Application Report

Solving Sleep Mode Entry System Issues in the DRV10987D I²C Speed Command Mode

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ABSTRACT

This application note shows how to solve system issues for entering sleep mode using I²C speed command mode. The DRV10987 device is used with an MCU and several power devices in a system. In a normal system, entering and exiting sleep mode is also related to the power sequence and initial setting. The *DRV10987 12- to 24-V, Three-Phase, Sensorless BLDC Motor Driver Data Sheet* explains how to enter sleep mode and exit from sleep mode and provides the sequence to enter and exit from sleep mode. If the initial setting state and the power sequence are not considered at the system level, an issue arises that sleep mode cannot be entered even if the sequence mentioned in the data sheet is followed. This document provides the detailed initial setting related to the power sequence and implementation code for solving issues of not entering sleep mode at the system level. The MSP-EXPFR4133 Development Kit and DRV10987EVM are used to verify the solutions of this issue.

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1 Introduction

1.1 Sleep and Standby Mode

The DRV10987 device provides a sleep version and a standby version. The DRV10987 part number is used for both devices, that is, DRV10987D (sleep version), DRV10987S (standby version). When the device enters either sleep or standby, the device stops driving the motor. The step-down regulator is disabled in the sleep mode version to conserve more energy. The I^2C interface is disabled and any register data not stored in EEPROM is reset for the sleep mode version. The switching regulator remains active in the standby mode version. The register data is maintained, and the I^2C interface remains active for the standby mode version. Table 1-1 shows the differences between DRV10987D sleep mode and DRV10987S standby mode.

Table 1-1. Sleep Mode and Standby Mode Comparison

	DRV10987D Sleep Mode	DRV10987S Standby Mode
I^2C	Disable	Active
Resister data	Not stored in EEPROM	Maintained
Step-down regulator	Off	On
3.3-V LDO	Off	On
1.8-V LDO	Off	On

1.2 Conditions for Entering or Exiting Sleep

Table 1-2 shows the timing and command to enter the sleep or standby condition. In I^2C speed command mode, *Sequence* is required to enter sleep mode. The *Speed* pin must be in a known state (pulled high and pull low) when the speed is controlled via I^2C.

Table 1-2. Conditions to Enter or Exit Sleep or Standby Condition

Speed Command Mode	Enter Standby Condition	Enter Sleep Condition	Exit From Standby Condition	Exit From Sleep Condition
Analog	SPEED pin voltage < VEN_SB for tEN_SB_ANA	SPEED pin voltage < VEN_SL for tEN_SL_ANA	SPEED pin voltage > VEX_SB for tEX_ SB_ANA	SPEED pin voltage > VEX_SL for tEX_SL_ANA
PWM	SPEED pin low (V < VDIG_IL) for tEN_SB_PWM	SPEED pin low (V < VDIG_IL) for tEN_SL_PWM	SPEED pin high (V > VDIG_IH) for tEX_SB_PWM	SPEED pin high (V > VDIG_IH) for tEX_SL_PWM
I2C	SpdCtrl[8:0] is programmed as 0 for tEN_SB_PWM	Required Sequence to Enter Sleep Mode	SpdCtrl[8:0] is programmed as non-zero for tEX_SB_PWM	SPEED pin high (V > VDIG_IH) for tEX_SL_PWM (PWM mode) or SPEED pin voltage > VEX_SL for tEX_SL_ANA (Analog mode)

1.3 Sequence to Enter Sleep Mode

The DRV10987D provides two options to enter sleep mode:

Option 1

1. Provide a non-zero value to the speed control register. For example, write 100 to register 0x30, speedCtrl[8:0].
2. Set the I^2C OverRide bit to 1. That is, write 1 to register 0x30, speedCtrl[15]
3. In analog mode, be sure SPEED pin voltage is less than VEN_SL for tEN_SL_ANA. In PWM mode, make sure SPEED pin is low (V < VDIG_IL) for tEN_SL_PWM.
4. Provide the value of zero to the speed control register to enter sleep mode. That is, write 0 to register 0x30, speedCtrl[8:0].

Option 2

1. Provide a non-zero value to the speed control register. For example, write 100 to register 0x30, speedCtrl[8:0].
2. Set the I2C OverRide bit to 1. That is, write 1 to register 0x30, speedCtrl[15]
3. In analog mode, be sure SPEED pin voltage is less than VEN_SL for tEN_SL_ANA. In PWM mode, make sure SPEED pin is low (V < VDIG_IL) for tEN_SL_PWM.
4. Provide the value of zero to the speed control register to enter sleep mode. That is, write 0 to register 0x30, speedCtrl[8:0].

2 Implementation

2.1 Hardware Setup

The DRV10987EVM and MSP-EXPFR4133 Development Kit are used. The following list shows the setup:

1. VCC of the DRV10987EVM is connected to a 24-V power supply
2. SD (SDA of I2C) of the DRV10987EVM is connected to the P5.2 pin of MSP-EXPFR4133
3. SC (SDA of I2C) of the DRV10987EVM is connected to the P5.3 pin of MSP-EXPFR4133
4. SPEED of the DRV10987EVM is connected to the P1.5 pin of MSP-EXPFR4133

Figure 2-1 displays the setup of the EVM and the development kit.

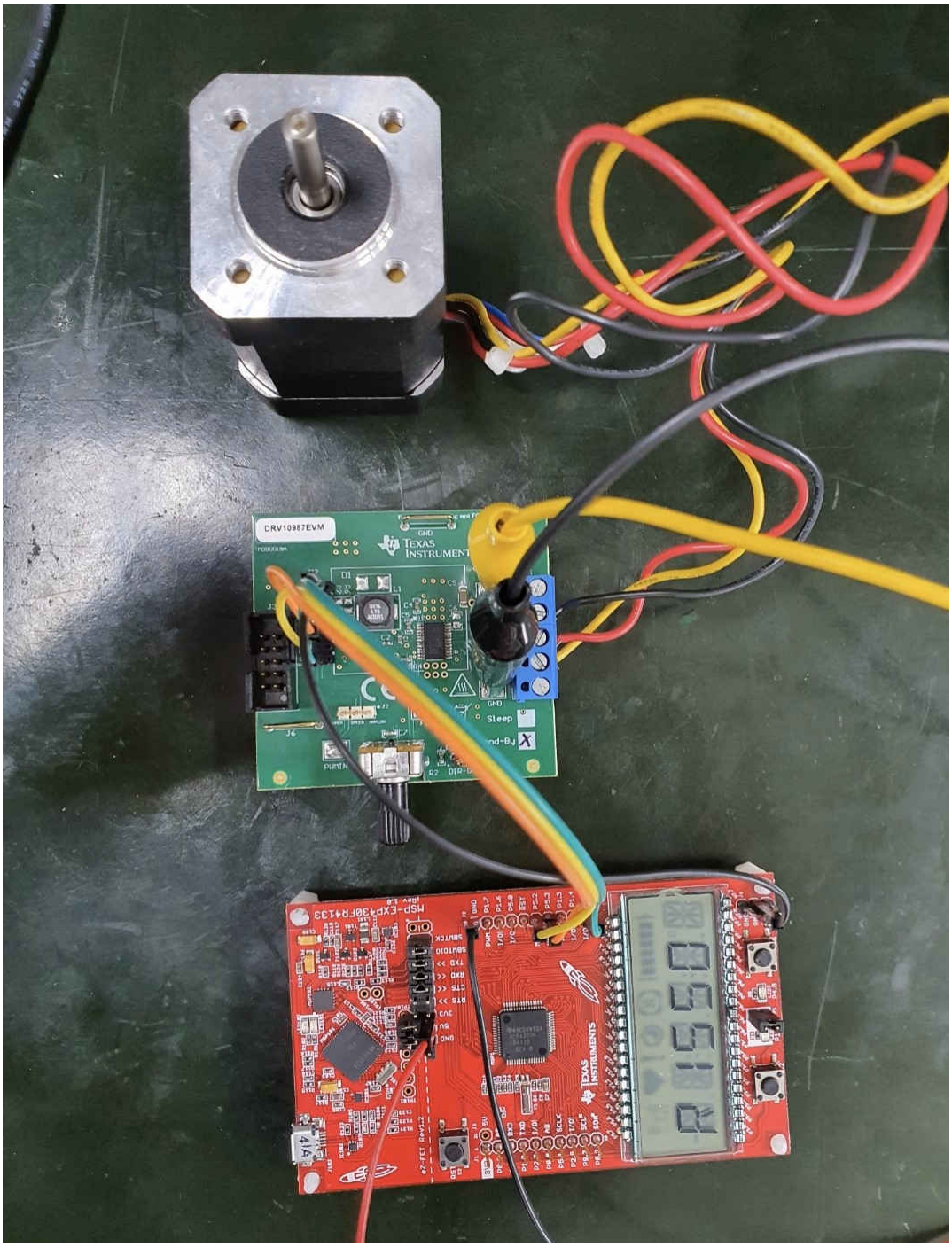


Figure 2-1. DRV10987EVM and MSP-EXPFR4133 Development Kit Setup

2.2 Power Up Sequence With Speed Pin in I²C Speed Command Mode

When the DRV10987 powers up, it cannot move to I²C mode. When powering up, it operates in PWM or analog mode according to the value stored in EEPROM. When the power is on, the motor parameters are not yet accurately determined, and if low is not applied to the speed pin, unexpected motor operation may occur. If it is necessary to apply low to the speed pin at the beginning of booting from the microcontroller, and the DRV10987 boots first when power is on, a pulldown resistor is needed. In the initial stage of power on, pulldown is applied to the speed pin or input low from the microcontroller to enter sleep. Before entering sleep, there is already a speed command and it is not a non-zero value. For this reason, Step1 is omitted in this implementation. However, there is a caveat here. Even if you proceed with Step2, Step3, and Step4 with SpeedCtrl value of 00, it does not enter sleep. Before proceeding to Step3 and Step4, there must be a non-zero value in SpeedCTrl. To operate I²C speed mode, the register setting is required after power up.

```
int main(void)
{
    /*** STOP WATCHDOG TIMER ***/
    WDTCTL = WDTPW | WDTHOLD;
    Init_Clock();// Sys_CLK_init();

    P1OUT &= ~BIT5;// P1.5 out put, Speed pin voltage low 0V. go into sleep mode
    P1DIR |= BIT5;
    GPIO_I2C_Init();
```

2.3 Implementing Option 1

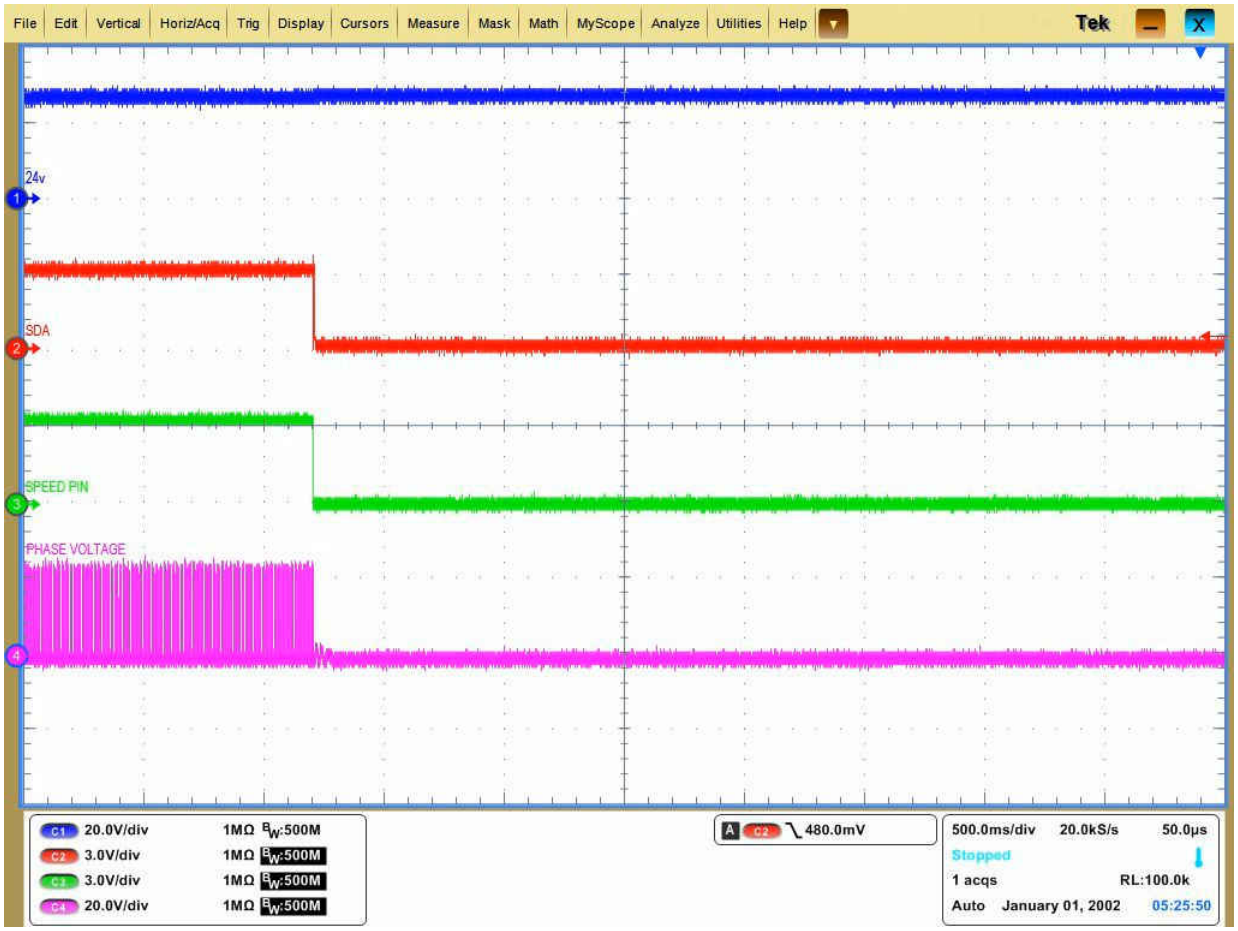
To accurately implement sleep entry using Option 1, Step3 and Step4 must be performed in which Speed is a non-zero value, see Table 2-1.

In example code, Step1 and Step2 are skipped, because Step1 and Step3 are executed to run the motor at active state.

Table 2-1. Implementing C Code With Option 1

	DRV10987 Data Sheet	Implementation in C code
Step1	Provide a non-zero value to the speed control register. For example, write 100 to register 0x30, speedCtrl[8:0].	
Step2	Set the I 2C OverRide bit to 1. That is, write 1 to register 0x30, speedCtrl[15].	
Step3	In analog mode, be sure SPEED pin voltage is less than VEN_SL for tEN_SL_ANA. In PWM mode, make sure SPEED pin is low (V < VDIG_IL) for tEN_SL_PWM.	`P1OUT &= ~BIT5;//Speed pin voltage low 0V.`
Step4	Provide the value of zero to the speed control register to enter sleep mode. That is, write 0 to register 0x30, speedCtrl[8:0].	`DRV10987Q_Send(DRV10987Q_SpeedCtrl_Reg ,0x8000);// overRide 0, speed 00`

When DRV10987 enters sleep mode, 1.8 and 3.3 LDO are off and SDA that is pulled up with 3.3-V LDO is low. The current measured is 66.9 µA.



Ch1: 24 V, Ch2: SDA, Ch3: SPEED PIN Ch4: W PHASE VOLT of Motor

Figure 2-2. Waveform of Entering Sleep Using Option 1

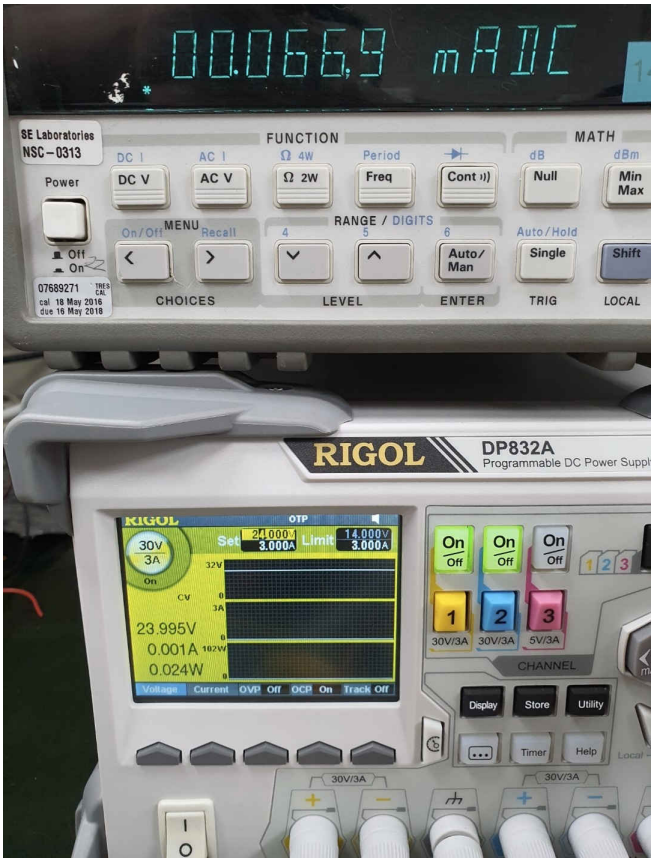
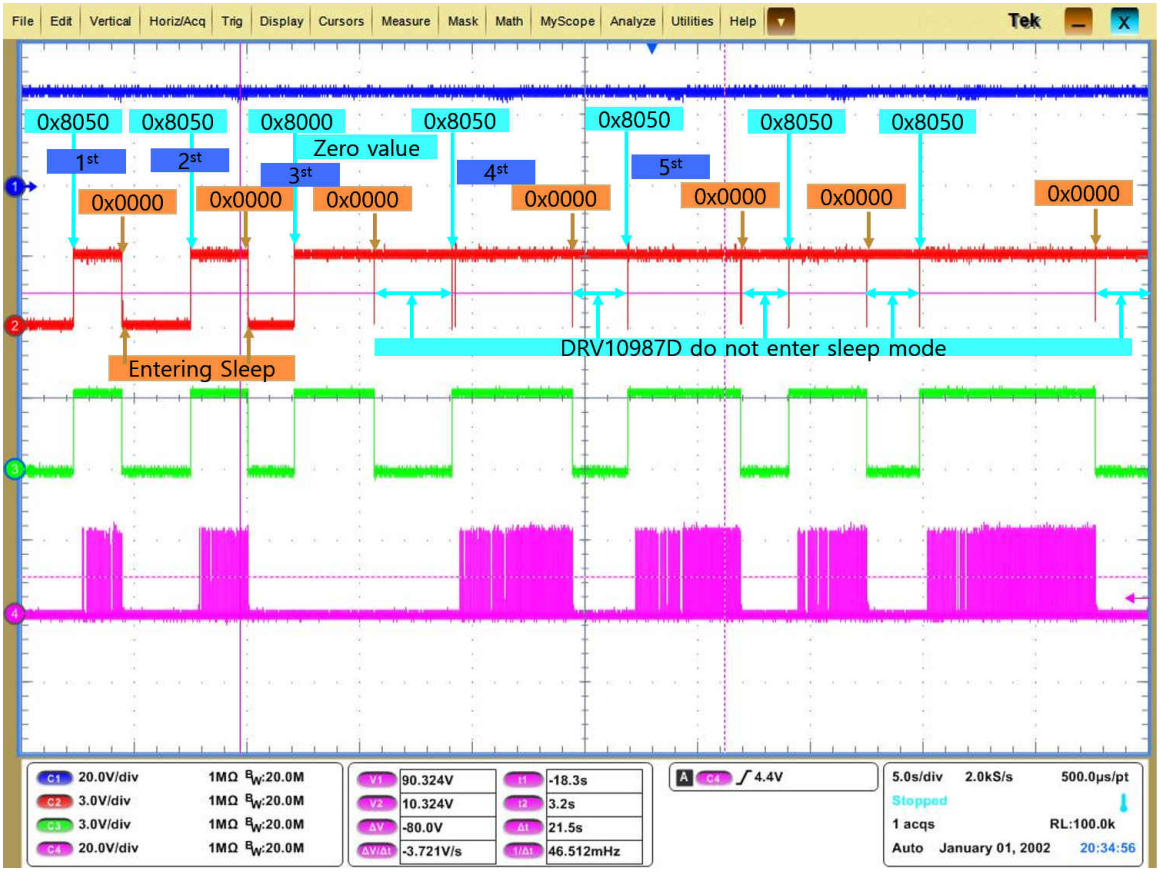


Figure 2-3. Measure of Sleep Current

2.4 Option 1 With Zero Value at Speed Register

Before executing Step3 and Step4 of Option 1, if the speed value is zero, DRV10987D is not able to enter sleep. Enter a non-zero value in the speed value as the first step in the DRV10987D data sheet . The following results are obtained through this test. Once a zero value is entered and entering sleep mode fails, DRV10987 sleep is not able to enter sleep mode even if a non-zero value is entered afterwords. At first and second speed command, a non-zero value is entered at speed value and the DRV10987 enters sleep mode. But at the third speed command, a zero value is entered at speed value and the DRV10987 is not able to enter sleep mode. After the third speed command, at fourth and fifth speed command non-zero value is entered but DRV10987D is not in sleep mode.

Waveform of Option 1 With Zero Value at Speed Register shows the waveform of Option 1 with a value of zero at the speed register.



Ch1: 24 V, Ch2: SDA, Ch3: SPEED PIN Ch4: W PHASE VOLT of Motor

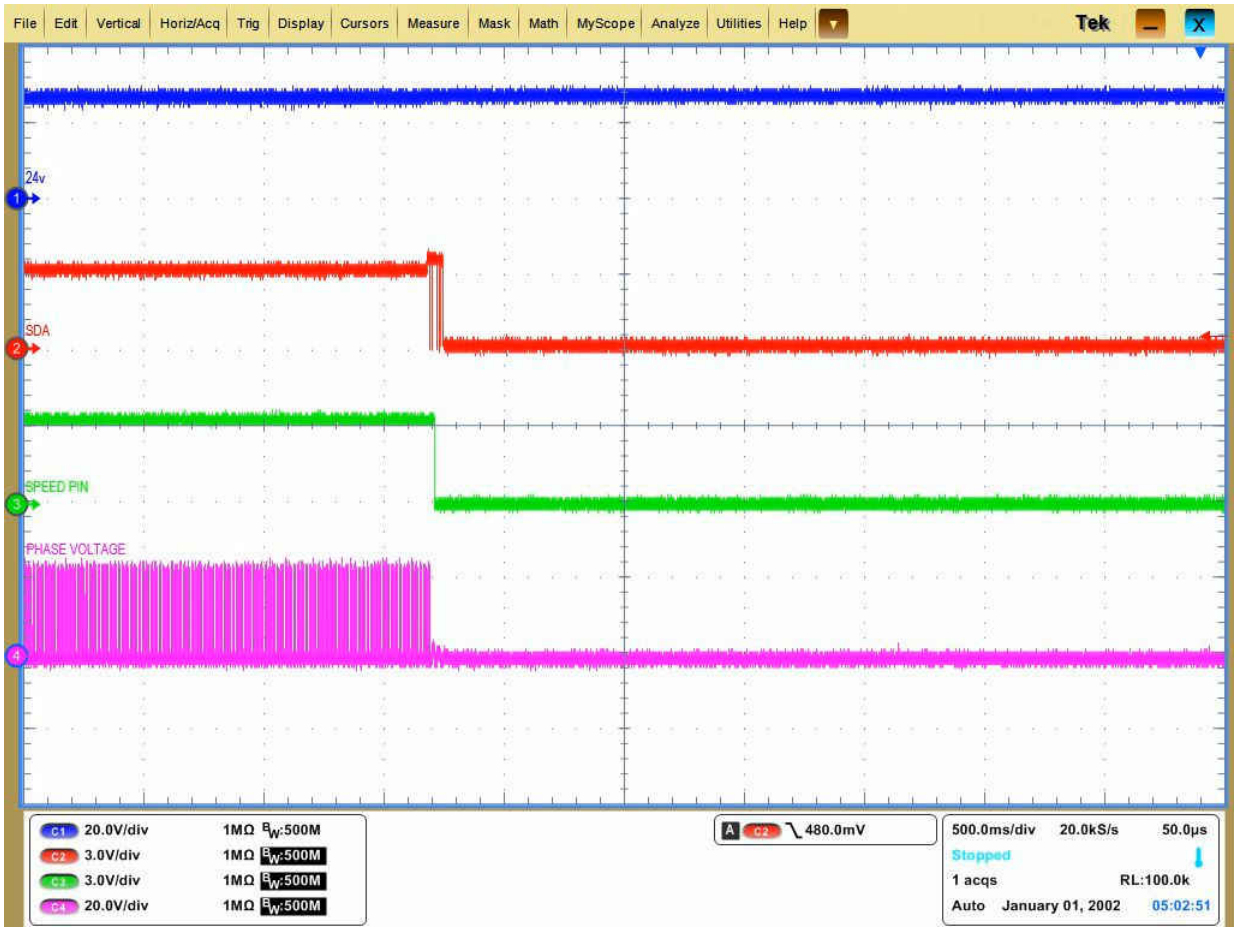
Waveform of Option 1 With Zero Value at Speed Register

2.5 Implementing C Code With Option 2

In the *DRV10987 12- to 24-V, Three-Phase, Sensorless BLDC Motor Driver Data Sheet*, the sequence of four steps is described to enter sleep mode. Not mentioned in the data sheet but necessary, Step3 is needed for implementation of Option 2. Apply *High* to the Speed pin to exit sleep mode. Before entering sleep mode, apply low to the Speed pin.

Table 2-2. Implementation C Code

	DRV10987 Data Sheet	Implementation in C Code
Step1	Set the motor disable bit to 1, that is, write 1 to register 0x60, EECtrl[15]	`/* Step1 disable motor. 0x8000 at 0x60 */` `DRV10987Q_Send(DRV10987Q_EECTRL_Reg ,0x8000);`
Step2	Set the I2C OverRide bit to 1, that is, write 1 to register 0x30, speedCtrl[15]	`//Step3 overRide 1` `DRV10987Q_Send(DRV10987Q_SpeedCtrl_Reg ,0x8000);`
Step3	Step3: Apply low to speed pin. After entering sleep mode This step is needed to exit sleep mode.	`P1OUT &= ~BIT5;//Speed pin voltage low 0V.`
Step4	Set the motor disable bit to 0, that is, write 0 to register 0x60, EECtrl[15].	`// Step4 enable motor` `DRV10987Q_Send(DRV10987Q_EECTRL_Reg ,0x0000);`
Step5	Provide the value of zero to the speed control register to enter sleep mode. That is, write 0 to register 0x30, speedCtrl[8:0].	`/* step6 overRide 0, speed 00 */` `DRV10987Q_Send(DRV10987Q_SpeedCtrl_Reg ,0x0000);`



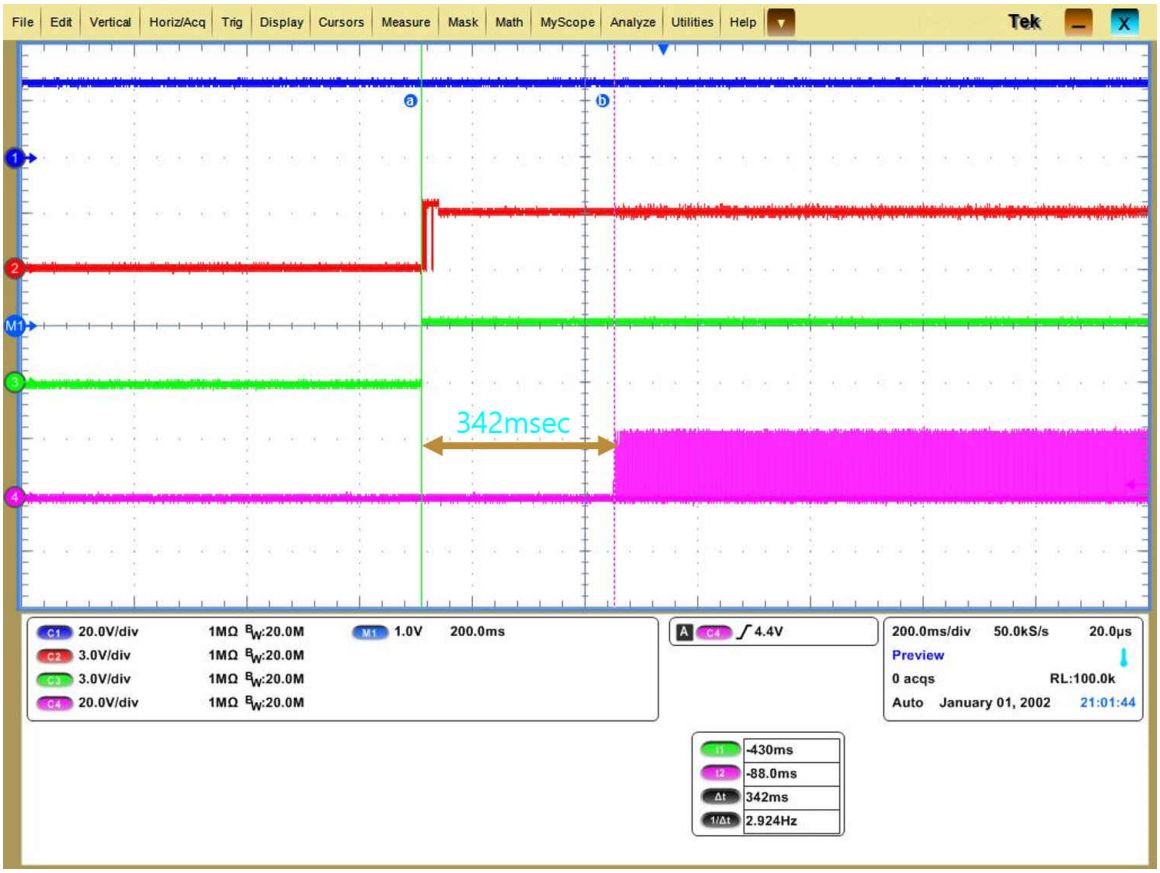
Ch1: 24 V, Ch2: SDA, Ch3: SPEED PIN Ch4: W PHASE VOLT of Motor

Figure 2-4. Waveform of Entering Sleep With Option 2

2.6 Implementation of Exiting From Sleep Mode

When exiting from sleep mode, the Speed command mode is analog mode or PWM mode according to EEPROM data and High is applied to the Speed pin. A value of 2 µs is needed to exit from sleep mode and 350 ms is required to drive the motor after exiting from sleep mode. The waveform of exiting from sleep mode shows 342 ms between exiting from sleep mode and running the motor.

```
    P1OUT |= BIT5;// Speed pin High 3.3V
/* input motor speed with I2C speed command mode */
    DRV10987Q_Send(DRV10987Q_SpeedCtrl_Reg  ,0x8050);
```



Ch1: 24 V, Ch2: SDA, Ch3: SPEED PIN Ch4: W PHASE VOLT of Motor

Figure 2-5. Waveform of Exiting From Sleep Mode

3 References

- Texas Instruments, *DRV10987 12- to 24-V, Three-Phase, Sensorless BLDC Motor Driver Data Sheet*

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