



AN139

MP5416

Optimizing Output Voltage Selection

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Application Note

Prepared by MPS Standard DC/DC Product Line

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TABLE OF CONTENTS

ABSTRACT.....3

INTRODUCTION3

OUTPUT VOLTAGE SELECTION GUIDE4

DESIGN EXAMPLE6

ABSTRACT

This application note introduces the operation of the [MP5416](#) clock, constant-on-time (COT) control mode, and discusses the relationship between the output voltage and steady state. This application note also describes how to select an appropriate output voltage for each channel.

This application note optimizes design by allocating V_{OUT} reasonably to ensure that the [MP5416](#) has the best performance.

INTRODUCTION

Operation of the [MP5416](#) Clock

The [MP5416](#) is a complete power management solution that integrates four high-efficiency, step-down, DC/DC converters, five low-dropout regulators, and a flexible logic interface. The [MP5416](#) employs out-of-phase synchronization to minimize the input ripple and reduce interference among each power rail during continuous conduction mode (CCM) operation. From Buck 1 to Buck 4, there is a sequential phase delay between each output (see Figure 1). The clock phase delay is 90° from Buck 1 to Buck 4, Buck 4 to Buck 2, Buck 2 to Buck 3, and Buck 3 to Buck 1. The steady state is made stable by using out-of-phase synchronization (see Figure 2).

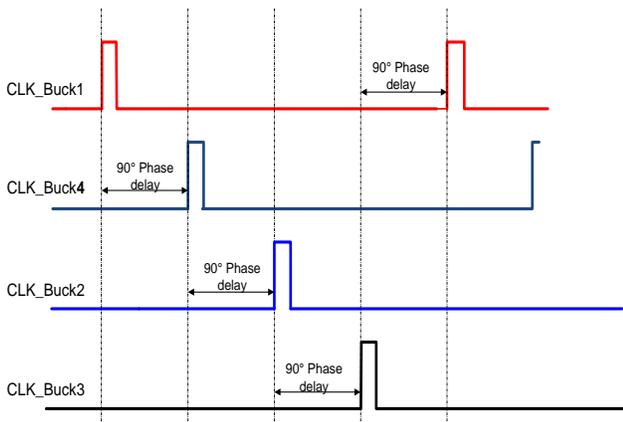


Figure 1: [MP5416](#) Clock Sequence

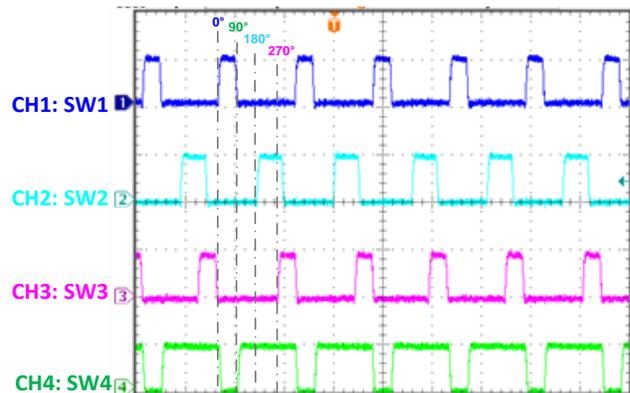


Figure 2: [MP5416](#) Steady State Waveform

Control Method of the [MP5416](#)

The [MP5416](#) adopts a constant-on-time (COT) control scheme to achieve reduced output overshoot and undershoot during load transient. The COT buck circuit diagram is shown in Figure 3. The feedback (FB) reference voltage (V_{REF}) is compared against $FB + V_{RAMP}$. The regulator turns on for a period (T_{ON}) when $FB + V_{RAMP} < V_{REF}$. V_{RAMP} is proportional to the output voltage, as shown in Equation (1):

$$V_{RAMP} = \frac{1-D}{R4 * C4} \cdot V_{out} \cdot t_{sw} \quad (1)$$

Where t_{sw} is the switching period, D is the duty cycle period, and R4 and C4 refer to components in Figure 3.

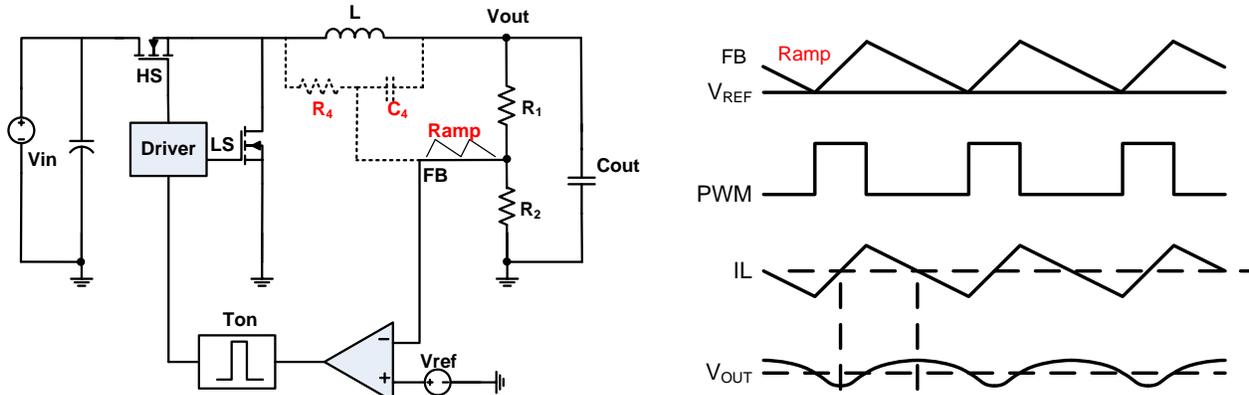


Figure 3: Circuit Diagram of COT Control and Operational Signal Diagram

OUTPUT VOLTAGE SELECTION GUIDE

COT control depends on the ramp of FB crossing V_{REF} to stabilize the system. Therefore, the ramp on FB should be large enough to reduce the jitter induced by the FB noise.

At T_0 , the SW1 falling edge is close to the SW4 rising edge. The SW1 falling edge may couple a negative voltage spike to Buck 4's FB signal. If this noise is larger than the ramp on FB4, Buck 4 SW4 will be turned on falsely. This can result in jitter on SW4 (see Figure 4).

To ensure proper phase-shift operation and to avoid interference, the falling switch node edge of regulator A can be delayed minimally from the rising switch node edge of regulator B if the V_{RAMP} signal of regulator B is sufficiently large. This implies that the output voltage of regulator B must be large enough to minimize interference.

If swapping the output voltages of Buck 2 and Buck 4, change the Buck 4 output voltage from 1V to 2.5V. For a 2.5V output voltage, the V_{RAMP} amplitude is larger. With the same FB voltage noise coupling, the Buck 4 stability will not be affected (see Figure 5).

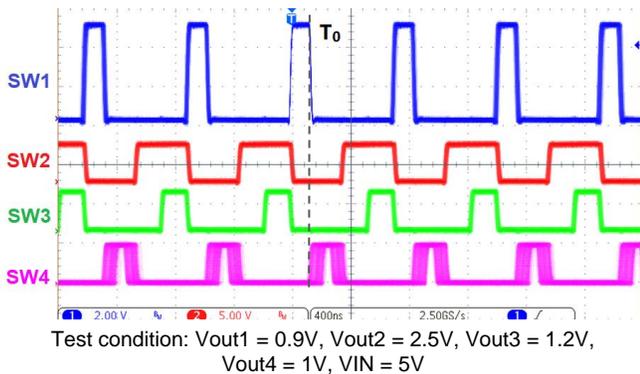


Figure 4: Unstable Waveform

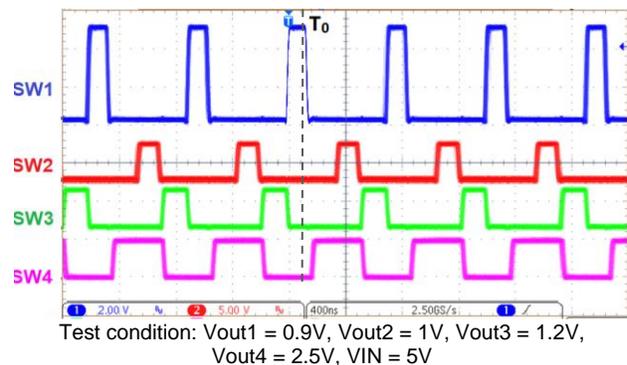


Figure 5: Stable Waveform

The [MP5416](#) output voltage selection Excel file can help users properly determine the output voltage selection for each buck converter. Please contact an MPS FAE for this Excel file or download it from the MPS website.

The image of the [MP5416](#) output voltage selection excel file is shown in Figure 6.

Notes:
 1. The SW operation frequency is 1.5MHz.
 2. Please choose the output voltage by the Filter Button, DO NOT fill out it.

ID	Buck1	Buck2	Buck3	Buck4	Result	Comment
1	0.9	0.9	0.9	1.2	OK	
2	0.9	0.9	0.9	1.3	OK	
3	0.9	0.9	0.9	1.5	OK	
4	0.9	0.9	0.9	2.5	OK	
5	0.9	0.9	0.9	3.3	OK	
6	0.9	0.9	1	1.2	OK	
7	0.9	0.9	1	1.3	OK	
8	0.9	0.9	1	1.5	OK	
9	0.9	0.9	1	2.5	OK	
10	0.9	0.9	1	3.3	OK	
11	0.9	0.9	1.1	1.2	OK	
12	0.9	0.9	1.1	1.3	OK	
13	0.9	0.9	1.1	1.5	OK	
14	0.9	0.9	1.1	2.5	OK	
15	0.9	0.9	1.1	3.3	OK	
16	0.9	0.9	1.2	1.2	OK	
17	0.9	0.9	1.2	1.3	OK	
18	0.9	0.9	1.2	1.5	OK	

5Vin 3.3Vin

Figure 6: MP5416 Output Voltage Selection Excel File

Users can use the MP5416 I²C GUI to program the IC. This GUI cannot be used to filter the output voltage. The image for the [MP5416](#) I²C GUI is shown in Figure 7.

MP5416-5V POWER MANAGEMENT IC WITH I2C NO LOCKED V1.2

Part Numbers Debug Tool Help OTP

ADDRESS: 69

REGISTER CONTROL:
 BUCKCONTROL
 LDOCTRL
 SYSCtrl

REGISTER	HEX	D7	D6	D5	D4	D3	D2	D1	D0
CTL0(0x0)	8F	1	0	0	0	1	1	1	1
CTL1(0x1)	87	1	0	0	0	0	1	1	1
CTL2(0x2)	7F	0	1	1	1	1	1	1	1
ILIMIT(0x3)	AA	1	0	1	0	1	0	1	0
VSET1(0x4)	C0	1	1	0	0	0	0	0	0
VSET2(0x5)	9C	1	0	0	1	1	1	0	0
VSET3(0x6)	C0	1	1	0	0	0	0	0	0
VSET4(0x7)	E4	1	1	1	0	0	1	0	0
VSET5(0x8)	DC	1	1	0	1	1	1	0	0
VSET6(0x9)	28	0	0	1	0	1	0	0	0
VSET7(0xa)	A8	1	0	1	0	1	0	0	0
VSET8(0xb)	54	0	1	0	1	0	1	0	0
Status1(0xd)	BF	1	0	1	1	1	1	1	1
Status2(0xe)	0	0	0	0	0	0	0	0	0
Status3(0xf)	0	0	0	0	0	0	0	0	0
ID2(0x11)	80	1	0	0	0	0	0	0	0

read all

Figure 7: [MP5416](#) I²C GUI

DESIGN EXAMPLE

Customer Specs ⁽¹⁾:

- VIN: 5V (typ)
- VOUT1: 0.9V@1.24A (typ), 1.55A (max)
- VOUT2: 2.5V@300mA (typ), 375mA (max)
- VOUT3: 1.2V@700mA (typ), 900mA (max)
- VOUT4: 1.0V@220mA (typ), 280mA (max)

Using the [MP5416](#) Output Voltage Selection Excel File

Open the output voltage selection Excel file. Navigate to the 5Vin sheet and choose the output voltage using the filter button. Users do not need to choose the V_{OUT} of each buck sequentially with this Excel file. If the desired voltage combination cannot be found, this means that this option is not recommended.

The customer specs above are not in the [MP5416](#) output voltage selection Excel file (see Figure 8).

Notes:							
1. The SW operation frequency is 1.5MHz.							
2. Please choose the output voltage by the Filter Button, DO NOT fill out it.							
ID	Buck1	Buck2	Buck3	Buck4	Result	Comment	
193	0.9	2.5	0.9	3.3	OK		
194	0.9	2.5	1	3.3	OK		
195	0.9	2.5	1.1	3.3	OK		
196	0.9	2.5	1.2	3.3	OK		
197	0.9	2.5	1.3	2.5	OK		
198	0.9	2.5	1.3	3.3	OK		
199	0.9	2.5	1.5	2.5	OK		
200	0.9	2.5	1.5	3.3	OK		
1486							
1487							
1488							
1489							
1490							

Figure 8: No 1.0V Buck 4 Option in the Output Selection Excel File

If swapping the output voltages of Buck 2 and Buck 4, this voltage combination is one of the options in the Excel file (see Figure 9).

Notes:							
1. The SW operation frequency is 1.5MHz.							
2. Please choose the output voltage by the Filter Button, DO NOT fill out it.							
ID	Buck1	Buck2	Buck3	Buck4	Result	Comment	
48	0.9	1	1.2	1.2	OK		
49	0.9	1	1.2	1.3	OK		
50	0.9	1	1.2	1.5	OK		
51	0.9	1	1.2	2.5	OK		
52	0.9	1	1.2	3.3	OK		

Figure 9: Recommended Option in the Output Selection Excel File

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