Hysteresis Modulator

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Instead of using an externally generated triangle wave, as is typically done for PWM modulation, a self-oscillating hysteresis modulator makes use of the switching waveform generated at the output, in conjunction with an integrator, to provide a triangular waveform to feed to a comparator.

It also utilizes the effective delay in the feedback loop, provided by hysteresis, for setting the self-oscillation frequency. The basic circuit consists of an integrator and a comparator with feedback taken directly from the switching node (i.e. before the output filter).

Advantages

- Potential for high loop gain allows for good THD+N, especially at lower audio frequencies
- Instability, a concern with typical amplifiers, is not so much of an issue
  - The amplifier is already an oscillator

Disadvantages

- “Integrator windup” results in overhang, or “rail sticking” following clipping
  - This is generally perceived as very harsh and very abrupt clipping
  - Amplifiers that use this approach often include “soft-clipping” to mask the problem
- Feedback is usually taken from before the output filter
  - Frequency response anomalies due to load variations are not corrected
- Frequency variability
  - More difficult to filter, especially at duty cycle extremes
  - Not as simple to integrate multiple channels

Basic Circuit Diagram

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List of Variables

\(D\) Duty cycle, a value from 0 to 1

\(V_s\) Supply voltage of split \(\pm V_s\) supply

\(f_s\) Switching frequency of amplifier

\(f_0\) Switching frequency at idle

\(L\) Output filter inductance

Other variables are as shown in the basic circuit diagram.

Open-Loop Gain and Switching Frequency

\[
t_H = \frac{R_z C}{2(1-D)} \left( \frac{R_A}{R_A + R_B} \right) \quad \text{period output is high (at } +V_s) \text{ versus } D
\]

\[
t_L = \frac{R_z C}{2D} \left( \frac{R_A}{R_A + R_B} \right) \quad \text{period output is low (at } -V_s) \text{ versus } D
\]

\[
f_s = \frac{2D(1-D)}{R_z C} \left( 1 + \frac{R_B}{R_A} \right) \quad \text{switching frequency versus } D
\]

\[
f_s = 4D(1-D)f_0 \quad \text{where } f_0 \text{ is the frequency at idle (} D=0.5 \text{)}
\]

\[
i_{pk} = \frac{D(1-D)V_s}{f_s L} = \frac{V_s}{4f_0 L} \quad \text{peak circulating current (independent of } D\text{)}
\]

\[A_{OL} = 1 + \frac{R_B}{R_A} \quad \text{open-loop gain}\]

\[A_{CL} = \frac{R_2}{R_1} \quad \text{closed-loop gain}\]