MP5416
Optimizing Output Voltage Selection

Application Note

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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).

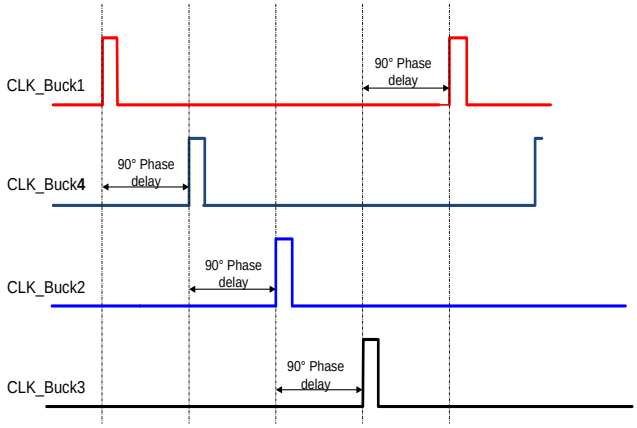


Figure 1: MP5416 Clock Sequence

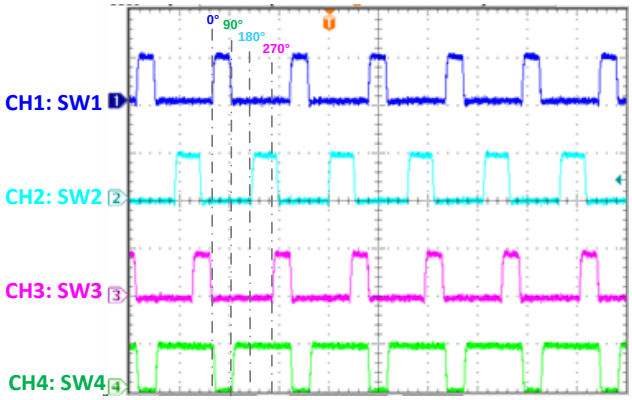


Figure 2: MP5416 Steady State Waveform

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):

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

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

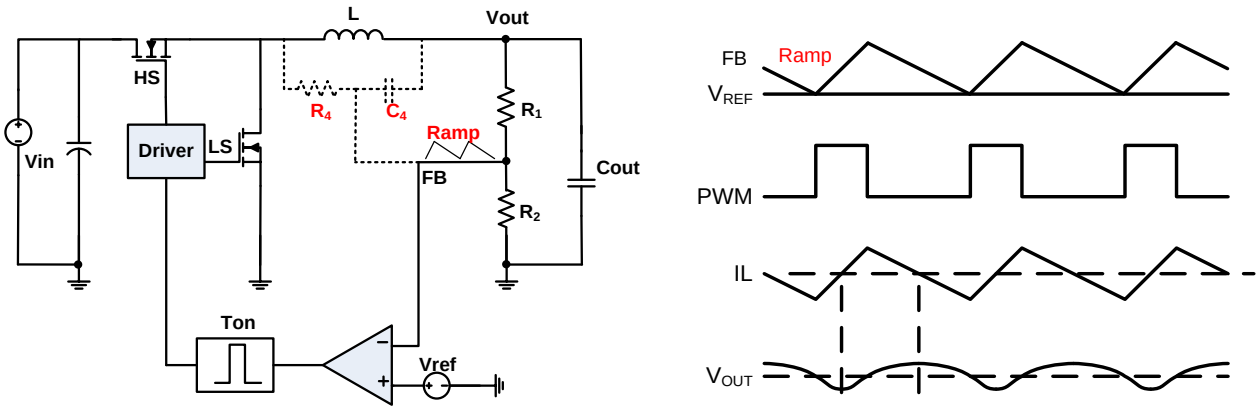


Figure 3: Circuit Diagram of COT Control and Operational Signal Diagram

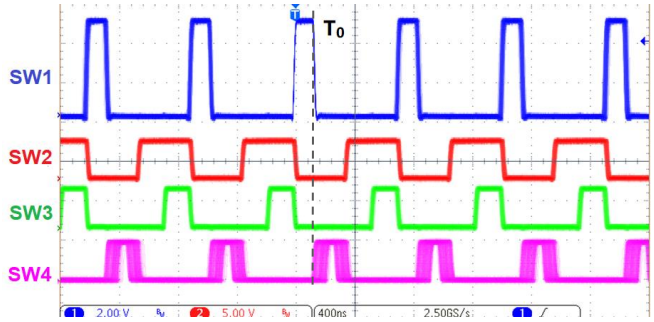
OUTPUT VOLTAGE SELECTION GUIDE

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).

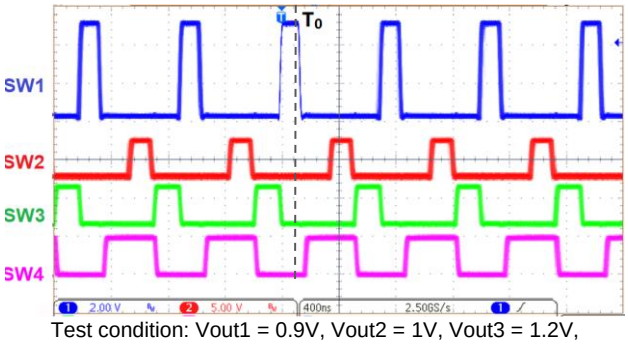
To ensure proper phase-shift operation and to avoid interference, the falling switch node edge of regulator A can be delayed minimally from the rising switch node edge of regulator B if the V_{RAMP} signal of regulator B is sufficiently large. This implies that the output voltage of regulator B must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



Test condition: Vout1 = 0.9V, Vout2 = 2.5V, Vout3 = 1.2V, Vout4 = 1V, VIN = 5V

Figure 4: Unstable Waveform



Test condition: Vout1 = 0.9V, Vout2 = 1V, Vout3 = 1.2V, Vout4 = 2.5V, VIN = 5V

Figure 5: Stable Waveform

The MP5416 evaluation GUI and 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 GUI and Excel file. In the future, they will be available on 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

The MP5416 evaluation GUI is only for users to filter the appropriate output voltage in the pre-design period. The GUI cannot program the IC. The image for the MP5416 evaluation GUI is shown in Figure 7.

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 8.

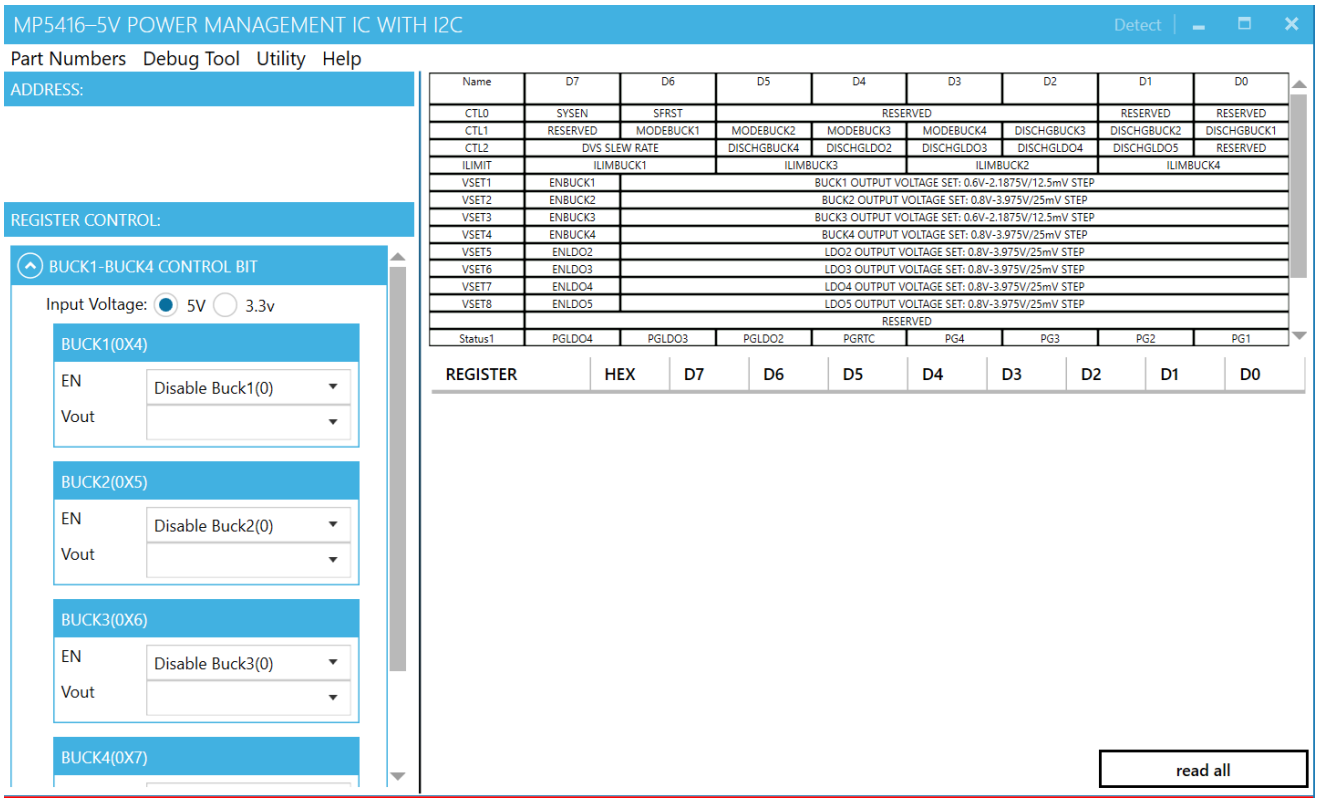
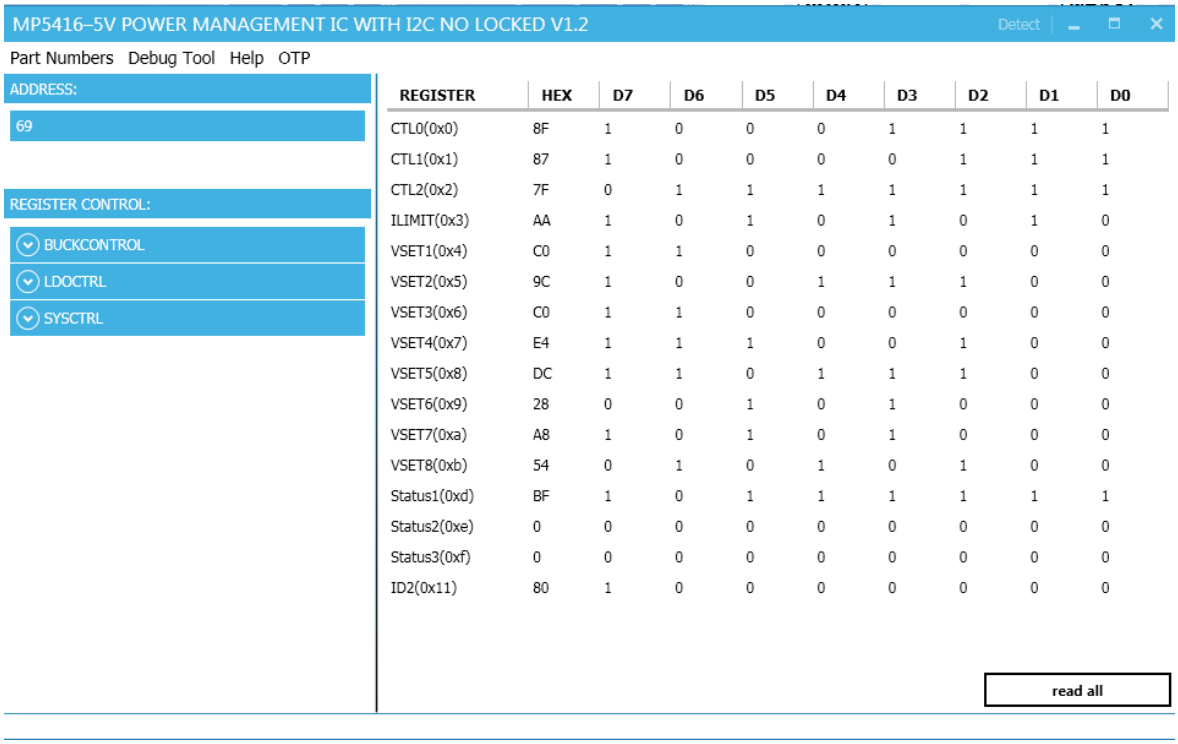


Figure 7: MP5416 Evaluation GUI



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

Figure 8: 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 Evaluation GUI

Open this GUI .exe file and install it on your computer. Open the software and follow the operation steps below to check output voltage options.

Step1: Select the part number (MP5416).

Step2: Click on the Buck 1 - Buck 4 control bit.

Step3: Choose input voltage (5V).

Step4: Check available voltage options for each buck (2)

Select VOUT1 to 0.9V, VOUT2 to 2.5V, and VOUT3 to 1.2V. There is no 1.0V option when selecting VOUT4 (see Figure 9). This means the specs above are not recommended, and the test waveform in Figure 4 shows that the steady state at these specs is unstable.

If swapping the output voltages of Buck 2 and Buck 4, change the Buck 4 output voltage from 1V to 2.5V. The steady state waveform is stable (see Figure 5), and the evaluation GUI also has this option (see Figure 10).

NOTES:

1) These settings are not optimized.
2) The V_{OUT} of each buck must be selected sequentially. For example, after the V_{OUT} of Buck 1 is selected, then the V_{OUT} of Buck 2 can be selected. This cannot be done in reverse.

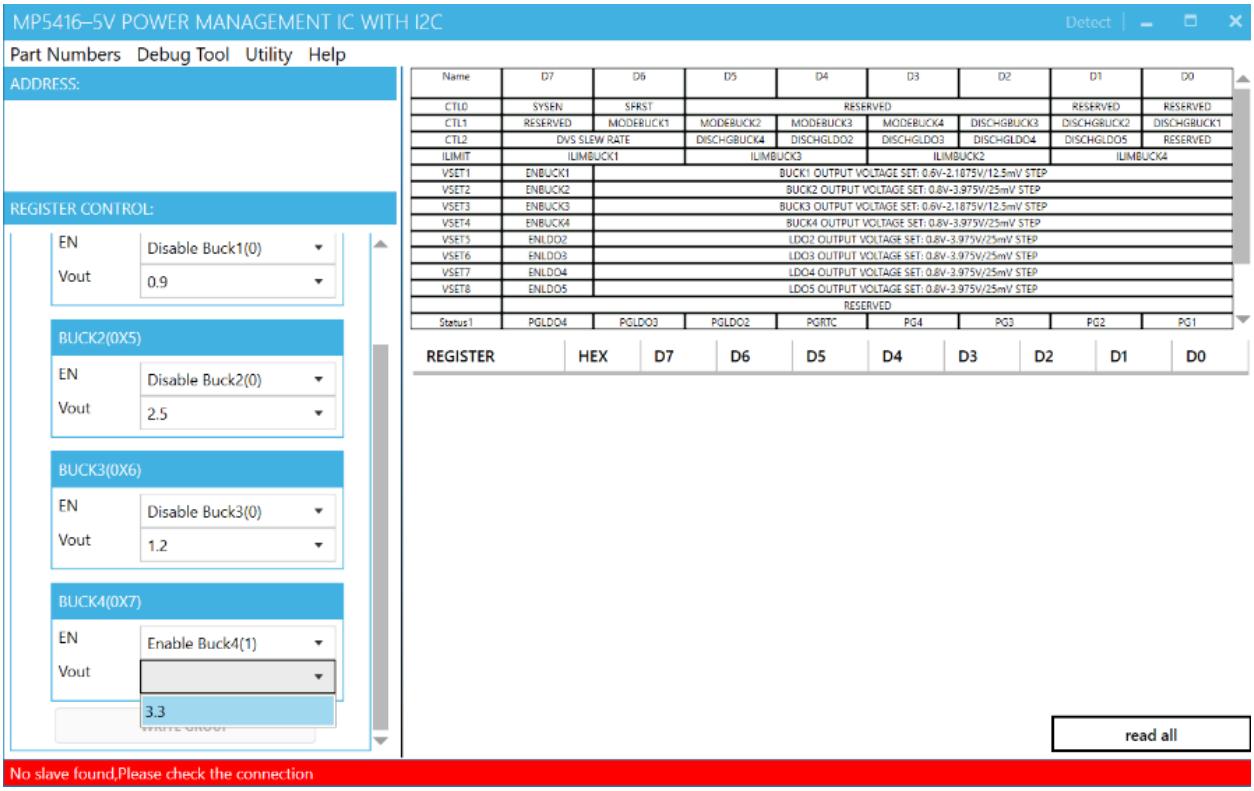


Figure 9: No 1.0V Vout 4 Option in the Evaluation GUI

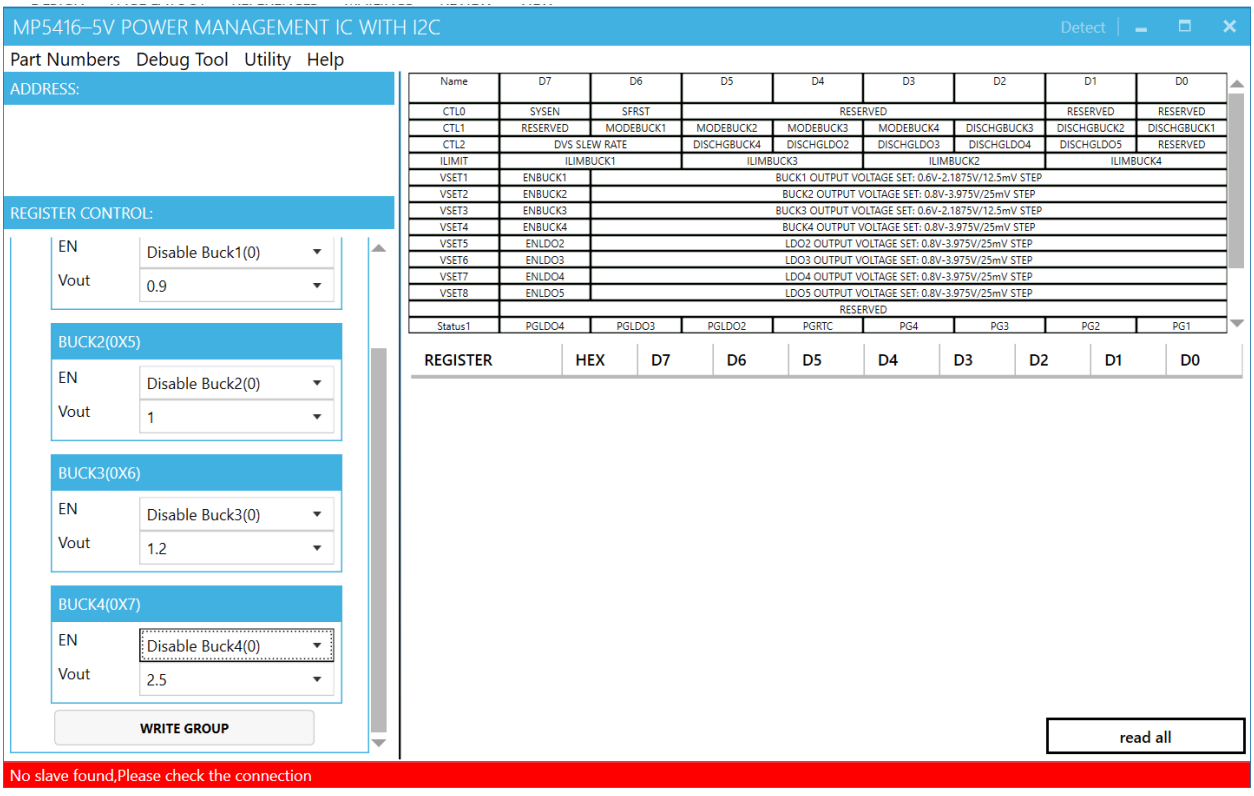


Figure 10: Recommended Option in the Evaluation GUI

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 11).

1		Notes: 1. The SW operation frequency is 1.5MHz. 2. Please choose the output voltage by the Filter Button, DO NOT fill out it.					
2	ID	Buck1	Buck2	Buck3	Buck4	Result	Comment
195	193	0.9	2.5	0.9	3.3	OK	
196	194	0.9	2.5	1	3.3	OK	
197	195	0.9	2.5	1.1	3.3	OK	
198	196	0.9	2.5	1.2	3.3	OK	
199	197	0.9	2.5	1.3	2.5	OK	
200	198	0.9	2.5	1.3	3.3	OK	
201	199	0.9	2.5	1.5	2.5	OK	
202	200	0.9	2.5	1.5	3.3	OK	
1486							
1487							
1488							
1489							
1490							

Figure 11: 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 12).

1		Notes: 1. The SW operation frequency is 1.5MHz. 2. Please choose the output voltage by the Filter Button, DO NOT fill out it.					
2	ID	Buck1	Buck2	Buck3	Buck4	Result	Comment
50	48	0.9	1	1.2	1.2	OK	
51	49	0.9	1	1.2	1.3	OK	
52	50	0.9	1	1.2	1.5	OK	
53	51	0.9	1	1.2	2.5	OK	
54	52	0.9	1	1.2	3.3	OK	

Figure 12: Recommended Option in the Output Selection Excel File