P059

Spread Spectrum Technology with Automatic Notch Generation Used for Switching Converter

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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

Spread spectrum:

⇒ EMI reduction & Noise diffusion

Further more

Noise suppression near receive frequency

Research Summary

Proposed method

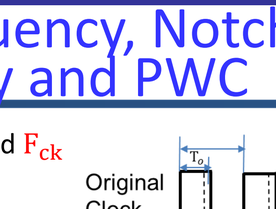
Pulse coding method

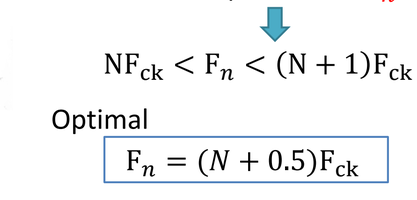
Design modulation circuit

⇒ generate notch frequency automatically

Achievement

① EMI reduction
② Noise removal
③ Automatic generation of F_{notch}

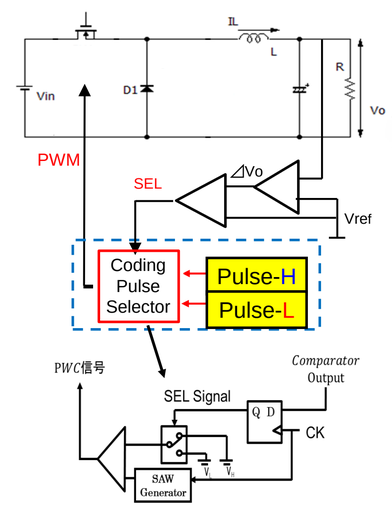


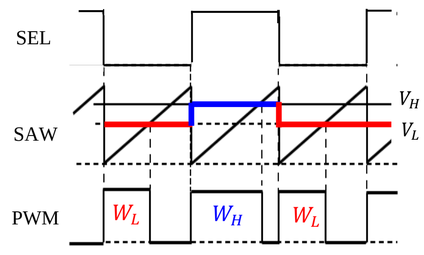


Application

Receive frequency change
⇒ Notch frequency automatically change

Pulse Width Modulation in Switching Converter





Input High
①SEL: High
②MUX select V_H
③Generate pulse with long width in comparator

Input Low
①SEL: Low
②MUX select V_L
③Generate pulse with short width in comparator

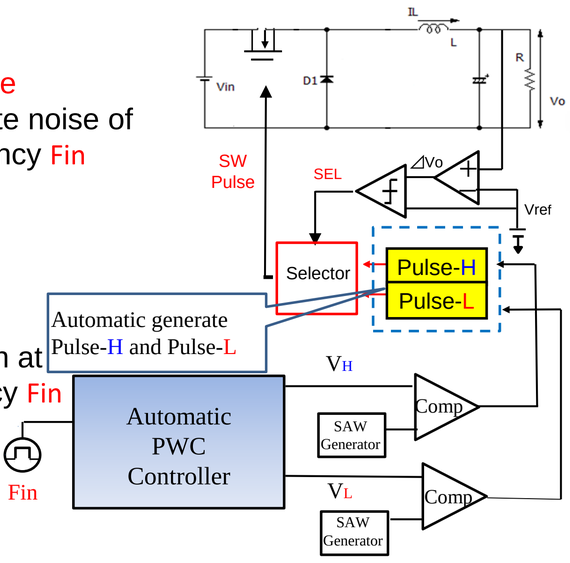
Buck converter with pulse width modulation

Automatic Pulse Width Coding Control

Automatic PWC Control

Objective
Reduction generate noise of receive frequency Fin

Method
PWC generate notch at receive frequency Fin



Clock Frequency, Notch Frequency and PWC

The relationship between F_n and F_{ck}

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

Optimal

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

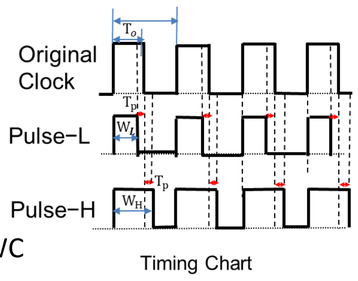
The relationship between F_n and PWC

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

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}

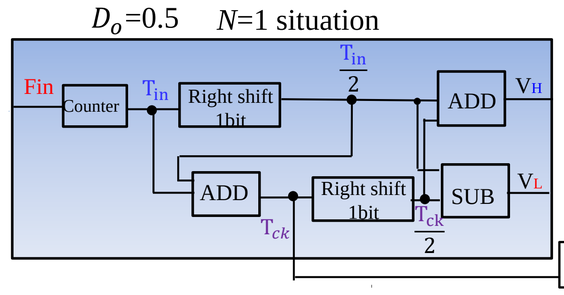
T_{ck}=$(N$+0.5$)$ ・T_{in}

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

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

$T_n = 2 \times T_p$

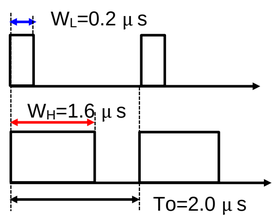
D_o=0.5 N=1 situation



Automatic PWC Controller

Simulation Results

PWC Control

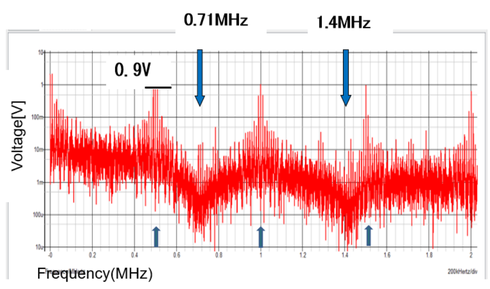


Pulse widths of the coding pulses

★manually set W_L and W_H

Design clock pulse to determine the notch frequency

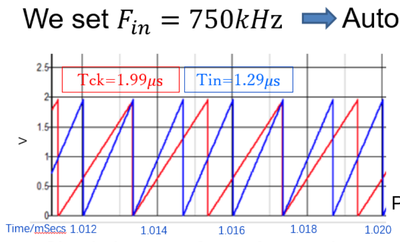
$$F_n \cong N \times \frac{1}{(W_H - W_L)} \quad [N = 1,2,3,\cdots,n]$$
$$= N \times \frac{1}{1.6\mu s - 0.2\mu s} = 0.71\text{MHz}$$



PWM signal spectrum using PWC control

Waveforms of W_H, W_L Generation Automatically

We set $F_{in} = 750kHz$ ⇒ Automatic generated $F_{ck} = 500kHz$



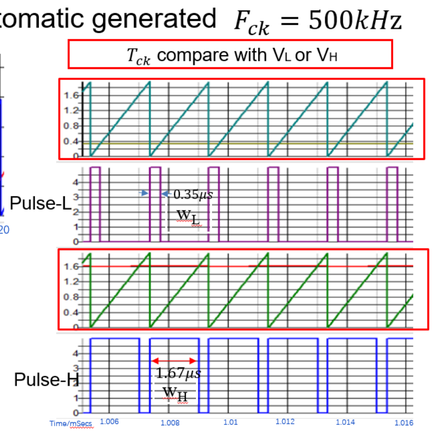
Simulation waveform of T_{ck} and T_{in}

T_{ck}=$(N + 0.5)T_{in} = 1.5T_{in}$

Theoretical formula
W_H= $1.66\mu s$
W_L= $0.29\mu s$

Simulation result
$W_H = 1.67\mu s$
$W_L = 0.35\mu s$

Well matched



Simulation waveforms of W_H and W_L

Noise Spectrum of PWM Signal Automatically

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

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

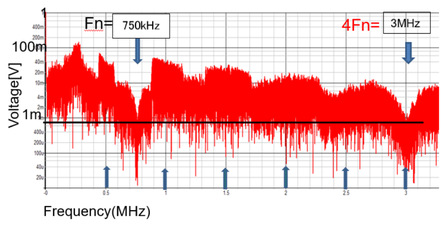
Fin=750kHz ⇒Fck=500kHz （ W_H=1.66μs, W_L=0.29μs）

◎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
$F_{in} = 750kHz$ ⇒$F_{notch} = 750kHz$

Experimental Results

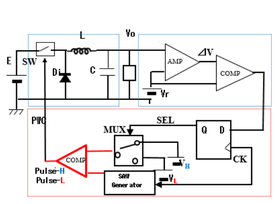
Implementation of PWC Control

Generation of W_H and W_L

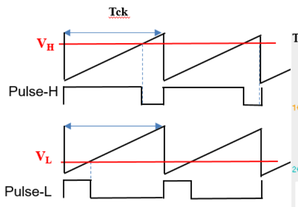
V_o	Op amp output	comparator output	SEL	PWM output	Duty
＞5V	L	L	L	P_L	L
＜5V	H	H	H	P_H	H

◎ Condition

W_H	W_L	f_{notch}
$1.0\mu s$	$0.4\mu s$	1.66MHz



Converter with PWC control



Theoretical PWM signal

Waveform of W_H and W_L

Spectrum of PWC Control

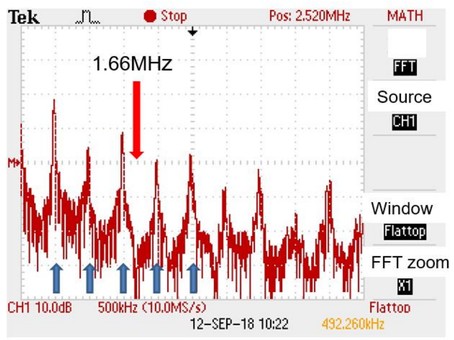
Theoretical formula

$$F_{notch} = \frac{N}{(W_H - W_L)} = \frac{N}{(1.0us - 0.4us)} = 1.66\text{MHz}$$

◎Condition

Buck DC-DC converter
V_{in}：12V
V_{out}：5V
L：22 μH
C：100 μF
I_{out}：0.4A

W_H= $1.0\mu s$
W_L= $0.4\mu s$
f_{clock}=1.66MHz



Notch between $3f_{ck}$ and $4f_{ck}$

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}
- Implementation of PWC control switching converter

Future work

- Notch generation using other pulse coding methods
- Investigate why the large notch at $4F_{notch}$ appear.