - L_-}{\beta L_- - L_-} \right) \approx C_1R_3 \ln \left( \frac{1}{1-\beta} \right)$$