Automotive Power and Motor Drive

40V Max Stepping Motor Driver for Automotive BD63800MUF-C Application Note

The ROHM BD63800MUF-C is an AEC-Q100 automotive qualified bipolar low-consumption stepping motor driver that is driven by PWM current. It is suitable for Automotive applications such as LED Headlight, Heat pump, Intake Air Control Valve and Head-up Display. This document describes how to design the external circuit and PCB layout in order to operate the stepping motor safety and efficiency. Moreover, it guides standard start up sequence how to set parameter for stall detection and decay mode simply with some attentions.

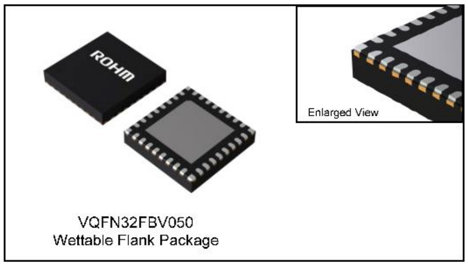
● Specifications:

BD63800MUF-C operates with single power supply which can simplify the set design.

- Absolute maximum supply voltage ……...…………………. 40 V
- Recommended operating supply voltage range…………….6.0 to 28 V
- Output Current Rating (peak) …..……………………………1.35 A (Note1)

  (Note1) Pulse width tw ≤ 1 ms, duty 20 %
- Output Current Rating (DC) …..…………………..............1.20 A
- Output On Resistance (Total of upper and lower side) ....0.75 Ω
- VCC quiescent supply current (max) ………………………..10 μA

Package	W(Typ) x D(typ) x H (Max)
VQFN32FBV050	5.0mm x 5.0mm x 1.0mm



● Features

- CLK-IN and SPI-IN Drive mode
- Supported stepping Modes: Full step, 1/2, 1/4, 1/8, 1/16 and 1/32 step
- Current Decay Mode Switch Function: Fast, Slow, Mix, Auto
  - Mix Decay: Linear Adjustment of Slow Decay and Fast Decay Ratio with external pin.
  - Auto Decay: Automatic Switch of Slow Decay and Fast Decay.

  Further features and protections are referred to the datasheet.

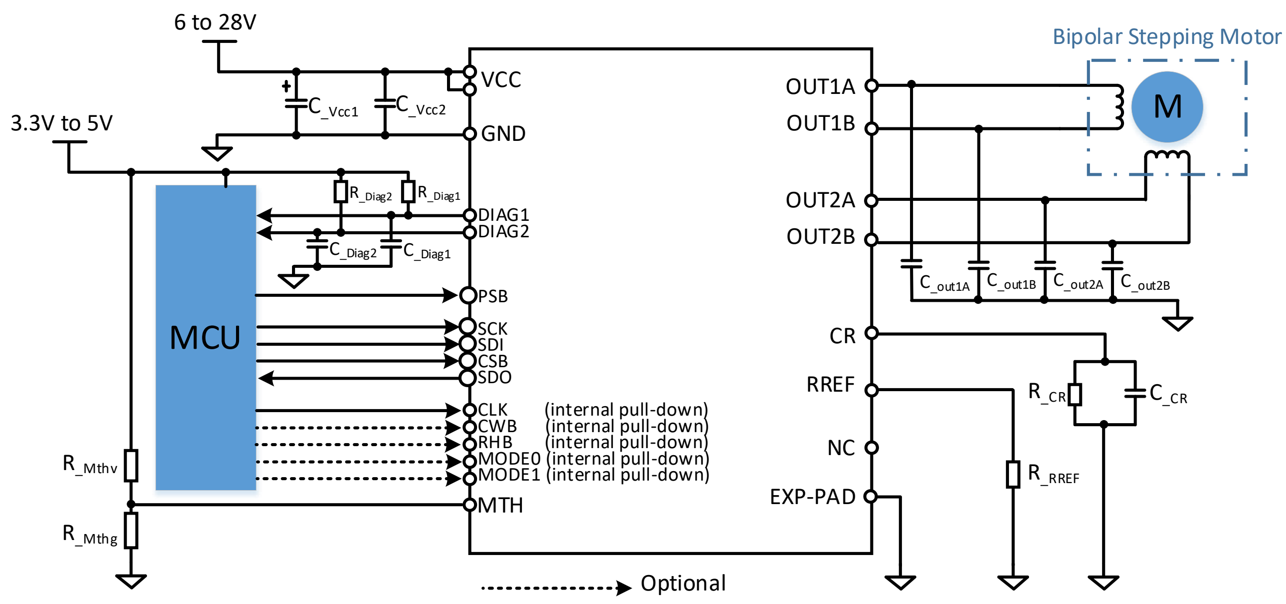
● Application

LED leadlight, Heat pump, Intake Air control, Head-up display etc.

Contents

1. Hardware Peripheral Design

Fig.1-1 shows the typical application circuit to control bipolar stepping motor. Some connections and parts, represented by the dashed line, are optional. The functions controlled with CWB(2pin), RHB(9pin), MODE0(7pin) and MODE1(8pin) can be operated with SPI register settings too. So, these pins can be set fix to low or high according to your SPI control software specification. MTH (30pin) and RREF (31pin) can be set to open if it used as default settings. The BD63800MUF-C have the SPI-IN Drive Mode, CLK(4pin) can be set fix to low when this mode used with your application.



Symbol	Parts	Recommend Value, (EVK reference parts value)
C_Vcc1	Electrolytic capacitor	100 µF to 470 µF, (100 µF / 63 V)
C_Vcc2	Ceramic capacitor	0.01 µF to 0.1 µF, (0.1 µF)
R_Diag1	Resistor	1 kΩ to 100 kΩ, (10 kΩ)
R_Diag2	Resistor	1 kΩ to 100 kΩ, (10 kΩ)
C_Diag1	Capacitor	(no stuff)
C_Diag2	Capacitor	(no stuff)
R_MTHV	Resistor	10 kΩ to 100 kΩ, (no stuff)
R_MTHG	Resistor	10 kΩ to 100 kΩ, (no stuff)
R_RREF	Resistor	6.2 kΩ [1.1 A] to 9.1 kΩ [0.75 A], (6.2 kΩ)
R_CR	Resistor	10 kΩ to 200 kΩ, (39 kΩ)
C_CR	Capacitor	470 pF to 1500 pF, (1000 pF)
C_OUT1A	Capacitor	(no stuff)
C_OUT1B	Capacitor	(no stuff)
C_OUT2A	Capacitor	(no stuff)
C_OUT2B	Capacitor	(no stuff)

Fig.1-1 Typical application circuit and recommend value for peripheral parts.

1.1 [VCC] Input capacitor for Power Supply: C_Vcc1 and C_Vcc2

The input capacitor (C_Vcc1 and C_Vcc2) lowers the power supply impedance and averages the input current. These values are selected according to the impedance of the power supply that is used. VCC voltage has large fluctuations due to back electromotive force of the motor, PWM switching noise etc. In order to stabilize VCC voltage level, place the bypass capacitors (ranged from 100 μF to 470 μF). Larger capacitors are necessary especially when the application needs larger current or when the motor has large back electromotive force. In addition, we recommend placing multilayer ceramic capacitors (ranged from 0.01 μF to 0.1 μF) in parallel to the bypass capacitor. The purpose is to decrease the impedance of the power supply in a wide frequency bandwidth.

1.2 [DIAG1 and DIAG2] Pull-up resistor: R_Diag1 and R_Diag2

DIAG1(10pin) and DIAG2(11pin) are open drain output. So, these pins are used with pull-up resistor connected to the external voltage source. Recommend pull-up resistor value is between 1 kΩ and 100 kΩ. DIAG1 and DIAG2 are tended to receive some noise due to long pattern length. So, it is recommended to make footprints for the capacitors which can be reduced the noise as necessary.

1.3 [MTH] Current Decay Method Setting: $R_{\_Mthv}$ and $R_{\_Mthg}$

Tab. 1-1 shows the MTH input voltage and input method selection. When Mix decay is selected, input the accurate voltage in order to set the Slow/Fast decay ratio. When MTH input voltage is set with a voltage divider of resistors, select the R_Mthv and R_Mthg value in taking the outflow current (Max 2 μA) and the internal pull-up resistor (1 MΩ) into consideration. Recommend the total resistor value of R_Mthv and R_Mthg is between 10kΩ and 100kΩ.

Tab. 1-1: MTH input voltage and input method selection.

Current Decay Method	MTH input voltage	Input method in the MTH pin
Slow Decay	0.0 V to 0.3 V	Connect to GND.
Mix Decay	0.4 V to 1.0 V	Set voltage with the voltage divider. Slow/Fast decay ratio is set by the input voltage.
Fast Decay	1.5 V to 2.0 V	Set voltage with the voltage divider
Auto Decay	2.5 V or more	Connect to external power source (3.3V to 5V).

1.4 [RREF] Resister for Output Current Level Setting: $R_{\_RREF}$

Peak Motor Current for the drive mode and the hold mode are set the combination of RREF (31pin) input and SPI register value. Each value is calculated the following equation:

Drive mode: Maximum output current [A] (RREF input) × Peak Motor Current ratio [%] (IRUN [3:0] register)

Hold mode: Maximum output current [A] (RREF input) × Peak Motor Current ratio [%] (IHOLD [3:0] register)

RREF (31 pin) is used for setting the maximum output current value. $R_{\_RREF}$ range is from 6.2 kΩ to 43 kΩ. Following equation and table are showed the maximum output current according to $R_{\_RREF}$.

$$IOUT = \frac{V_{RREF}}{R_{RREF}} \times 14900\ [A]$$

Where:

$IOUT$ is the Maximum Output Current

V_{RREF} is the RREF Voltage [V]. BD63800MUF-C = 0.457 V (Typ).

R_{RREF} is the RREF Resistor [Ω] (6.2 kΩ to 43 kΩ)

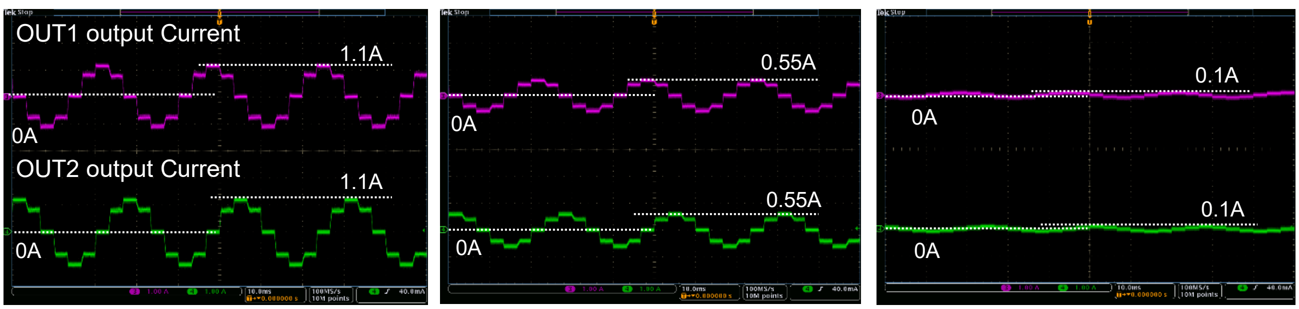
Tab. 1-2: RREF resister setting for maximum output current.

R_RREF	Maximum output current [typ.]
6.2 kΩ	1.10 A
6.8 kΩ	1.00 A
7.5 kΩ	0.91 A
8.2 kΩ	0.83 A
9.1 kΩ	0.75 A

The output current for the drive mode and the holding mode are calculated by the percentage of the maximum output current. the percentage is set by the IRUN[3:0] and IHOLD[3:0] register value on SPI . Following examples are the peak motor output current value and waveform when R_RREF resister is 6.2 kΩ as 1.10 A max current setting.

Tab 1-3: Peak motor current examples on drive mode (e.g. maximum output current = 1.1 A)

IRUN[3:0] (Bit assign)	Peak Motor Current ratio on drive mode	Peak Motor Current on drive mode (If maximum output current = 1.1 A)
0000	9.1 %	1.1A × 9.1% = 0.1 A
1011	50.0 %	1.1A × 50.0% =0.55 A
1111	100.0 %	1.1A × 100% =1.1 A

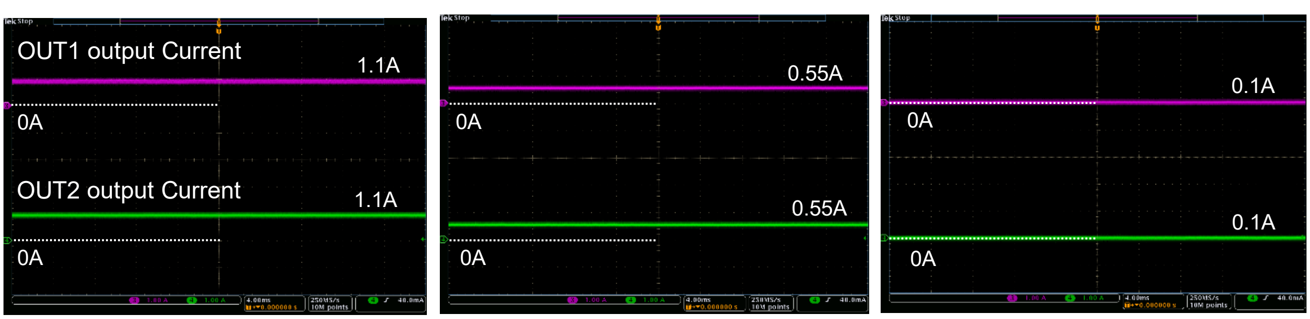


IRUN[3:0] = 1111 (1.1 A) IRUN[3:0] = 1011(0.55 A) IRUN[3:0] = 0000 (0.1 A)

Fig. 1-2 : Output current for IRUN register settings ($R_{\_RREF}$ = 6.2 kΩ, Half-step)

Tab 1-4: Peak motor current value examples on hold mode (e.g. maximum output current = 1.1 A)

IHOLD[3:0] (Bit assign)	Peak Motor Current ratio on hold mode	Peak Motor Current value on hold mode (If maximum output current = 1.1 A)
0000	0 %	1.1A × 0% =0 A
1100	50.0 %	1.1A × 50.0% =0.55 A
1111	83.9 %	1.1A × 83.9% =0.92 A



IHOLD[3:0] = 1111 (0.92 A) IHOLD[3:0] = 1100 (0.55 A) IHOLD[3:0] = 0000 (0 A)

Fig. 1-3 : Output current for IHOLD register settings ($R_{\_RREF}$ = 6.2 kΩ, Half-step)

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1.5 [CR] Chopping Frequency Setting: R_CR, C_CR

CR (29pin) is used for setting the chopping frequency. The chopping frequency/period can be calculated with the CR timer which is described on datasheet. Recommend R_CR is between 10 kΩ and 200 kΩ. For C_CR, the minimum ON time(t_{ONMIN}) which can be cancel spike noise on charging time will become long by the capacitance value. So, note that output current may exceed the target current level depending on L and R values of the motor coils. Recommend R_CR is between 470 pF and 1,500 pF. Chopping frequency can be calculated by followings when R_CR = 39kΩ and C_CR = 1000pF settings.

$$VCR = \frac{R}{R+R'} \times V \;=\; \frac{39k}{39k+5k} \times 5V \approx 4.43$$

$$t_{ONMIN} \approx C \times \frac{R \times R'}{R+R'} \times \ln\left(\frac{VCR-0.4}{VCR-1.0}\right) = 1000p \times \frac{39k \times 5k}{39k+5k} \times \ln\left(\frac{4.43-0.4}{4.43-1.0}\right) = 0.7\mu s$$

$$t_{DISCHARGE} \approx C \times R \times \ln\left(\frac{1+\alpha}{0.4}\right) = 1000p \times 39k \times \ln\left(\frac{1+0.11}{0.4}\right) = 39.8\mu s$$

$$t_{CHOP} \approx t_{ONMIN} + t_{DISCHARGE} = 40.5\mu s$$

Where:

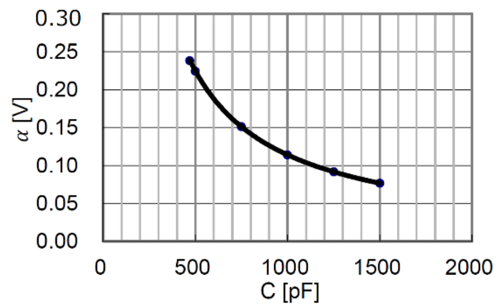
R is the external resistor in the CR pin (R_CR)

C is the external capacitor in the CR pin (C_CR)

V is the internal regulator output voltage. 5 V (Typ)

R' is the internal impedance in the CR pin. 5 kΩ (Typ)

α is referred to the chart to the right



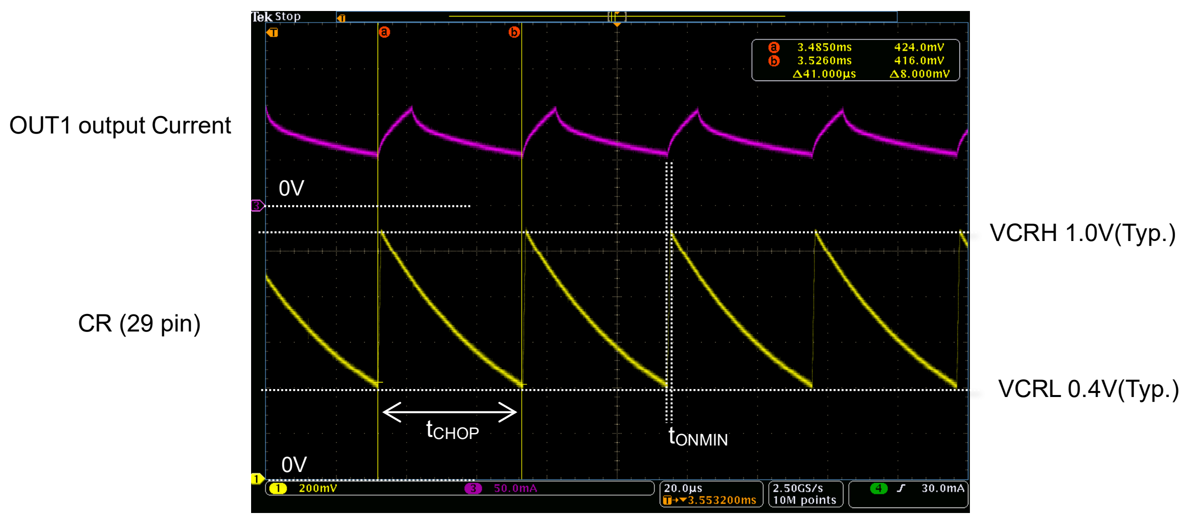


Fig.1-4: Waveform of CR Voltage and Motor Output current (Full step, Slow Decay)

In order to select the optimum value of the chopping frequency to minimize motor sound and distortion of output current waveform, following consideration should be checked:

- long chopping cycle time (t_{CHOP}) causes larger ripple in output current, smaller average output current and lower rotation efficiency. Short chopping cycle time causes high frequency switching noise emission and overheat with switching loss. As an example of the chopping frequency is 25 kHz in order to avoid the acoustic noise on the BD63800MUF-C evaluation board.

- As shown Fig. 1-5, The actual chopping cycle time could be extended when charging time is exceeded t_{CHOP}. This phenomenon might be generating the undesired acoustic noise. The charging time depends on the stepping motor characteristics and decay mode. So please check the output current carefully whether actual chopping cycle time is acceptable.

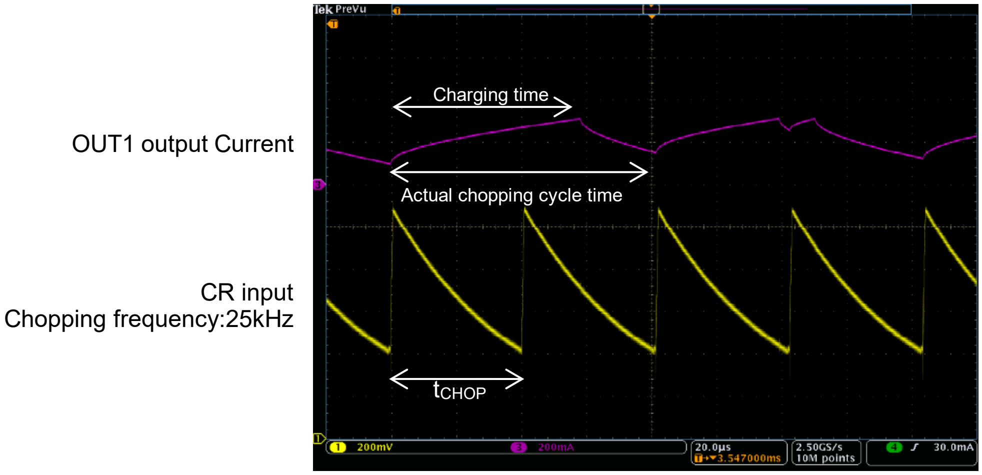


Fig.1-5: Extended chopping time due to long charging time

At the first step of R_{CR} and C_{CR} value selection example for the chopping frequency, C_{CR} value can be selected by deciding the minimum ON time(t_{ONMIN}).

1.6 [OUT1A, OUT1B, OUT2A, OUT2B] Output: C_{OUT1A}, C_{OUT1B}, C_{OUT2A}, C_{OUT2B}

Output current to the stepping motor could be caused undesired noise source. So, it is recommended to make footprints for the capacitors which can be reduced the noise as necessary.

2. PCB Pattern Layout Guideline

This section describes the layout guidelines in order to achieve safety operation and good performance from BD63800MUF-C. For each guideline, example layout is showed from BD63800MUF-C evaluation board.

2.1 VCC (Power Supply Pin): 14 and 27pin

Since the motor driving current flows into the VCC pin, design the PCB layout with low impedance by making the trace for the VCC pin thick and short. VCC voltage has large fluctuations due to back electromotive force of the motor, PWM switching noise etc. In order to stabilize VCC voltage level, place the bypass capacitors as close as possible to the VCC pin.
Also, multilayer ceramic capacitors are placing multilayer ceramic capacitors in parallel to the bypass capacitor. Make sure to short all VCC pins on the PCB layout though they are shorted inside IC. When these are not shorted, malfunction or destruction may occur because of current flow concentration.

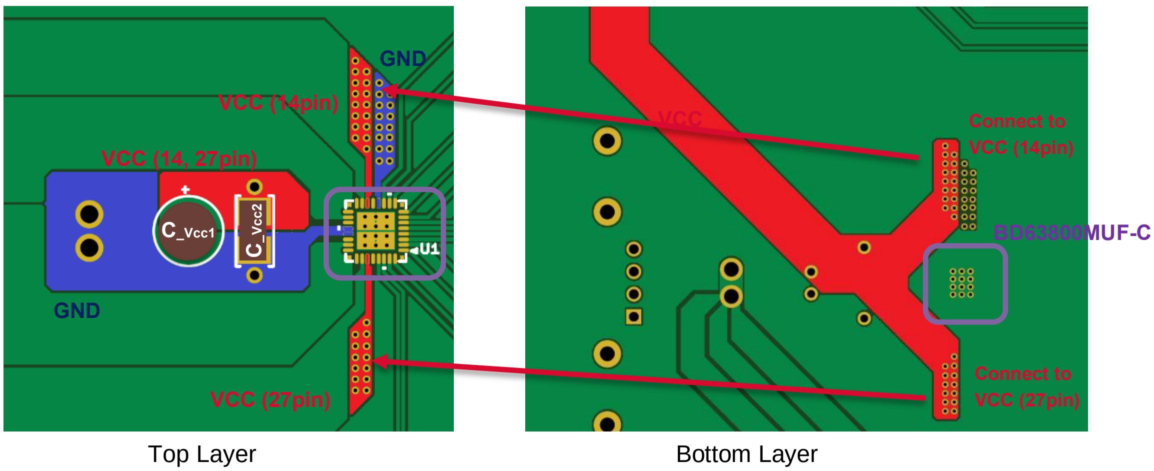


Fig. 2-1: Layout example for VCC (BD63800MUF-C Evaluation Board rev.1)

2.2 GND (Ground Pin): 12, 20 and 21 pin

In order to reduce the noise caused by switching current and to stabilize the internal reference voltage of IC, design the PCB layout to make the wiring impedance from these pins as low as possible to achieve the lowest electrical potential in any operating conditions. Design the PCB layout so that it does not have common impedance with other GND patterns.

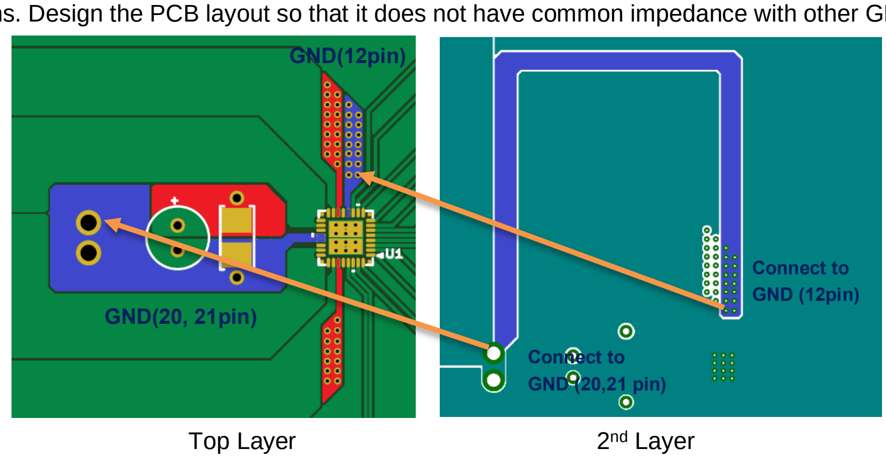


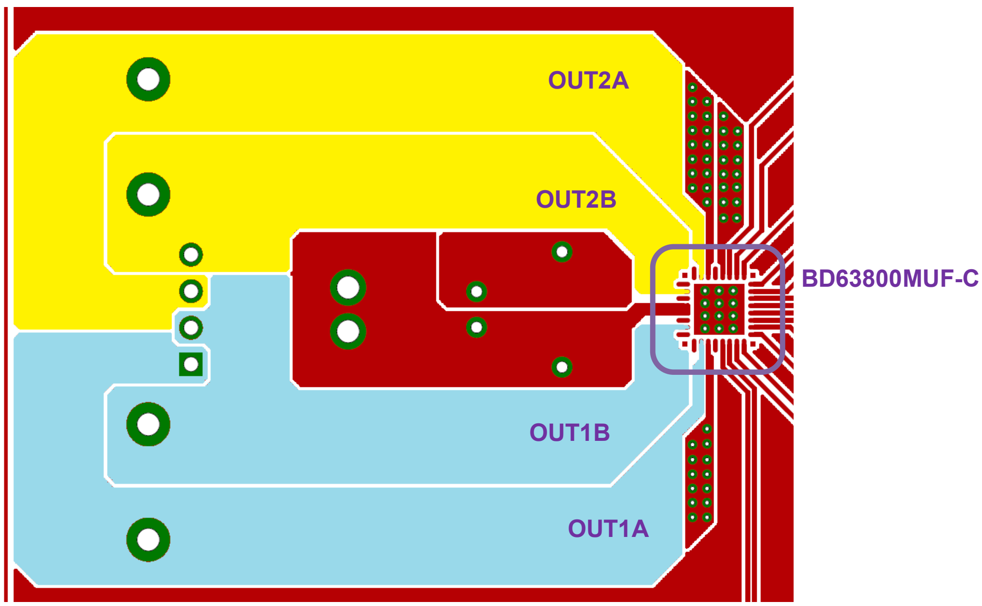
Fig. 2-2: Layout example for GND (BD63800MUF-C Evaluation Board rev.1)

Tab. 2-1: Layout check list (VCC, GND)

No.	Pin	item
1	VCC	Thick and short pattern as much as possible
2	VCC	Place the capacitor (100 µF to 470 µF) as close as possible to the VCC pin.
3	VCC	Place the capacitor (0.01 µF to 0.1 µF) as close as possible to the VCC pin.
4	VCC	Connect all VCC pins (14, 27pin) on the PCB.
5	GND	GND Pattern is not to have common impedance with other GND

2.3 OUT1A, OUT1B, OUT2A, OUT2B (H-Bridge Output Pin): 15, 18, 23, and 26pin

Since the motor driving current flows into these pins, design the PCB layout with low impedance by making the trace for the OUT1A, OUT1B, OUT2A, OUT2B pin thick and short.



Top Layer

Fig. 2-3: Layout example for OUT1 and OUT2 (BD63800MUF-C Evaluation Board rev.1)

Tab. 2-2: Layout check list (OUT1A, OUT1B, OUT2A, OUT2B)

No.	Pin	item
1	OUT	Thick and short pattern as much as possible

2.4 CR (Chopping Frequency Setting Pin): 29pin

In PCB, ensure that GND line from the external components has no common impedance with other GND patterns. Also ensure that it is far from wires with steep pulses like square waves, etc. to prevent noise.

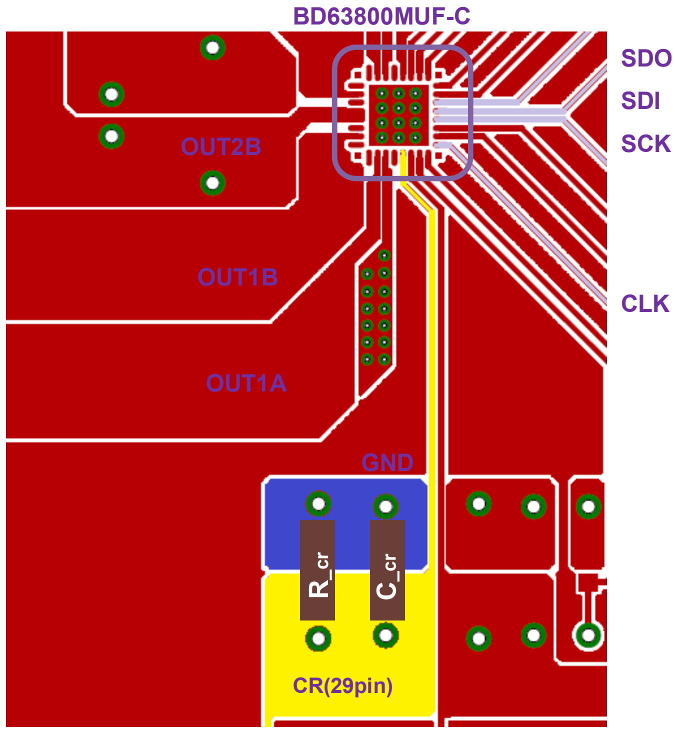


Fig. 2-4: Layout example for CR (BD63800MUF-C Evaluation Board rev.1)

Tab. 2-3: Layout check list (CR)

No.	Pin	item
1	CR	GND of the parts has no common impedance with other GND patterns.
2	CR	Place pattern far from wires with steep pulses [CLK etc.]

2.5 IC Backside Metal: EXP-PAD

BD63800MUF-C package has a metal for heat dissipation on the back of the IC. Since the heat is supposed to be dissipated through this metal, the metal must be connected to GND plane on substrate with soldering and GND pattern as large as possible must be used for the sufficient heat dissipation area. In addition, the backside metal is shorted to the back of the IC chip. So, the backside metal is at GND potential. If it is shorted to a potential other than GND potential, malfunction and destruction will occur. Don’t route signals other than GND potential at the back-side of the IC. Fig. 2-5 shows the example of the PCB layout for EXP-PAD. Please make sure to follow the package information of BD63800MUF-C Package.

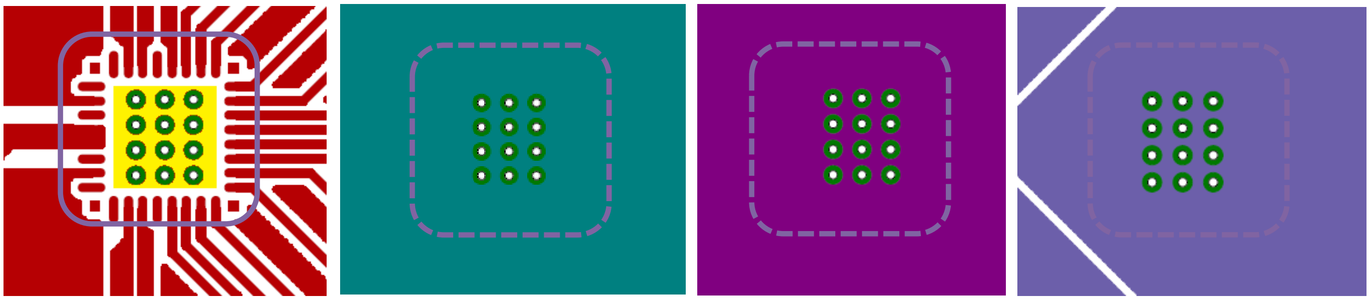


Fig. 2-5: Layout example for Backside Metal (BD63800MUF-C Evaluation Board rev.1)

Tab. 2-4: Layout check list (Backside Metal)

No.	Pin	item
1	EXP-Pad	Connect to GND plane with soldering as large as possible
2	EXP-Pad	Don't route signals other than GND potential

3. Standard Operate Sequence

Following flowchart is the standard operation sequences with BD63800MUF-C application. It has three types of state for operation. Standby state is not able to accept the SPI command and the motor output keeps open state. It can be used as power saving mode. Normal State can be accepted the SPI commands, but the motor output keeps still open state. Active state can be control motor with SPI command. Regarding the detailed SPI register settings, please check the Control Register section on BD63800MUF-C Datasheet.

[Standby State]
Reset Condition

Power-on in Standby mode
- VCC: Applied and stable
- PSB = Lo
- SPI: Inactive
- CLK = Lo

Release Reset (PSB = Hi)

Wait > 40μs

[Normal State]
Set Registers with SPI

- Protection
  Thermal Warning
  Under Voltage Lock-out
  Under Voltage Motor Hold
- Detection
  Stall
- Report
  DIAG1 and DIAG2
- Drive mode
  CLK-IN or SPI-IN
- Drive settings
  Motor excitation mode
  Motor rotation direction
  Drive / Hold mode
  Peak motor current
  Switching slew rate

Command issued in normal mode
- VCC: Applied and stable
- PSB = Hi
- SPI: Active
  'MOTEN' bit = 0 (Disable motor driving operation)
- CLK = Lo

Set Control Register in no order.

5-bit Address	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
01h(CR1)	CWBP	RHBP	CLKP	MOTEN	StThr7	StThr6	StThr5	StThr4
	0	0	0	0	0	0	0	0
02h(CR2)	IHOLD3	IHOLD2	IHOLD1	IHOLD0	IRUN3	IRUN2	IRUN1	IRUN0
	0	0	0	0	0	0	0	0
03h(CR3)	-	-	EMC1	EMC0	UVM3	SM2	SM1	SM0
	0	0	1	0	0	0	0	0
05h(CR5)	SpThr7	SpThr6	SpThr5	SpThr4	SpThr3	SpThr2	SpThr1	SpThr0
	0	0	0	0	0	0	0	0
06h(CR6)	UVThr3	UVThr2	UVThr1	UVThr0	-	-	-	-
	0	0	0	0	0	0	0	0
07h(CR7)	AD4	BeGain	UVM2	UVM1	-	-	-	-
	0	0	0	0	0	0	0	0
11h(CR1A)	UVM0	BeGain2	StCnt1	StCnt0	TwThr3	TwThr2	TwThr1	TwThr0
	0	0	0	1	0	0	0	0
12h(CR2A)	StHys3	StHys2	StHys1	StHys0	StThr3	StThr2	StThr1	StThr0
	0	0	0	0	0	0	0	0
15h(CR5A)	SelSPI1	SelSHORT1	SelOPEN1	SelTW1	SelTSD1	SelSTALL1	SelUV1	SelOV1
	1	1	1	1	1	1	1	1
16h(CR6A)	SelSPI2	SelSHORT2	SelOPEN2	SelTW2	SelTSD2	SelSTALL2	SelUV2	SelOV2
	0	0	0	0	0	1	0	0

Set Registers with SPI
'MOTEN' bit = 1

[Active State]
Drive / Hold Motor

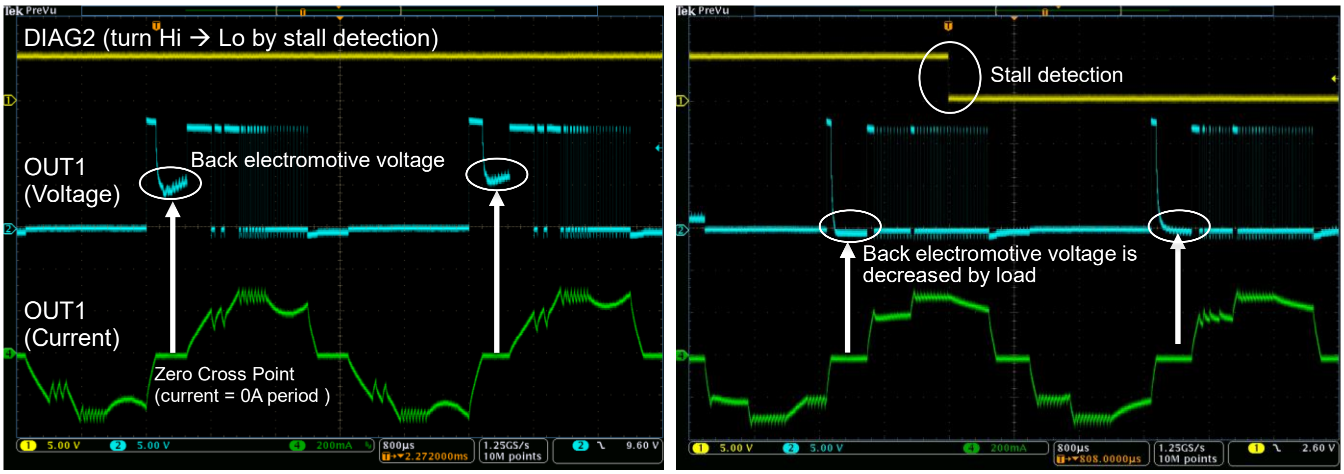
Drive motor with CLK
- VCC: Applied and stable
- PSB = Hi
- SPI: Active (Set from the Control Register Map)
  'MOTEN' bit = 1 (Enable motor driving operation)
- CLK: operation according to the drive mode
  CLK-IN: Input clock pulse to CLK pin
  SPI-IN: Write 'CLKP' bit = 1 repeatedly
  with target pulse rate.

4. Stall Detection Settings

Stall Detection is available in 1/2, 1/4, 1/8, 16, and 1/32 step mode. It is not available in Full step mode.

As shown Fig 4-1, Stall is detected by monitoring the back electromotive voltages at zero cross points which is period of output current = 0 A. The back electromotive voltage at zero cross point is decreased by load to the motor. Stall detection is compared this voltage and the threshold voltage which is set by the register.

It reports by DIAG1/DIAG2 pin output or SPI status register during stall detecting. Operation don't stop with the detection by itself.



No Load Overload Stall (Motor stopped)

Fig. 4-1: Back electromotive voltage in zero cross point (1/2 step mode)

Following parameters are needed to set appropriately in order not to false detection:

- Stall detection voltage level: StThr[7:0], BeGain / BeGain2 bit

Unit [V] (all values are typical)

StThr[7:0]	n	BeGain2/BeGain			
		'0' / '0'	'0' / '1'	'1' / '0'	'1' / '1'
0000 0000	0	Stall detection: Disabled			
0000 0001	1	0.20	0.15	0.06	0.03
0000 0010	2	0.39	0.29	0.12	0.06
0000 0011	3	0.59	0.44	0.18	0.09
0000 0100	4	0.78	0.59	0.24	0.12
:	:	:	:	:	:
1111 1110	254	49.80	37.35	14.94	7.47
1111 1111	255	50.00	37.50	15.00	7.50
Calculation Formula		$\frac{10}{51} \times n$	$\frac{5}{34} \times n$	$\frac{2}{34} \times n$	$\frac{1}{34} \times n$

Stall detection is disabled in StThr[7:0] = '00000000'.The combination of BeGain/BeGain2 and StThr[7:0] are not restricted for the threshold voltage settings. so, it is enough to only adjust the StThr[7:0] under fixed BeGain/BeGain2.

- Stall detection voltage hysteresis: StHys[3:0]

StHys[3:0]	m	Hysteresis (Typ)
0000	0	4 %
0001	1	8 %
0010	2	12%
:		:
1110	14	60%
1111	15	64%
Calculation Formula		$4 \times (m + 1)$

- CLK-IN period in stall detection available: SpThr[7:0]
  Set SpThr[7:0] referring to the table below. Stall detection is enabled when CLK-IN period is less than or equal to the values in the table.

SpThr[7:0]	Threshold setting of CLK-IN Period for Stall detection (Typ)
0000 0000	Stall detection: Disabled
0000 0001	20 µs
0000 0010	40 µs
:	:
1111 1110	5,080 µs
1111 1111	5,100 µs

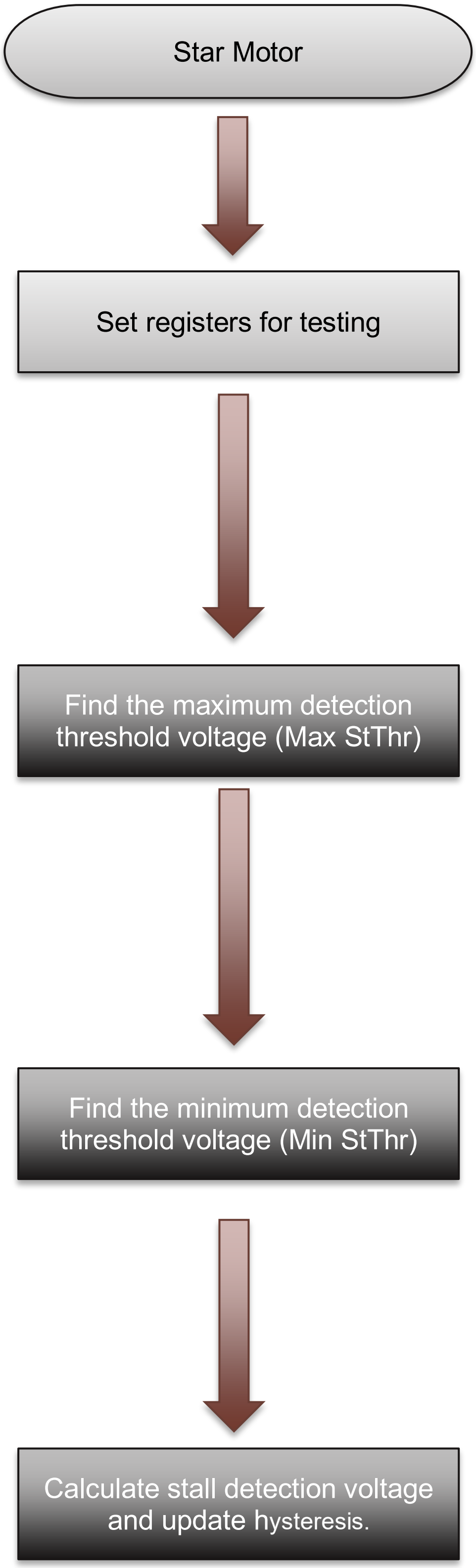
  When SpThr[7:0] = ‘0000 0101’ (100µs), stall detection function is available under 10,000pps.

- Total count of asserting Stall detection: StCnt[1:0]
  Stall detection is asserted when the back electromotive voltage at zero cross point falls below the stall detection voltage level in consecutive certain times indicated in the table below.

StCnt[1:0]	Total times of stall status for asserting stall detection
00	1 time stall status
01	2 times consecutive stall status
10	4 times consecutive stall status
11	8 times consecutive stall status

These parameters are needed to be updated when “motor speed”, “VCC voltage”, “maximum motor drive current”, “Peak Motor Current (IRUN)”, “Decay mode” are changed. Also, please make sure to evaluate the stall detection threshold whether is enough for operation temperature, voltage range, sample variation on your application.

The following is the flow chart how to get the stall detection threshold:



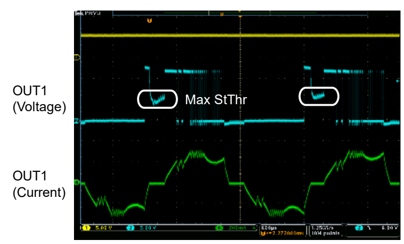
Check the conditions are expected as your application settings:

1. VCC voltage
2. Motor speed
3. Maximum motor drive current
4. Peak Motor Current (IRUN)
5. Decay mode

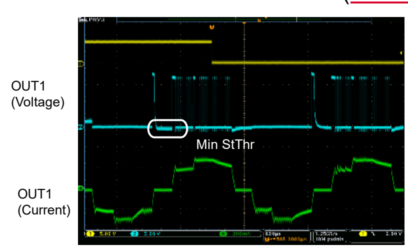
Set the following register to find stall detection threshold voltage:

6. StHys[3:0] = 0000 (Hysteresis = 4%, default settings)
7. StCnt[1:0] = 10 (4 times consecutive stall status)
8. SelSTAL2 = 1 (DIAG2 output selector for Stall detection result, default)
   Other bits for DIAG2 output selector (address:CR6A) are set to zero in order to detect only the stall.
9. [BeGain2,BeGain]: Set value according to the VCC voltage and expected accuracy.
   [0,0] = 0.2V to 50V (10/51V step)
   [0,1] = 0.15 to 37.5V (5/34V step)
   [1,0] = 0.06 to 15.0V (2/34V step)
   [1,1] = 0.03 to 7.5V (1/34V step)

1. Set StThr[7:0] to ‘0000 0001’
2. Increase the StThr[7:0] value until stall detection during normal operation.
   Stall detection can be monitored with DIAG2 output (Hi → Lo)
3. Record result StThr[7:0] value as the maximum detection threshold (Max StThr)
4. Reset StThr[7:0] to ‘0000 0001’. Then check DIAG2 output changed (Lo → Hi)

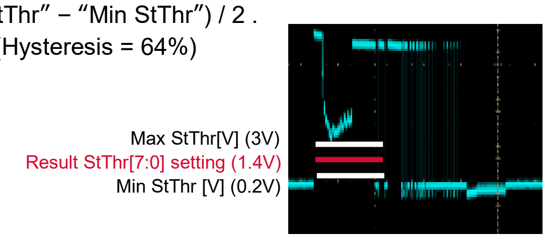


5. Check StThr[7:0] = ‘0000 0001’
6. Stall (Stop) motor on purpose
7. Increase the StThr[7:0] value until stall detection during motor stalled (stopped).
   Stall detection can be monitored with DIAG2 output (Hi → Lo)
8. Record result StThr[7:0] value as the minimum detection threshold (Min StThr)



Set StThr[7:0] and StHys[3:0] as follows:

- StThr[7:0]= (“Max StThr” – “Min StThr”) / 2 .
- StHys[3:0] = 1111 (Hysteresis = 64%)



5. Decay mode and Chopping frequency Selection

The BD63800MUF-C have four type of decay modes (Slow/ Fast/ Mix/ Auto).

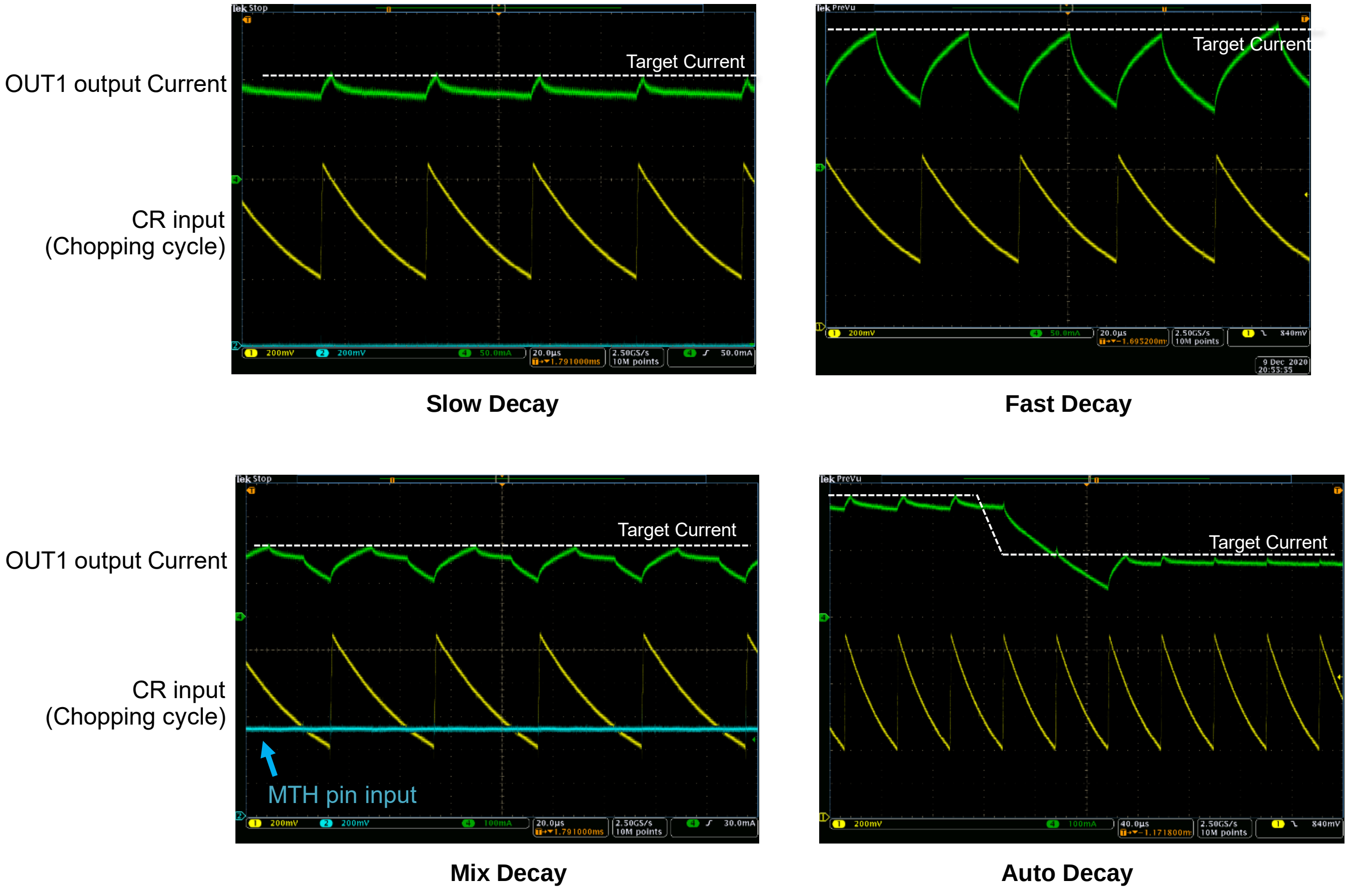


Fig. 5-1: Output current in BD63800MUF-C decay modes (1/4 step mode)

5-1. Slow Decay Mode

During current decay period, regenerative current decreases slowly.

This decay mode is suitable for Full step mode or low-pulse-rate driven 1/2 step to 1/32 step modes.

Advantage:

- Ripple on output current smaller and torque of motor higher.
- Silent, Low heat generation and Low power consumption

Disadvantage:

- Output current increases in the lower operating current condition due to lower controllability.
- The current distortion could be generated due to the motor back electromotive voltage in high-pulse-rate driving with 1/2 step to 1/32 step.

5-2. Fast Decay Mode

During current decay period, regenerative current decreased quickly.

This decay mode is stable for high-pulse rate 1/2 step to 1/32 step modes.

Advantage:

- The current distortion is reduced even in the high-pulse-rate driving condition

Disadvantage:

The average current is reduced by large ripple of output current.

- Motor torque reduction
  It can be solved by larger current limit setting.
- Increase heat Generation caused by motor power loss.

5-3. Mix Decay Mode

During current decay period, both of fast and slow are used by switching. Switch timing can be set by MTH (30pin) input voltage. This decay mode can provide the optimal control state for almost kind of motors.

Advantage:

- Improve current controllability without increasing the current ripple.
- User Adjustable slow and fast decay ratio

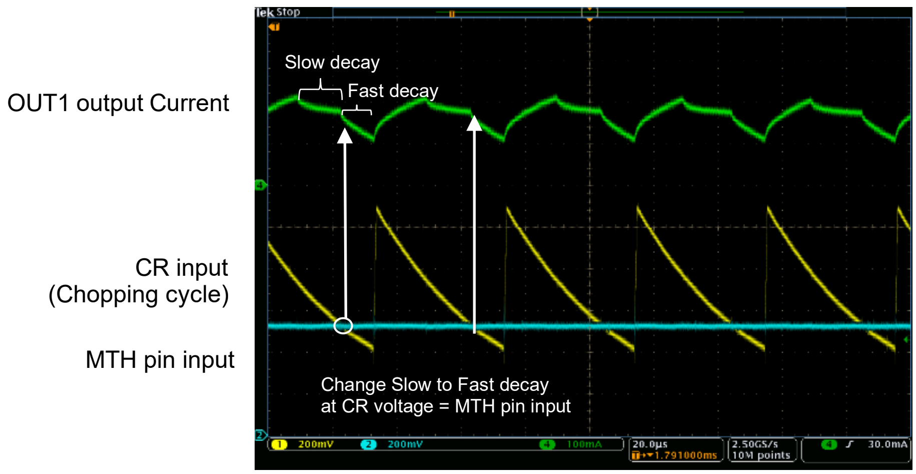


Fig. 5-2: Adjusting Slow to Fast decay mode on Mix decay mode (1/4 step mode)

5-4. Auto Decay Mode

During current decay period, both of fast and slow are switched automatically according to the output current. This decay mode can provide the optimal control state without external control.

Advantage:

- Small current ripple and quick following for the change of target current.
- No current distortion, high power conversion efficiency, Low heat generation

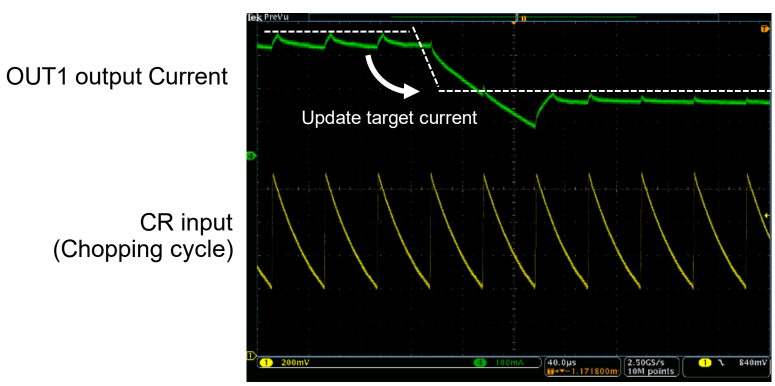


Fig. 5-3: Adjusting Slow to Fast decay mode on Mix decay mode (1/4 step mode)

5-5. Decay mode and Chopping frequency Selection flowchart

Fig. 4-4 shows the flowchart for reference sequence how to select decay mode. Decay mode should be selected by the application priority and evaluation. Also, chopping frequency should be considered combination with decay mode. Chipping frequency is related to the EMC emission noise. And it could be changed by charging time of the OUT1 and OUT2 current. (refer to the CR pin of hardware peripheral section)

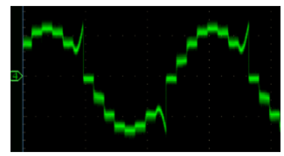
Evaluation condition:
- Motor speed: max speed for application

Check item:
- Current waveform (chopping frequency, distortion)
- Acoustic Noise

Select slow decay
if noise reduction is highly required

Slow Decay

Evaluation, Criteria:
Check the followings with adjust the chopping time.
- Is current distortion acceptable?
- Actual chopping frequency acceptable?

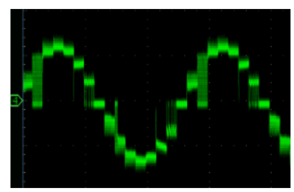


Current distortion

Not acceptable

Auto Decay

Evaluation, Criteria:
Check the followings with adjust the chopping time.
- Current waveform acceptable?
- Actual chopping frequency acceptable?



Unsmoothed
Current waveform due to
Fast decay

Not acceptable

Mix Decay

Evaluation, Criteria:
Check the followings with adjust chopping time and the mix decay ratio.
- Is IC temperature acceptable?
- Is current distortion acceptable? → Adjust mix decay ratio
- Actual chopping frequency acceptable? →Adjust chopping frequency.

Not acceptable

Fast Decay

Evaluation, Criteria:
Check the followings with adjust the chopping time.
- Is current distortion acceptable?
- Is IC temperature acceptable?

Fig. 5-4: Decay mode and Chopping time selection example

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