Hysteresis Modulator

Joey White

Hephaestus Audio

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

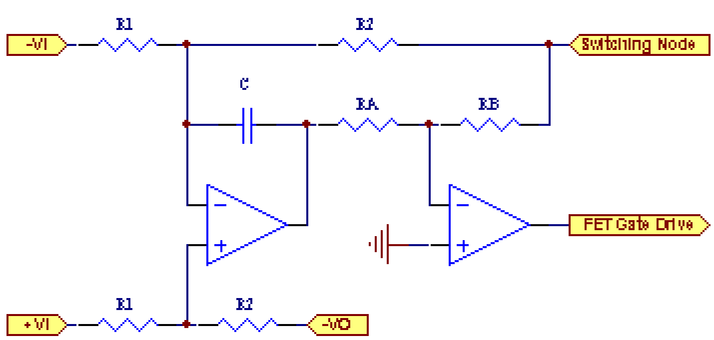
Disadvantages

- "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



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

$$t_H = \frac{R_2 C}{2(1-D)}\left(\frac{R_A}{R_A + R_B}\right)$$ period output is high (at +Vs) versus D

$$t_L = \frac{R_2 C}{2D}\left(\frac{R_A}{R_A + R_B}\right)$$ period output is low (at –Vs) versus D

$$f_S = \frac{2D(1-D)}{R_2 C}\left(1 + \frac{R_B}{R_A}\right)$$ switching frequency versus D

$$f_S = 4D(1-D) f_0$$ where f_0 is the frequency at idle (D=0.5)

$$i_{pk} = \frac{D(1-D)V_S}{f_S L} = \frac{V_S}{4 f_0 L}$$ peak circulating current (independent of D)

$$A_{OL} = 1 + \frac{R_B}{R_A}$$ open-loop gain

$$A_{CL} = \frac{R_2}{R_1}$$ closed-loop gain