1B-09

Adjustable Conversion Voltage Ratio Notch Frequency Generation for Noise Spectrum in Pulse Coding Control Switching Converter

Yifei Sun, Minhtri Tran, Yasunori Kobori, Anna Kuwana, Haruo Kobayashi

Division of Electronics and Informatics, Faculty of Science and Technology, Gunma University, Japan

Research Background

Research Objective

- **Problem**
  Electro-Magnetic Interference (EMI) reduction in electronic circuits is important
- **Focus on**
  Spread noise spectrum in order to reduce EMI

Research Objective

①Spread spectrum：

⇒ EMI reduction & Noise diffusion

②Noise suppression near receive frequency Fin

③Full-automatically generating notch characteristics at the Fin

Research Summary

Proposed method

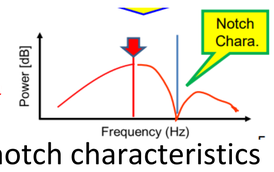
Pulse coding method

Design modulation circuit

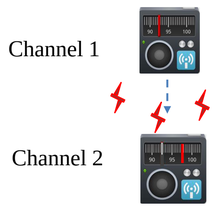
⇒ generate notch frequency automatically

Achievement

① Automatic generation of F_{notch}



② Full-automatically generating notch characteristics



Application

Receive frequency change

⇒ Notch frequency automatically change

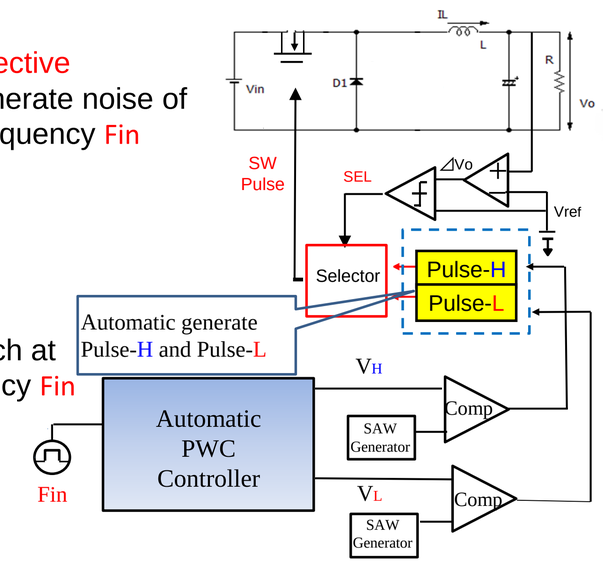
Automatic PWC Control Circuit

Objective

Reduction generate noise of receive frequency Fin

Method

PWC generate notch at receive frequency Fin



Automatic Notch Frequency Generation with Pulse Width Coding Control and Simulation Results

Clock Frequency, Notch Frequency and PWC

The relationship between F_n and F_{ck}

$$NF_{ck} < F_n < (N+1)F_{ck}$$

Optimal

$$F_n = (N+0.5)F_{ck}$$

The relationship between F_n and PWC

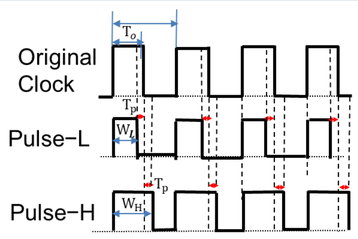
$$F_n \cong N \times \frac{1}{(W_H - W_L)}$$

When N =1

$$T_n \cong (W_H - W_L)$$

W_H and W_L

Generated at the center of the original clock



Timing Chart

$$T_o = D_o \times T_{ck} = \frac{V_o}{V_{in}} \times T_{ck}$$

$$W_L = T_o - T_p$$

$$W_H = T_o + T_p$$

$$T_n = W_H - W_L = 2 \times T_p$$

Generate Pulse-H and Pulse-L Automatically

Generate T_{ck} from T_{in} using

F_{in}=(N+0.5) ▪ F_{ck}

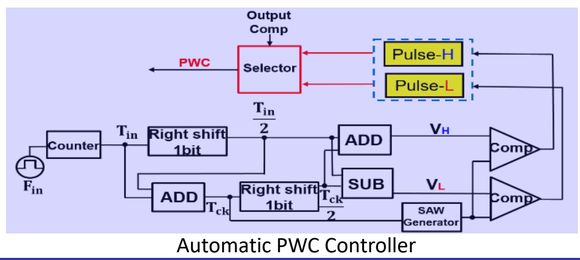
T_{ck}=(N+0.5) ▪ T_{in}

$$W_L = T_o - T_p = D_o \times T_{ck} - \frac{1}{2}T_{in}$$

$$W_H = T_o + T_p = D_o \times T_{ck} + \frac{1}{2}T_{in}$$

$$T_n = 2 \times T_p$$

D_o=0.5 N=1 situation



Automatic PWC Controller

Noise Spectrum of PWM Signal Automatically

$$F_{in} = (N+0.5)F_{ck}$$

N=1 Best position : Fck < Fn < 2Fck

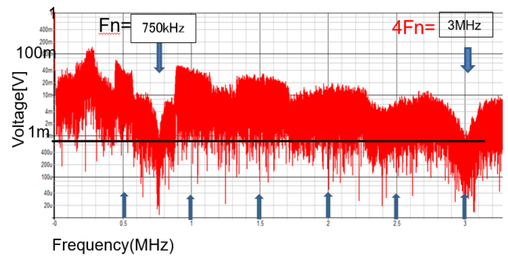
Fin=750kHz ⇒Fck=500kHz （ W_H=1.66μs, W_L=0.29μs）

◎Condition

Buck DC-DC converter
V_{in}：10V
V_{out}：5V
L：200 μH
C：470 μF
I_{out}：0.25A

◎Result

Fn=750kHz
4・Fn=3.0MHz



Simulated spectrum with EMI reduction

Assume to suppress influence on AM in 750kHz

$F_{in} = 750kHz \Rightarrow F_{notch} = 750kHz$

Conversion Voltage Ratio D_o Analysis

Previous discussion

We set $D_o = \frac{V_o}{V_{in}} = \frac{5v}{10v} = 0.5$

Power supply IC

Necessary to automatically detect or set the condition for D_o when V_i change

Because

$$W_L = D_o T_{ck} - \frac{T_{in}}{2}$$

$$W_H = D_o T_{ck} + \frac{T_{in}}{2}$$

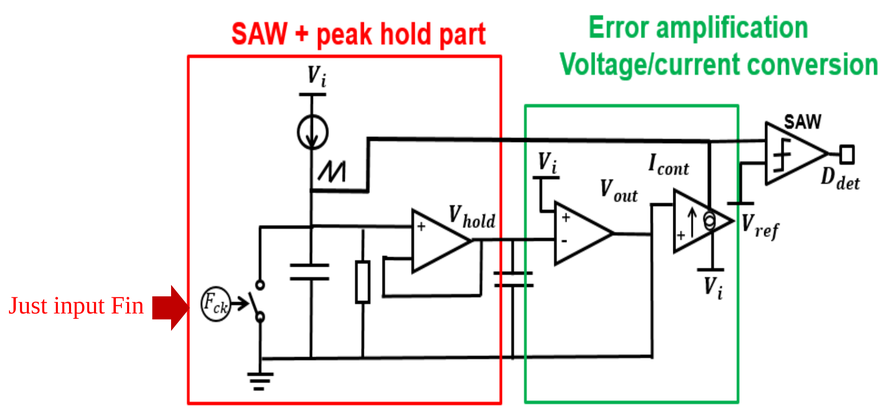
D_o setting method

$$D_o T_{ck} + \frac{T_{in}}{2} < T_{ck} \qquad D_o T_{ck} - \frac{T_{in}}{2} > 0$$

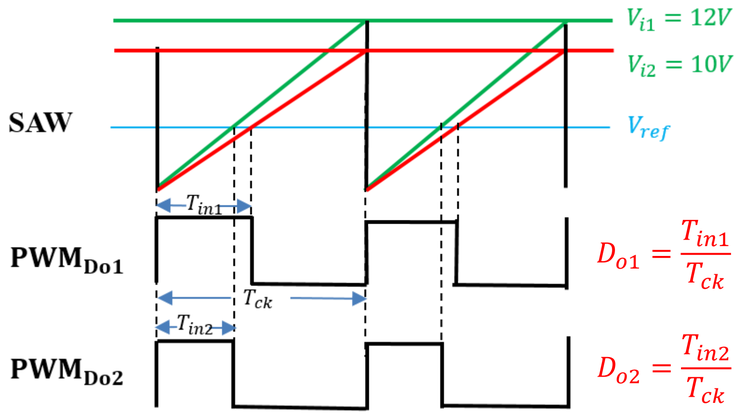
$$0.33 < D_o < 0.67$$

D_o Automatic Detection Method

Just input Fin



Main Signal Waveforms of D_o Detection Method



Generate Pulse-H and Pulse-L

$$W_L = D_o T_{ck} - \frac{T_{in}}{2}$$

$$W_H = D_o T_{ck} + \frac{T_{in}}{2}$$

Simulation Results

Simulated Spectrum with the Full Automatic Method

$$F_{in} = (N+0.5)F_{ck}$$

N=1 Best position : Fck < Fn < 2Fck

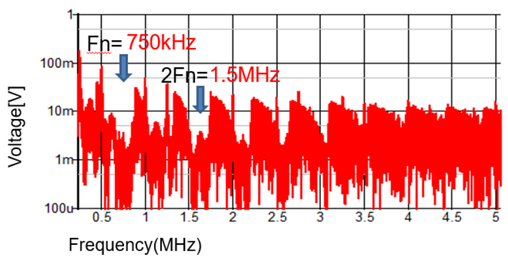
Fin=750kHz ⇒Fck=500kHz

◎Condition

Buck DC-DC converter
V_{in}：15V
V_{out}：5.0V
L：200 μH
C：470 μF
I_{out}：0.25A
D=0.33

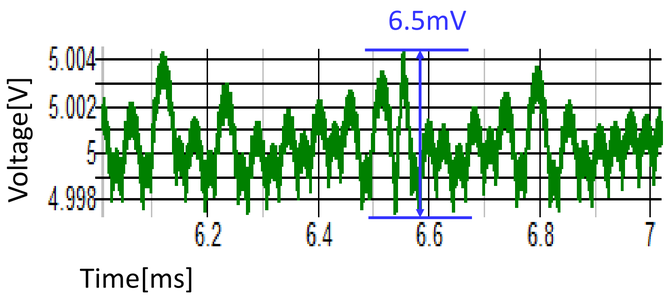
◎Result

Fn=750kHz



Simulated spectrum with the full EMI reduction

Output Voltage Ripple



Ripple is small

Realized the full-automatic notch frequency generation technology

Conclusion

For EMI problem handling in switching power converter

- Developed pulse coding control in order to generate notch characteristics at desired frequency
- Automatic generate the F_{notch} from F_{in}
- Realized the full-automatic notch frequency generation technology by detect conversion voltage ratio Do

Future work

Implementation of automatic PWC control switching converter