Rectifier Circuits

Simplist rectifier:

Vin \rightarrow \text{Vout} \rightarrow R_L

Vin vs. Vout:

\begin{align*}
\text{Vin} & \quad \uparrow \quad \text{Vout} \\
0.7 & \quad \downarrow
\end{align*}

- Assume diode has ideal I-V curve:
  \text{Vout} \quad \text{Id}

- Actually exponential

Half-wave rectifier:
- Works fine if inputs are \geq 0.7 V.
- Some applications dealing with small input voltages require a different approach (as in lecture 5).

Improved version: the "superdiode"

- Use an opamp to reduce the offset voltage by a factor equal to the open-loop gain of the op-amp.

\begin{align*}
\text{Vin} & \quad \uparrow \quad \text{Vout} \\
\text{Vout} & \quad \downarrow
\end{align*}

- Initially \text{Vin} = \text{Vout} = 0.
- Consider 2 cases:

1. \text{Vin} goes positive
   - When \text{Vin} = 0.7 V, \text{Vout} = 0.7 V, so diode starts to conduct:

\begin{align*}
\text{Vin} & \quad \uparrow \quad 0.7 V \\
\text{Vout} & \quad \downarrow
\end{align*}

- Voltage follower so \text{Vin} = \text{Vout}.
- \text{Vout} is 0.7 V above the output voltage.

2. \text{Vin} goes negative
   - Opamp drives \text{Vout} negative, diode shuts off, open-circuit:

\begin{align*}
\text{Vin} & \quad \uparrow \quad \text{Vout} \\
\text{Vout} & \quad \downarrow
\end{align*}

- \text{Vout} = 0 V (pulled to 0 by \text{RL})
- Opamp is open-loop, \text{Vout} is driven into negative saturation of the op-amp.

\rightarrow Transfer Characteristic:

\begin{align*}
\text{Vin} & \quad \uparrow \quad \text{Vout} \\
0.7 & \quad \downarrow
\end{align*}

\text{Vin} \leq 0.7 \text{ V}

\leq 1 \text{ mV}
- Drawback of the "speed-dialer" is that for negative \( V_{in} \), op-amp enters saturation, can be slow to return to normal operation. This limits the input frequency range for which this will operate.

To avoid this, we can modify the circuit as follows:

- Familiar circuit symbol.

Again consider two cases:

1. \( V_{in} \) goes positive:
   - Op-amp output goes negative, turning off \( D_2 \).
   - Feedback channel as virtual ground at negative input.
   - Op-amp output is at \(-0.7\,\text{V}\), so \( D_2 \) is off.

\[ V_{out} = 0\,\text{V} \]

- Op-amp output is pinned at \(-0.7\,\text{V}\), avoiding saturation problem.

2. \( V_{in} \) goes negative:
   - Op-amp output goes positive, turning off \( D_2 \), turning on \( D_1 \).
   - \( D_1 \) allows feedback through \( R_2 \), leading to virtual ground at op-amp input, no inverting op-amp configuration.

\[ V_{out} = -\frac{R_2}{R_1} \cdot V_{in} \]

for \( R_2 = R_1 \)

- Transfer characteristic:

- Oscillators:

- Basic oscillator structure. (Oh no! More feedback!)

\[ X_0 \quad + \quad \begin{array}{c} \text{A} \\ \text{(Freq. selective)} \end{array} \quad \rightarrow \quad X_0 \]

- In the amplifier feedback circuits, we had -ve feedback, avoiding the case where \( \angle \alpha = 180^\circ \), since it resulted in +ve feedback.

- Here we want positive feedback to obtain oscillation.
Recall that if $A\beta = 180^\circ$ we have positive feedback.
- Due to freq. dependence of $A$ & $\beta$, this will occur at a specific freq., which will be the freq. of oscillation.
- Must also consider $|A\beta|$.

Three Cases:

1. $|A\beta| < 1$: Gain around the loop is less than one, any oscillation will die out. This is the case with feedback amplifiers.

2. $|A\beta| = 1$: Gain around the loop is unity, we can remove input & signal will continue to propagate around the loop.
   - Sustained oscillation (what we want).

3. $|A\beta| > 1$: Signal grows as it moves around the loop.
   - Growing oscillation
   - At some point the loop gain will be reduced due to non-linearity, and we will settle into case (2).

If we design for case (2), any variation due to temperature, etc. could result in our circuit not starting oscillation.

Design for case (3), so for small oscillations the loop gain will be $>1$, oscillating grows until we have case (2) due to non-linearity.

Conditions for sustained oscillation are formally defined as the:

\[ |A(j\omega)\beta(j\omega)| = 1, \quad \angle A(j\omega)\beta(j\omega) = 180^\circ \]

(for negative feedback, $\theta^\circ$ for positive feedback).