

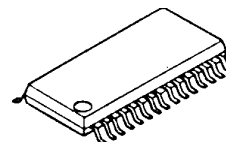
## PWM 3-PHASE DC BRUSHLESS MOTOR CONTROLLER

### ■ GENERAL DESCRIPTION

The NJW4303 is a 3-Phase Brushless DC Motor Control pre-driver IC with PWM control. It generates the most optimal current flow patterns by receiving rotor magnetic pole detection signals from hall elements of 3-phase brushless motor.

Operational voltage range for the IC has margin as 9.0V to 35V(maximum voltage of 40V), and it fits for a 12V/24V power supply. It is possible to put practical use such as speed control by internal oscillation circuit, and torque limiter control by current sensory circuit. With NJW4303, high reliability of various motor drive controls can be realized by a variety of function and a substantial protection circuit.

### ■ PACKAGE OUTLINE

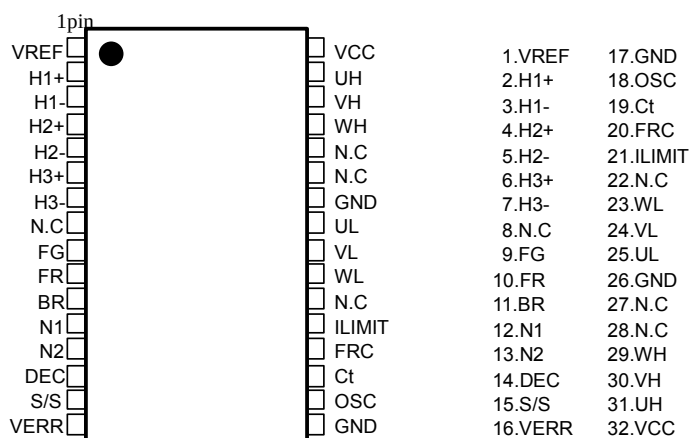


NJW4303V

### ■ FEATURES

- Maximum Supply Voltage : 40V
- Operating Voltage : 9.0 V to 35V
- 3-Phase Full-Wave PWM Predriver : Hi-side: Pch-FET/ Low-side: Nch-FET
- Low-side Gate Voltage Clamp : Gate Voltage=18V max.
- Internal PWM Oscillation Circuit : Frequency Setting by External Capacitor
- Current Protection Circuit : Current limit=0.25V±10%
- Low-Voltage Protection Circuit
- Forward/Reverse Direction : Changeable while Rotating
- Soft-Start Function : Controllable Dead-Time Settings
- ON/OFF Function : Using External Capacitor
- Brake Function : Stop with S/S Pin
- Lock Protection System
- Thermal Shutdown Circuit
- 120°/60° Phase Difference Change Function
- Multi-FG Output : 2bit Input Change Type
- Bi-CDMOS Technology
- Package Outline : SSOP32

### ■ PIN CONNECTION



## PIN FUNCTION LIST

| Pin#       | Terminal Name | Function                                      | Remark                                                                                                                                                 |
|------------|---------------|-----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1          | VREF          | 5V Output Voltage Terminal                    | Outputs Supply Voltage of 5V                                                                                                                           |
| 2          | H1+           | Hall Element Input Terminal H1+               | Use with H1-                                                                                                                                           |
| 3          | H1-           | Hall Element Input Terminal H1-               | Use with H1+                                                                                                                                           |
| 4          | H2+           | Hall Element Input Terminal H2+               | Use with H2-                                                                                                                                           |
| 5          | H2-           | Hall Element Input Terminal H2-               | Use with H2+                                                                                                                                           |
| 6          | H3+           | Hall Element Input Terminal H3+               | Use with H3-                                                                                                                                           |
| 7          | H3-           | Hall Element Input Terminal H3-               | Use with H3+                                                                                                                                           |
| 8,22,27,28 | N.C.          | No Connection                                 | No Connection                                                                                                                                          |
| 9          | FG            | FG pulse Output Terminal                      | Output Rotary Signal                                                                                                                                   |
| 10         | FR            | Forward/Reverse Direction Input Terminal      | L, or Open=Forward Direction, H=Reverse Direction                                                                                                      |
| 11         | BR            | Short Brake Input Terminal                    | L, or Open=Rotation, H=Short Brake                                                                                                                     |
| 12         | N1            | FG Pattern Switching Terminal1                | Set FG Pattern by Combination with N2. Cf. the below table                                                                                             |
| 13         | N2            | FG Pattern Switching Terminal2                | Set FG Pattern by Combination with N1. Cf. the below table                                                                                             |
| 14         | DEC           | Hall Input Phase Switching Terminal           | L, or Open=120° Hall Input, H=60° Hall Input                                                                                                           |
| 15         | S/S           | Start and Stop input Terminal                 | L, or Open=Start, H=Stop                                                                                                                               |
| 16         | VERR          | Error Amp Voltage Input Terminal              | Set Output ON Duty<br>H=Output ON Duty 100%, L=Output ON Duty 0%<br>Pull-up to VREF PIN in nonuse                                                      |
| 17,26      | GND           | Logic Ground Terminal                         | Connecting with Ground                                                                                                                                 |
| 18         | OSC           | PWM Control Capacitor Terminal                | Insert a Capacitor between Grounds. Set PWM frequency depending on the value of the Capacitor                                                          |
| 19         | Ct            | Lock Protection Capacitor Connection Terminal | Insert a Capacitor between Grounds. Depending on the value of the Capacitor, set On/Off timer for the Output at the time of activated Lock Protection. |
| 20         | FRC           | Dead-Time Capacitor Connection Terminal       | Insert a Capacitor between Grounds. Depending on the value of the Capacitor, set Output Dead Band at the time of FR switching                          |
| 21         | ILIMIT        | Over Current Sensing Terminal                 | Connect to the ground side of the external driver                                                                                                      |
| 23         | WL            | Output Terminal WL                            | Connect to Nch Gate Driver                                                                                                                             |
| 24         | VL            | Output Terminal VL                            | Connect to Nch Gate Driver                                                                                                                             |
| 25         | UL            | Output Terminal UL                            | Connect to Nch Gate Driver                                                                                                                             |
| 29         | WH            | Output Terminal WH                            | Connect to Pch Gate Driver                                                                                                                             |
| 30         | VH            | Output Terminal VH                            | Connect to Pch Gate Driver                                                                                                                             |
| 31         | UH            | Output Terminal UH                            | Connect to Pch Gate Driver                                                                                                                             |
| 32         | VCC           | Motor Voltage Supply Terminal                 | Connect motor power source to the terminal                                                                                                             |

\* All Ground Pins must be connected at the outside.

\* Electrical potential of all unused output pins must be fixed at the outside.

| FG Pattern by combination with N1 and N2 |        |        |                                                   |
|------------------------------------------|--------|--------|---------------------------------------------------|
| No.                                      | N1     | N2     | FG                                                |
| 1                                        | H      | H      | 1/2 Frequency Signal from H1                      |
| 2                                        | H      | L/OPEN | Signal from H1                                    |
| 3                                        | L/OPEN | H      | 1/2 Frequency Signal from 3 Hall Compound Signals |
| 4                                        | L/OPEN | L/OPEN | 3 Hall Compound Signals                           |



# NJW4303

## ■ ABSOLUTE MAXIMUM RATINGS

(Ta=25°C)

| PARAMETER                        | SYMBOL     | RATINGS     | UNIT | Remark                           |
|----------------------------------|------------|-------------|------|----------------------------------|
| Supply Voltage                   | $V_{CC}$   | 40          | V    | VCC PIN                          |
| Hi-side Output Terminal Voltage  | $V_{OH}$   | 40          | V    | UH, VH, WH PIN                   |
| FG Terminal Voltage              | $V_{FG}$   | 7           | V    | FG PIN                           |
| LIMIT Terminal Voltage           | $V_{LIM}$  | 3.5         | V    | ILIMIT PIN                       |
| VERR Terminal Voltage            | $V_{VERR}$ | 6           | V    | VERR PIN                         |
| Hall Input Terminal Voltage      | $V_{IH}$   | 4.5         | V    | H1+, H1-, H2+, H2-, H3+, H3- PIN |
| Logic Input Terminal Voltage     | $V_{IN}$   | 7           | V    | BR, FR, DEC, N1/N2, S/S PIN      |
| Reference Voltage Output Current | $I_{REF}$  | 30          | mA   | VREF PIN                         |
| Hi-side Output Current           | $I_{OH}$   | 40          | mA   | UH, VH, WH PIN                   |
| Low-side Output Current          | $I_{OL}$   | ±40         | mA   | UL, VL, WL PIN                   |
| FG Output Current                | $I_{FG}$   | 15          | mA   | FG PIN                           |
| Power Dissipation                | $P_D$      | 1190        | mW   | ※ Board Mounted                  |
| Operating Ambient Temperature    | Topr       | -40 to +85  | °C   |                                  |
| Storage Temperature              | Tstg       | -50 to +150 | °C   |                                  |

※ Mounted on designated board based on EIA/JEDEC. (114.3x76.2x1.6mm: 2Layers, FR-4)

## ■ RECOMMENDED OPERATIONAL CONDITIONS

(Ta=25°C)

| PARAMETER            | SYMBOL   | TEST CONDITION | MIN. | TYP. | MAX. | UNIT |
|----------------------|----------|----------------|------|------|------|------|
| Logic Supply Voltage | $V_{CC}$ |                | 9.0  | 24.0 | 35.0 | V    |

**■ ELECTRICAL CHARACTERISTICS**

( $V_{CC}=24V$ ,  $V_{IH1+}=V_{IH3+}=3.0V$ ,  $V_{IH1-}=V_{IH2-}=V_{IH3-}=2.0V$ ,  $V_{IH2+}=1.0V$ ,  $V_{IN}=V_{LIM}=V_{CT}=0V$ ,  
 $V_{VERR}=4.5V$ ,  $V_{OSC}=4.5V \rightarrow 0.5V$ ,  $C_{VREF}=1\mu F$ ,  $T_a=25^{\circ}C$ )

| PARAMETER                                                  | SYMBOL                 | TEST CONDITION                      | MIN. | TYP. | MAX. | UNIT        |
|------------------------------------------------------------|------------------------|-------------------------------------|------|------|------|-------------|
| <b>■ GENERAL</b>                                           |                        |                                     |      |      |      |             |
| Supply current 1                                           | $I_{CC1}$              | $V_{CC}=12V$                        | -    | 5.3  | 8.3  | mA          |
| Supply current 2                                           | $I_{CC2}$              |                                     | -    | 6.4  | 9.4  | mA          |
| <b>■ THERMAL SHUTDOWN BLOCK</b>                            |                        |                                     |      |      |      |             |
| Thermal shutdown operating                                 | $T_{TSD1}$             |                                     | -    | 170  | -    | $^{\circ}C$ |
| Thermal shutdown recovery                                  | $T_{TSD2}$             |                                     |      | 135  |      | $^{\circ}C$ |
| Thermal shutdown hysteresis                                | $\Delta T_{TSD}$       |                                     | -    | 35   | -    | $^{\circ}C$ |
| <b>■ UNDER VOLTAGE LOCK OUT BLOCK</b>                      |                        |                                     |      |      |      |             |
| UVLO operating voltage                                     | $V_{UML01}$            | $V_{CC}$ Decreasing                 | 6.3  | 6.8  | 7.3  | V           |
| UVLO recovery voltage                                      | $V_{UML02}$            | $V_{CC}$ Increasing                 | 6.8  | 7.3  | 7.8  | V           |
| UVLO hysteresis voltage                                    | $\Delta V_{UML0}$      |                                     | -    | 0.5  | -    | V           |
| <b>■ LOCK PROTECTION BLOCK (Ct PIN)</b>                    |                        |                                     |      |      |      |             |
| High level voltage                                         | $V_{Hct}$              |                                     | 3.30 | 3.55 | 3.80 |             |
| Low level voltage                                          | $V_{Lct}$              |                                     | 0.90 | 1.00 | 1.30 |             |
| Lock charge current                                        | $I_{CHGct}$            |                                     | 2.5  | 5.5  | 9.0  | $\mu A$     |
| Lock discharge current                                     | $I_{DCHGct}$           |                                     | 0.25 | 0.55 | 0.90 | $\mu A$     |
| Lock charge/discharge current                              | $I_{CHGct}/I_{DCHGct}$ |                                     | -    | 10   | -    | -           |
| <b>■ REFERENCE VOLTAGE BLOCK (VREF PIN)</b>                |                        |                                     |      |      |      |             |
| Reference voltage supply                                   | $V_{REF}$              | $I_{VREF}=1mA$                      | 4.5  | 5.0  | 5.5  | V           |
| Load regulation                                            | $\Delta V_{LOVREF}$    | $I_{VREF}=1$ to 10 mA               | -    | 15   | 60   | mV          |
| Line regulation                                            | $\Delta V_{LIVREF}$    | $V_{CC}=9$ to 35V, $I_{VREF}=1$ mA  | -    | 50   | 100  | mV          |
| <b>■ HALL AMP BLOCK (H1+, H1-, H2+, H2-, H3+, H3- PIN)</b> |                        |                                     |      |      |      |             |
| Hysteresis Voltage range                                   | $\Delta V_{HYSIH}$     |                                     | 10   | 30   | 50   | mV          |
| Input bias current                                         | $I_{BIH}$              | Per each input                      | -    | -    | 1.5  | $\mu A$     |
| <b>■ HI-SIDE BLOCK (UH, VH, WH PIN)</b>                    |                        |                                     |      |      |      |             |
| Hi-side output voltage                                     | $V_{OLH}$              | $I_{OH}=30$ mA                      | -    | 0.5  | 1.0  | V           |
| Hi-side leak current                                       | $I_{OLEAKH}$           | $V_{OH}=35V$                        | -    | -    | 1    | $\mu A$     |
| <b>■ LOW-SIDE BLOCK (UL, VL, WL PIN)</b>                   |                        |                                     |      |      |      |             |
| Low-side output H voltage1                                 | $V_{OHL1}$             | $I_{OLSOURCE}=30$ mA, $V_{CC}=12V$  | 8.0  | 10.0 | -    | V           |
| Low-side output H voltage2                                 | $V_{OHL2}$             | $I_{OLSOURCE}=30$ mA                | 8.0  | 10.0 | -    | V           |
| Low-side output L voltage                                  | $V_{OLL}$              | $I_{OLSINK}=30$ mA                  | -    | 0.5  | 1.0  | V           |
| Low-side clamp voltage                                     | $V_{CLL}$              | $I_{OLSOURCE}=0.1$ mA, $V_{CC}=35V$ | -    | -    | 18   | V           |
| <b>■ FG OUTPUT (FG PIN)</b>                                |                        |                                     |      |      |      |             |
| Output voltage                                             | $V_{FGL}$              | $I_{FG}=10$ mA                      | -    | 0.3  | 0.7  | V           |
| Leak current                                               | $I_{LEAKFG}$           | $V_{FG}=5V$                         | -    | -    | 1    | $\mu A$     |

## ■ ELECTRICAL CHARACTERISTICS

( $V_{CC}=24V$ ,  $V_{IH1+}=V_{IH3+}=3.0V$ ,  $V_{IH1-}=V_{IH2-}=V_{IH3-}=2.0V$ ,  $V_{IH2+}=1.0V$ ,  $V_{IN}=V_{LIM}=V_{CT}=0V$ ,  
 $V_{VERR}=4.5V$ ,  $V_{OSC}=4.5V \rightarrow 0.5V$ ,  $C_{VREF}=1\mu F$ ,  $T_a=25^{\circ}C$ )

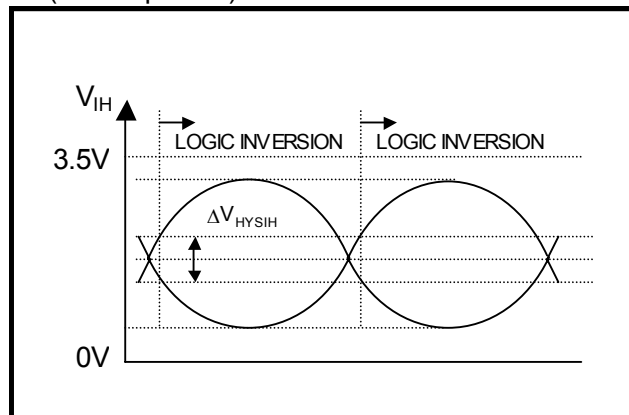
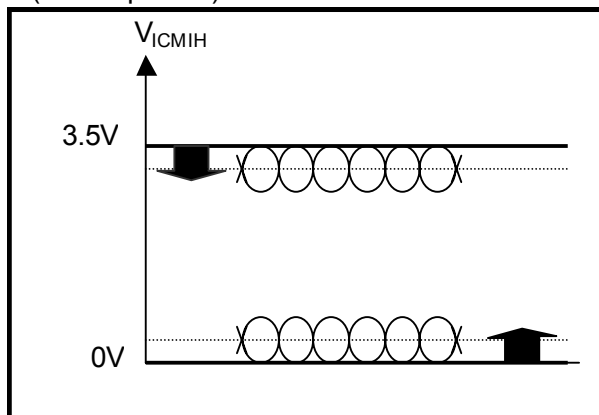
| PARAMETER                                             | SYMBOL         | TEST CONDITION                 | MIN.  | TYP.  | MAX.  | UNIT      |
|-------------------------------------------------------|----------------|--------------------------------|-------|-------|-------|-----------|
| ■ OVER CURRENT SENSOR BLOCK (ILIMIT PIN)              |                |                                |       |       |       |           |
| Sense voltage                                         | $V_{DETLIM}$   |                                | 0.225 | 0.250 | 0.275 | V         |
| Input bias current                                    | $I_{BILIM}$    |                                | -     | 1.6   | 5.0   | $\mu A$   |
| ■ ERROR AMP BLOCK (VERR PIN)                          |                |                                |       |       |       |           |
| PWM0% sense voltage                                   | $V_{PWM1VERR}$ | PWMDUTY=0%                     | -     | -     | 0.5   | V         |
| PWM100% sense voltage                                 | $V_{PWM2VERR}$ | PWMDUTY=100%                   | 3.6   | -     | -     | V         |
| Input bias current                                    | $I_{BVERR}$    |                                | -     | 1.6   | 5.0   | $\mu A$   |
| ■ OSCILLATOR BLOCK (OSC PIN)                          |                |                                |       |       |       |           |
| Saw wave peak voltage                                 | $V_{POSC}$     |                                | 2.7   | 3.0   | 3.3   | V         |
| Saw wave bottom voltage                               | $V_{BOSC}$     |                                | 1.00  | 1.35  | 1.60  | V         |
| OSC charge current                                    | $I_{CHGOSC}$   |                                | 30    | 50    | 70    | $\mu A$   |
| OSC discharge current                                 | $I_{DCHGOSC}$  |                                | 1     | 2     | 3     | mA        |
| Oscillation frequency                                 | $f_{OSC}$      | $C_{OSC}=1000pF$               | -     | 28    | -     | kHz       |
| ■ FR DEAD TIME BLOCK (FRC PIN)                        |                |                                |       |       |       |           |
| High level voltage                                    | $V_{HFRC}$     |                                | 3.15  | 3.5   | 3.85  | V         |
| Low level voltage                                     | $V_{LFRC}$     |                                | 0.9   | 1.0   | 1.2   | V         |
| FRC charge current                                    | $I_{CHGFRC}$   |                                | 16    | 26    | 36    | $\mu A$   |
| FRC discharge current                                 | $I_{DCHGFRC}$  |                                | 8     | 18    | 28    | $\mu A$   |
| FRC dead band time1                                   | $t_{DFRC1}$    | $C_{FRC}=1\mu F$               | -     | 140   | -     | ms        |
| FRC dead band time2                                   | $t_{DFRC2}$    | $C_{FRC}=1\mu F$               | -     | 100   | -     | ms        |
| ■ CONTOROL INPUT BLOCK (FR, BR, DEC, N1, N2, S/S PIN) |                |                                |       |       |       |           |
| Input High level current                              | $I_{HIN}$      | $V_{IN}=4.5V$ , per each input | 25    | 40    | 60    | $\mu A$   |
| Input low level current                               | $I_{LIN}$      | $V_{IN}=0V$ , per each input   | -     | -     | 1     | $\mu A$   |
| Pull-down resistance                                  | $R_{IN}$       |                                | -     | 110   | -     | $k\Omega$ |

## ■ PIN OPERATIONAL CONDITIONS

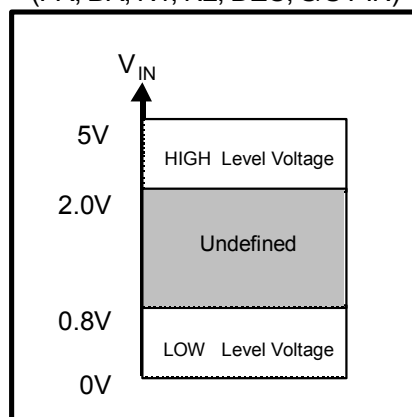
| PARAMETER                                          | SYMBOL           | TEST CONDITION | MIN. | TYP. | MAX. | UNIT |
|----------------------------------------------------|------------------|----------------|------|------|------|------|
| ■ HALLAMP INPUT (H1+, H1-, H2+, H2-, H3+, H3- PIN) |                  |                |      |      |      |      |
| Hall Input Sensitivity                             | $\Delta V_{MIH}$ | Peak to peak   | 0.1  | -    | -    | V    |
| Hall Input voltage range                           | $V_{ICMIH}$      |                | 0    | -    | 3.5  | V    |
| ■ CONTOROL INPUT (FR, BR, DEC, N1, N2, S/S PIN)    |                  |                |      |      |      |      |
| High level voltage                                 | $V_{HIN}$        |                | 2    | -    | 5    | V    |
| Low level voltage                                  | $V_{LIN}$        |                | 0    | -    | 0.8  | V    |
| ■ VERR INPUT (VERR PIN)                            |                  |                |      |      |      |      |
| Input voltage range                                | $V_{ICMVERR}$    |                | 0    | -    | 4.5  | V    |

# PIN / CIRCUIT OPERATIONAL DEFINITION

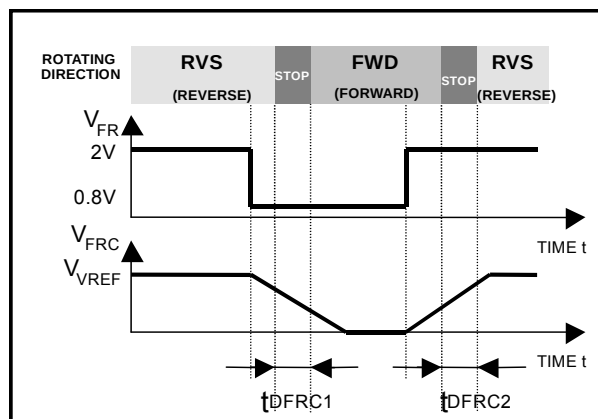
- ◆ Hall Input Pin Input Common-Mode Voltage Definition (Hall Amp Block)
- ◆ Hall Input Hysteresis Voltage Definition (Hall Amp Block)



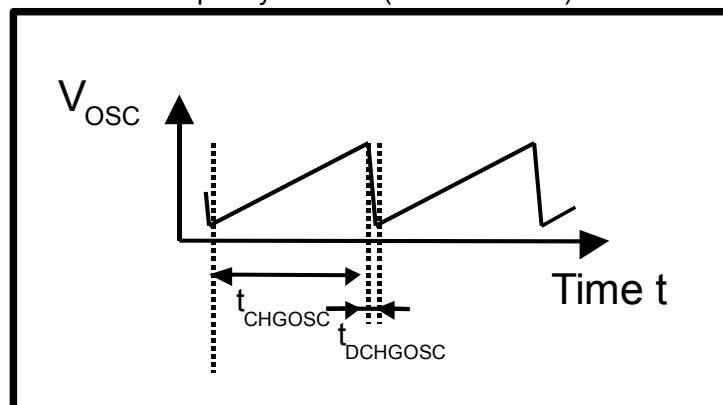
- ◆ Input pins thresh operational Definition (FR, BR, N1, N2, DEC, S/S PIN)



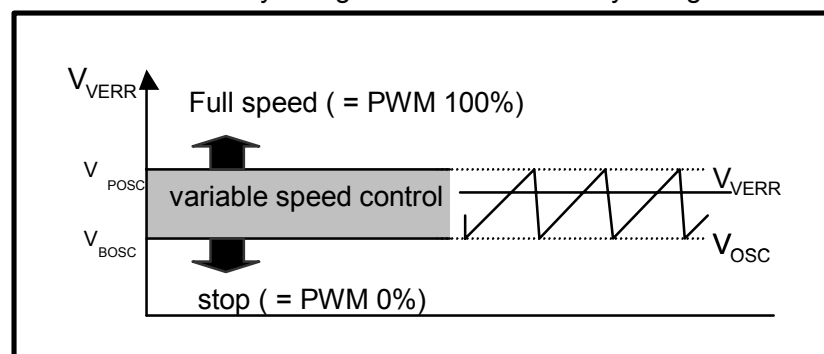
- ◆ FR Dead Time Definition (FR Dead Time Block)



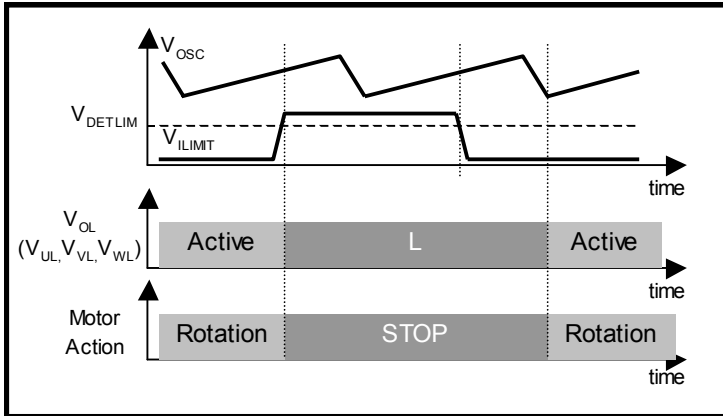
- ◆ Oscillation Frequency Definition (Oscillation Bloc)



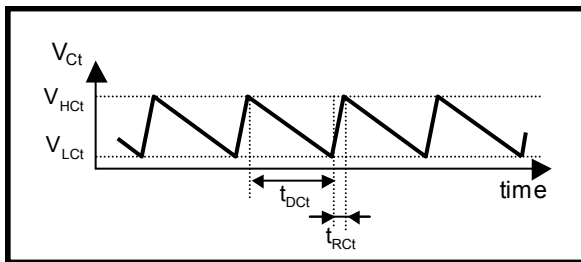
- ◆ PWM 100% Sensory Voltage / PWM 100% Sensory Voltage Definition (Error Amplifier Block)



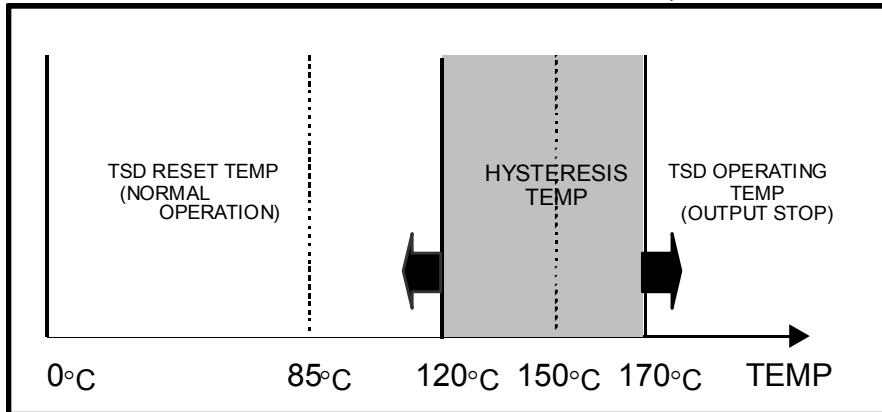
◆ Sensing Voltage/ Reset Voltage Definition (Over Current Sensing Block)



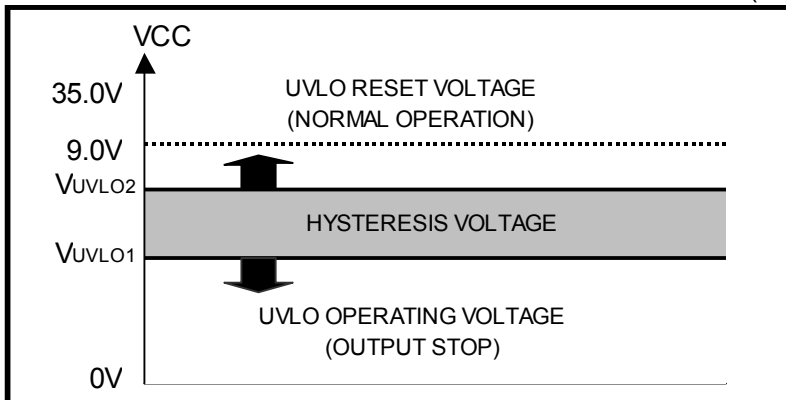
◆ Lock Protection Detection/ Reset Time Definition (Lock Protection Block)



◆ THERMAL SHUTDOWN OPERATIONS/SL DEFINITION (Thermal shutdown block)



◆ UNDER VOLTAGE PROTECTION OPERATIONAL DEFENITION (UNDER VOLTAGE PROTECTION BLOCK)





## ■ TRUTH TABLE

### ◆ INPUT VS OUTPUT TRUTH TABLE1 (DEC=L, H1+>H1-, H2+>H2-, H3+>H3-="H", Don't Care="X")

| H1 | H2 | H3 | BR | TSD | UVLO | S/S | VERR | FR | DEC | N1 | N2 | UH   | VH   | WH   | UL | VL | WL | FG   | VREF | COMMENT                      |
|----|----|----|----|-----|------|-----|------|----|-----|----|----|------|------|------|----|----|----|------|------|------------------------------|
| H  | L  | L  | L  | OFF | OFF  | L   | H    | L  | L   | L  | L  | Hi-Z | Hi-Z | L    | H  | L  | L  | L    | ON   | FR="L"<br>FWD Rotation       |
| H  | H  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | L    | L  | H  | L  | Hi-Z |      |                              |
| L  | H  | L  |    |     |      |     |      |    |     |    |    | L    | Hi-Z | Hi-Z | L  | H  | L  | L    |      |                              |
| L  | H  | H  |    |     |      |     |      |    |     |    |    | L    | Hi-Z | Hi-Z | L  | L  | H  | Hi-Z |      |                              |
| L  | L  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | L    | Hi-Z | L  | L  | H  | L    |      |                              |
| H  | L  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | L    | Hi-Z | H  | L  | L  | Hi-Z |      |                              |
| H  | L  | L  | L  | OFF | OFF  | L   | H    | H  | L   | L  | L  | L    | Hi-Z | Hi-Z | L  | L  | H  | L    | ON   | FR="H"<br>REV Rotation       |
| H  | H  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | L    | Hi-Z | L  | L  | H  | Hi-Z |      |                              |
| L  | H  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | L    | Hi-Z | H  | L  | L  | L    |      |                              |
| L  | H  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | L    | H  | L  | L  | Hi-Z |      |                              |
| L  | L  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | L    | L  | H  | L  | L    |      |                              |
| H  | L  | H  |    |     |      |     |      |    |     |    |    | L    | Hi-Z | Hi-Z | L  | H  | L  | Hi-Z |      |                              |
| H  | L  | L  | L  | OFF | OFF  | L   | H    | X  | L   | L  | L  | Hi-Z | Hi-Z | L    | H  | L  | L  | L    | ON   | FRC="L"<br>FWD Rotation      |
| H  | H  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | L    | L  | H  | L  | Hi-Z |      |                              |
| L  | H  | L  |    |     |      |     |      |    |     |    |    | L    | Hi-Z | Hi-Z | L  | H  | L  | L    |      |                              |
| L  | H  | H  |    |     |      |     |      |    |     |    |    | L    | Hi-Z | Hi-Z | L  | L  | H  | Hi-Z |      |                              |
| L  | L  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | L    | Hi-Z | L  | L  | H  | L    |      |                              |
| H  | L  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | L    | Hi-Z | H  | L  | L  | Hi-Z |      |                              |
| H  | L  | L  | L  | OFF | OFF  | L   | X    | X  | L   | L  | L  | Hi-Z | Hi-Z | L    | L  | L  | L  | L    | ON   | LOCK PROTECTION<br>Operation |
| H  | H  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | L    |    |    |    | Hi-Z |      |                              |
| L  | H  | L  |    |     |      |     |      |    |     |    |    | L    | Hi-Z | Hi-Z |    |    |    | L    |      |                              |
| L  | H  | H  |    |     |      |     |      |    |     |    |    | L    | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | L  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | L    | Hi-Z |    |    |    | L    |      |                              |
| H  | L  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | L    | Hi-Z |    |    |    | Hi-Z |      |                              |
| H  | L  | L  | L  | OFF | OFF  | L   | X    | X  | L   | L  | L  | Hi-Z | Hi-Z | L    | L  | L  | L  | L    | ON   | OVER CURRENT<br>Operation    |
| H  | H  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | L    |    |    |    | Hi-Z |      |                              |
| L  | H  | L  |    |     |      |     |      |    |     |    |    | L    | Hi-Z | Hi-Z |    |    |    | L    |      |                              |
| L  | H  | H  |    |     |      |     |      |    |     |    |    | L    | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | L  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | L    | Hi-Z |    |    |    | L    |      |                              |
| H  | L  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | L    | Hi-Z |    |    |    | Hi-Z |      |                              |
| H  | L  | L  | L  | OFF | OFF  | L   | L    | X  | L   | L  | L  | Hi-Z | Hi-Z | L    | L  | L  | L  | L    | ON   | VERR="L"<br>PWM Operation    |
| H  | H  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | L    |    |    |    | Hi-Z |      |                              |
| L  | H  | L  |    |     |      |     |      |    |     |    |    | L    | Hi-Z | Hi-Z |    |    |    | L    |      |                              |
| L  | H  | H  |    |     |      |     |      |    |     |    |    | L    | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | L  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | L    | Hi-Z |    |    |    | L    |      |                              |
| H  | L  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | L    | Hi-Z |    |    |    | Hi-Z |      |                              |
| H  | L  | L  | L  | X   | X    | H   | X    | X  | L   | L  | L  | Hi-Z | Hi-Z | Hi-Z | L  | L  | L  | L    | ON   | S/S="H"<br>STOP Operation    |
| H  | H  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | H  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | H  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | L  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| H  | L  | L  | L  | X   | ON   | X   | X    | X  | L   | L  | L  | Hi-Z | Hi-Z | Hi-Z | L  | L  | L  | L    | ON   | UVLO=ON<br>UVLO Operation    |
| H  | H  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | H  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | H  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | L  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| H  | L  | L  | L  | ON  | X    | X   | X    | X  | L   | L  | L  | Hi-Z | Hi-Z | Hi-Z | L  | L  | L  | L    | ON   | TSD=ON<br>TSD Operation      |
| H  | H  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | H  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | H  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | L  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| H  | L  | L  | H  | X   | X    | X   | X    | X  | L   | L  | L  | L    | L    | L    | L  | L  | L  | L    | ON   | BR="H"<br>BRAKE Operation    |
| H  | H  | L  |    |     |      |     |      |    |     |    |    | L    | L    | L    |    |    |    | Hi-Z |      |                              |
| L  | H  | L  |    |     |      |     |      |    |     |    |    | L    | L    | L    |    |    |    | Hi-Z |      |                              |
| L  | H  | H  |    |     |      |     |      |    |     |    |    | L    | L    | L    |    |    |    | Hi-Z |      |                              |
| L  | L  | H  |    |     |      |     |      |    |     |    |    | L    | L    | L    |    |    |    | Hi-Z |      |                              |

### ◆ INPUT VS OUTPUT TRUTH TABLE2 (DEC=L, Invalid Code Pattern)

(H1+>H1-, H2+>H2-, H3+>H3-="H", Don't Care="X")

| H1 | H2 | H3 | BR | TSD | UVLO | S/S | VERR | FR | DEC | N1 | N2 | UH   | VH   | WH   | UL | VL | WL | FG   | VREF | COMMENT                                        |
|----|----|----|----|-----|------|-----|------|----|-----|----|----|------|------|------|----|----|----|------|------|------------------------------------------------|
| H  | H  | H  | L  | X   | X    | X   | X    | X  | L   | L  | L  | Hi-Z | Hi-Z | Hi-Z | L  | L  | L  | L    | ON   | Invalid Code Pattern                           |
| L  | L  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                                                |
| H  | H  | H  | H  | X   | X    | X   | X    | X  | L   | L  | L  | L    | L    | L    | L  | L  | L  | L    | ON   | Invalid Code Pattern<br>BR="H" BRAKE Operation |
| L  | L  | L  |    |     |      |     |      |    |     |    |    | L    | L    | L    |    |    |    | Hi-Z |      |                                                |

◆ INPUT VS OUTPUT TRUTH TABLE3 (DEC=H, H1+>H1-, H2+>H2-, H3+>H3-="H", Don't Care="X")

| H1 | H2 | H3 | BR | TSD | UVLO | S/S | VERR | FR | DEC | N1 | N2 | UH   | VH   | WH   | UL | VL | WL | FG   | VREF | COMMENT                      |
|----|----|----|----|-----|------|-----|------|----|-----|----|----|------|------|------|----|----|----|------|------|------------------------------|
| H  | L  | L  | L  | OFF | OFF  | L   | H    | L  | H   | L  | L  | Hi-Z | Hi-Z | L    | H  | L  | L  | Hi-Z | ON   | FR="L"<br>FWD Rotation       |
| H  | H  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | L    | L  | H  | L  | L    |      |                              |
| H  | H  | H  |    |     |      |     |      |    |     |    |    | L    | Hi-Z | Hi-Z | L  | H  | L  | Hi-Z |      |                              |
| L  | H  | H  |    |     |      |     |      |    |     |    |    | L    | Hi-Z | Hi-Z | L  | L  | H  | L    |      |                              |
| L  | L  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | L    | Hi-Z | L  | L  | H  | Hi-Z |      |                              |
| L  | L  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | L    | Hi-Z | H  | L  | L  | L    |      |                              |
| H  | L  | L  | L  | OFF | OFF  | L   | H    | H  | H   | L  | L  | L    | Hi-Z | Hi-Z | L  | L  | H  | Hi-Z | ON   | FR="H"<br>REV Rotation       |
| H  | H  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | L    | Hi-Z | L  | L  | H  | L    |      |                              |
| H  | H  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | L    | Hi-Z | H  | L  | L  | Hi-Z |      |                              |
| L  | H  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | L    | H  | L  | L  | L    |      |                              |
| L  | L  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | L    | L  | H  | L  | Hi-Z |      |                              |
| L  | L  | L  |    |     |      |     |      |    |     |    |    | L    | Hi-Z | Hi-Z | L  | H  | L  | L    |      |                              |
| H  | L  | L  | L  | OFF | OFF  | L   | X    | X  | H   | L  | L  | Hi-Z | Hi-Z | L    | L  | L  | L  | Hi-Z | ON   | LOCK PROTECTION<br>Operation |
| H  | H  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | L    |    |    |    | L    |      |                              |
| H  | H  | H  |    |     |      |     |      |    |     |    |    | L    | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | H  | H  |    |     |      |     |      |    |     |    |    | L    | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | L  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | L    | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | L  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | L    | Hi-Z |    |    |    | L    |      |                              |
| H  | L  | L  | L  | OFF | OFF  | L   | X    | X  | H   | L  | L  | Hi-Z | Hi-Z | L    | L  | L  | L  | Hi-Z | ON   | OVER CURRENT<br>Operation    |
| H  | H  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | L    |    |    |    | L    |      |                              |
| H  | H  | H  |    |     |      |     |      |    |     |    |    | L    | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | H  | H  |    |     |      |     |      |    |     |    |    | L    | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | L  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | L    | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | L  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | L    | Hi-Z |    |    |    | L    |      |                              |
| H  | L  | L  | L  | OFF | OFF  | L   | L    | X  | H   | L  | L  | Hi-Z | Hi-Z | L    | L  | L  | L  | Hi-Z | ON   | VERR="L"<br>PWM Operation    |
| H  | H  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | L    |    |    |    | L    |      |                              |
| H  | H  | H  |    |     |      |     |      |    |     |    |    | L    | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | H  | H  |    |     |      |     |      |    |     |    |    | L    | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | L  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | L    | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | L  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | L    | Hi-Z |    |    |    | L    |      |                              |
| H  | L  | L  | L  | X   | X    | H   | X    | X  | H   | L  | L  | Hi-Z | Hi-Z | Hi-Z | L  | L  | L  | Hi-Z | ON   | S/S="H"<br>STOP Operation    |
| H  | H  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | L    |      |                              |
| H  | H  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | H  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | L  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | L  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | L    |      |                              |
| H  | L  | L  | L  | X   | ON   | X   | X    | X  | H   | L  | L  | Hi-Z | Hi-Z | Hi-Z | L  | L  | L  | Hi-Z | ON   | UVLO=ON<br>UVLO Operation    |
| H  | H  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | L    |      |                              |
| H  | H  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | H  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | L  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | L  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | L    |      |                              |
| H  | L  | L  | L  | ON  | X    | X   | X    | X  | H   | L  | L  | Hi-Z | Hi-Z | Hi-Z | L  | L  | L  | Hi-Z | ON   | TSD=ON<br>TSD Operation      |
| H  | H  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | L    |      |                              |
| H  | H  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | H  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | L  | H  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | Hi-Z |      |                              |
| L  | L  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z |    |    |    | L    |      |                              |
| H  | L  | L  | H  | X   | X    | X   | X    | X  | H   | L  | L  | L    | L    | L    | L  | L  | L  | Hi-Z | ON   | BR="H"<br>BRAKE Operation    |
| H  | H  | L  |    |     |      |     |      |    |     |    |    | L    | L    | L    |    |    |    | Hi-Z |      |                              |
| H  | H  | H  |    |     |      |     |      |    |     |    |    | L    | L    | L    |    |    |    | Hi-Z |      |                              |
| L  | H  | H  |    |     |      |     |      |    |     |    |    | L    | L    | L    |    |    |    | Hi-Z |      |                              |
| L  | L  | H  |    |     |      |     |      |    |     |    |    | L    | L    | L    |    |    |    | Hi-Z |      |                              |
| L  | L  | L  |    |     |      |     |      |    |     |    |    | L    | L    | L    |    |    |    | L    |      |                              |

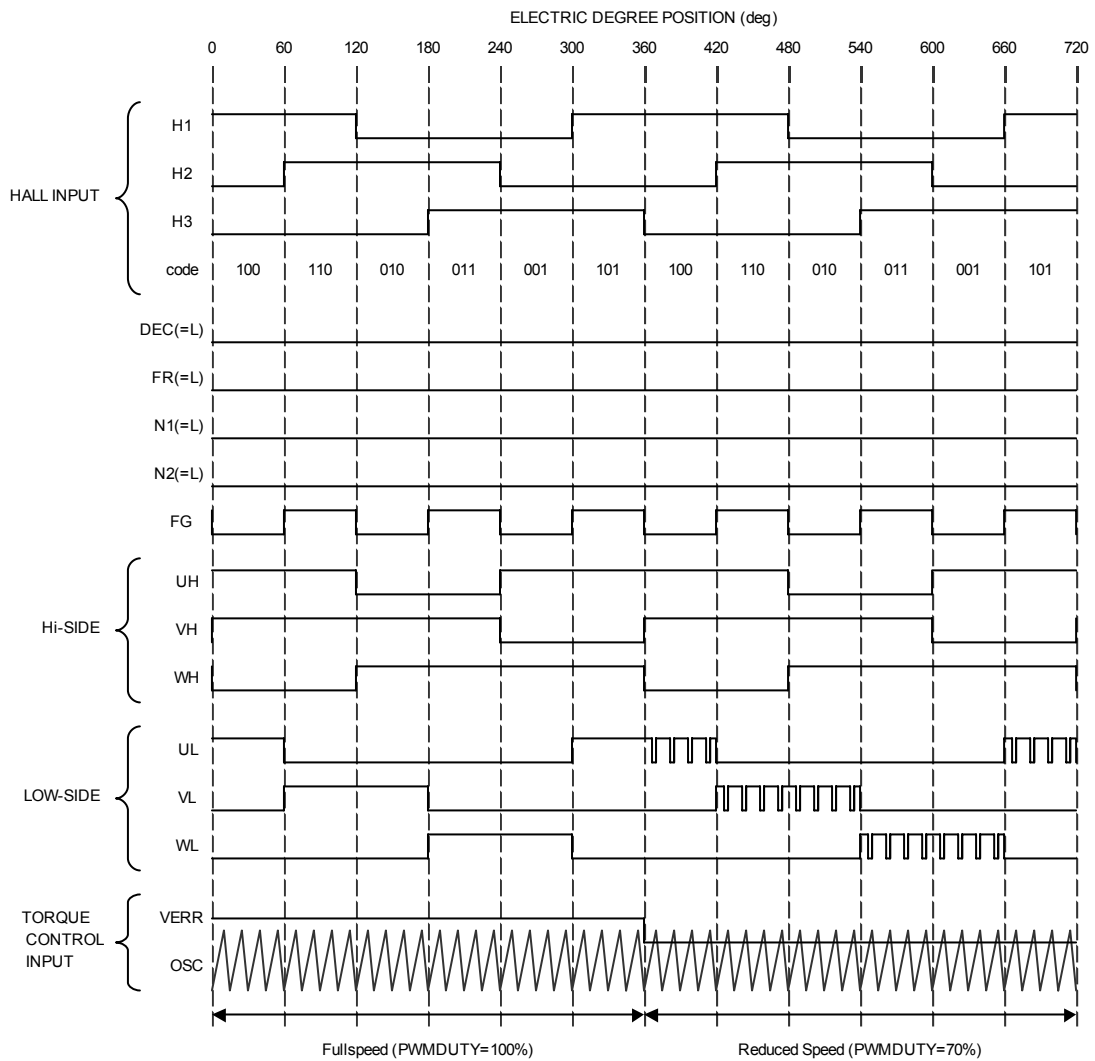
◆ INPUT VS OUTPUT TRUTH TABLE4 (DEC=H, Invalid Code Pattern)  
(H1+>H1-, H2+>H2-, H3+>H3-="H", Don't Care="X")

| H1 | H2 | H3 | BR | TSD | UVLO | S/S | VERR | FR | DEC | N1 | N2 | UH   | VH   | WH   | UL | VL | WL | FG   | VREF | COMMENT                                        |
|----|----|----|----|-----|------|-----|------|----|-----|----|----|------|------|------|----|----|----|------|------|------------------------------------------------|
| H  | L  | H  | L  | X   | X    | X   | X    | X  | H   | L  | L  | Hi-Z | Hi-Z | Hi-Z | L  | L  | L  | L    | ON   | Invalid Code Pattern                           |
| L  | H  | L  |    |     |      |     |      |    |     |    |    | Hi-Z | Hi-Z | Hi-Z | L  | L  | L  | Hi-Z |      |                                                |
| H  | L  | H  | H  | X   | X    | X   | X    | X  | H   | L  | L  | L    | L    | L    | L  | L  | L  | L    | ON   | Invalid Code Pattern<br>BR="H" BRAKE Operation |
| L  | H  | L  |    |     |      |     |      |    |     |    |    | L    | L    | L    | L  | L  | L  | Hi-Z |      |                                                |

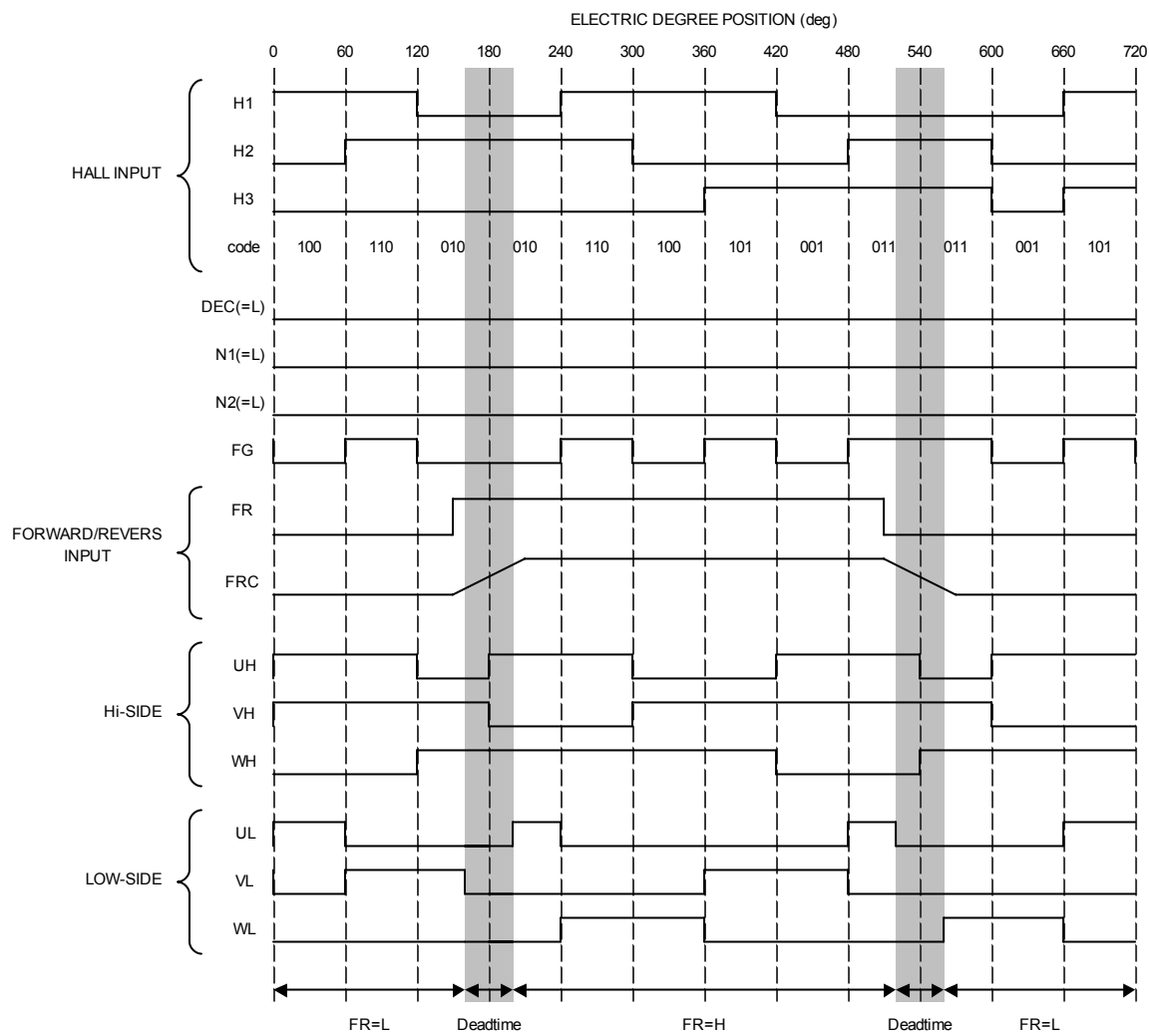
## ■ TIMING CHART

※ Codes used in Hall input:  
 Logics of H1, H2, H3 are expressed with each  
 3-column starting from the top.  
 High Logic = 1, Low Logic = 0

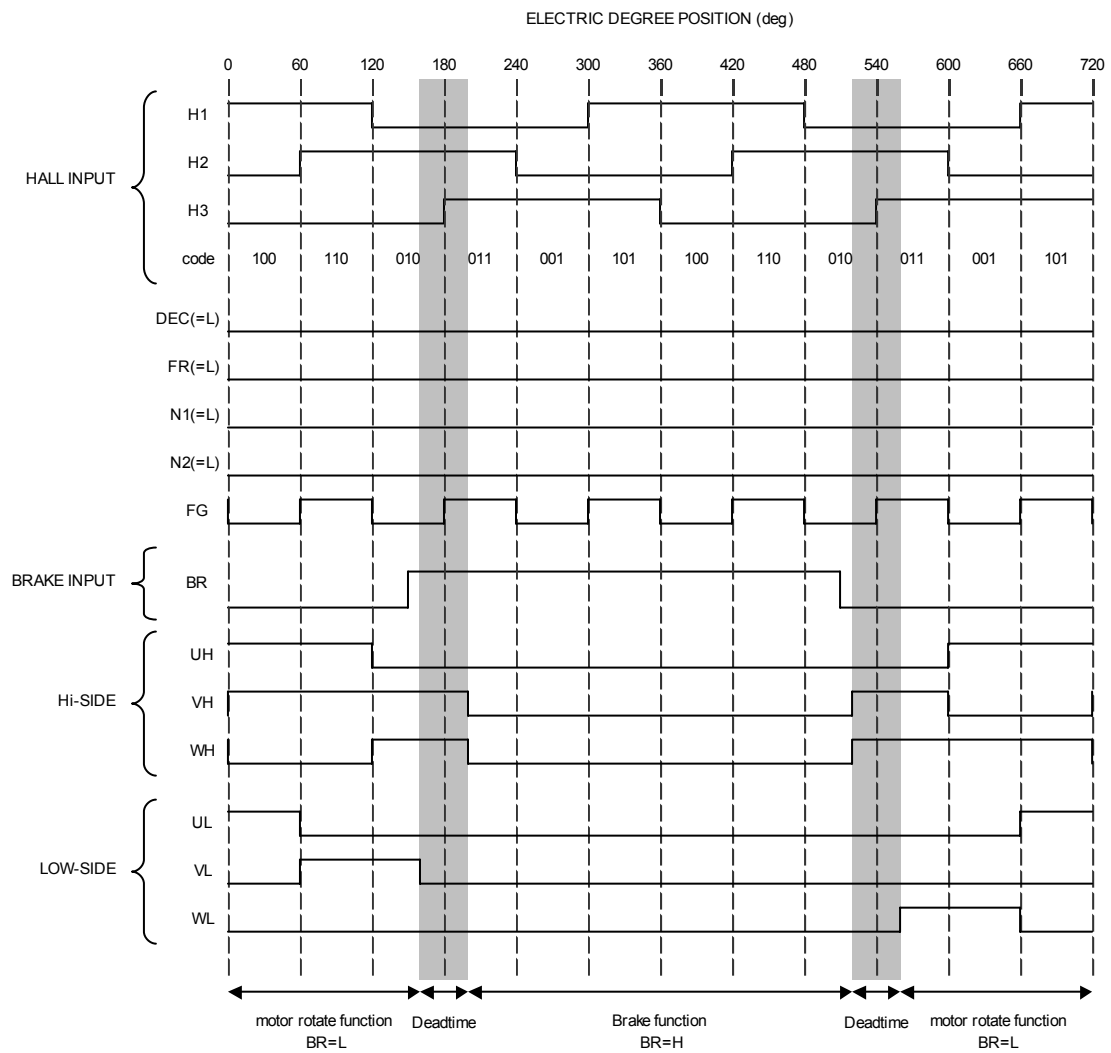
### 1. Normal Function→PWM Function



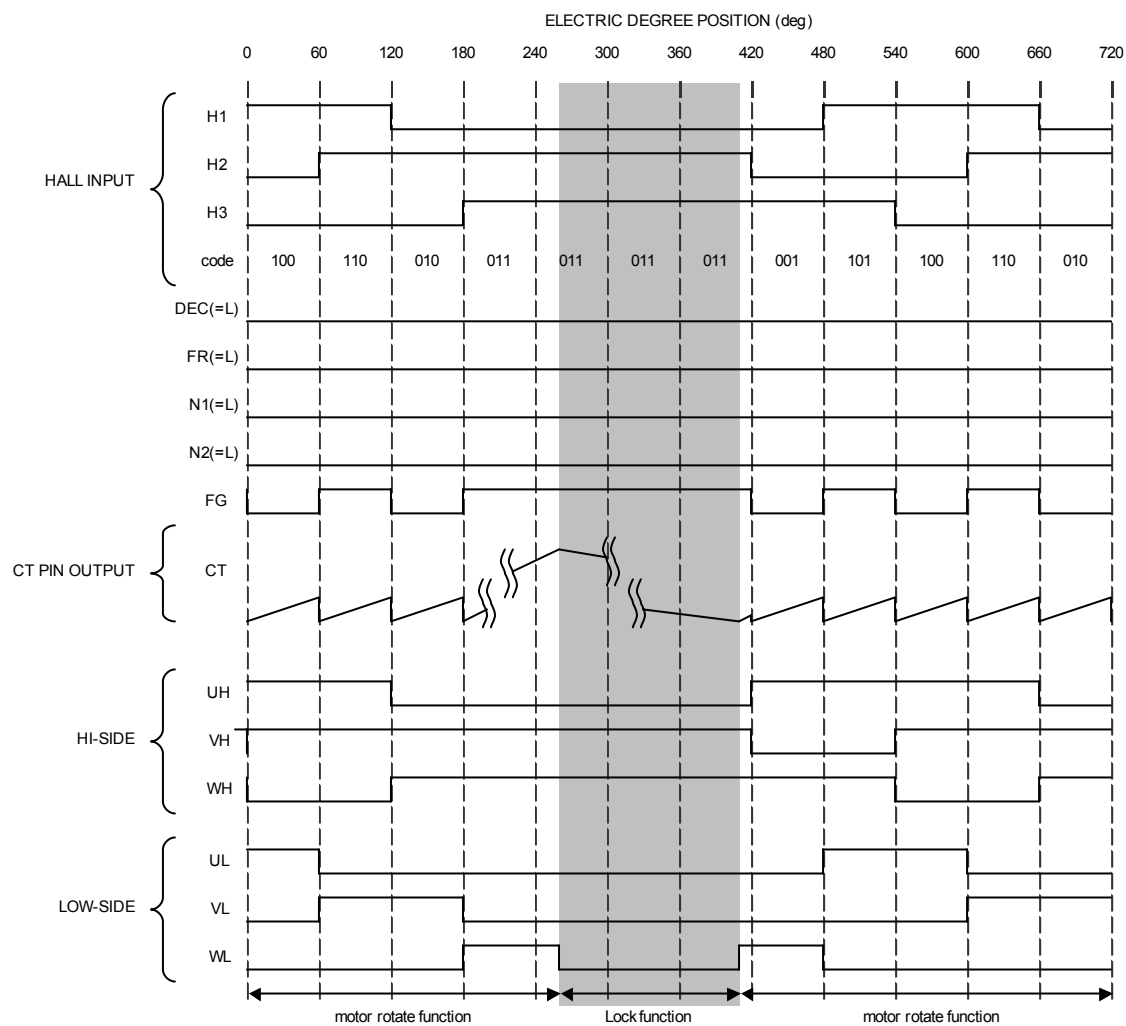
2. NORMAL FUNCTION→FORWARD/REVERSE SWITCHING while rotating



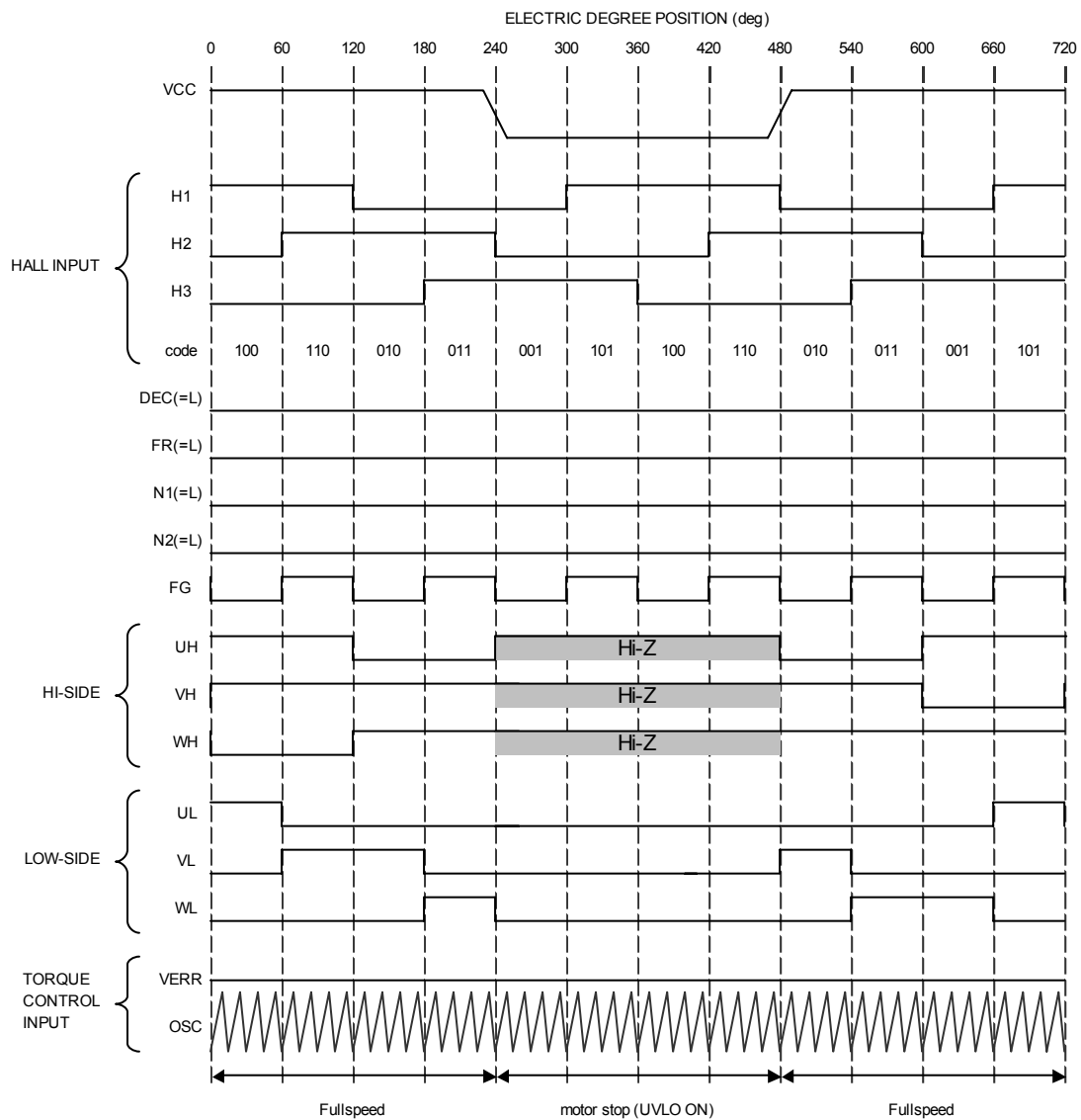
## 3. NORMAL FUNCTION→BRAKE CONTROL→BRAKE RESET



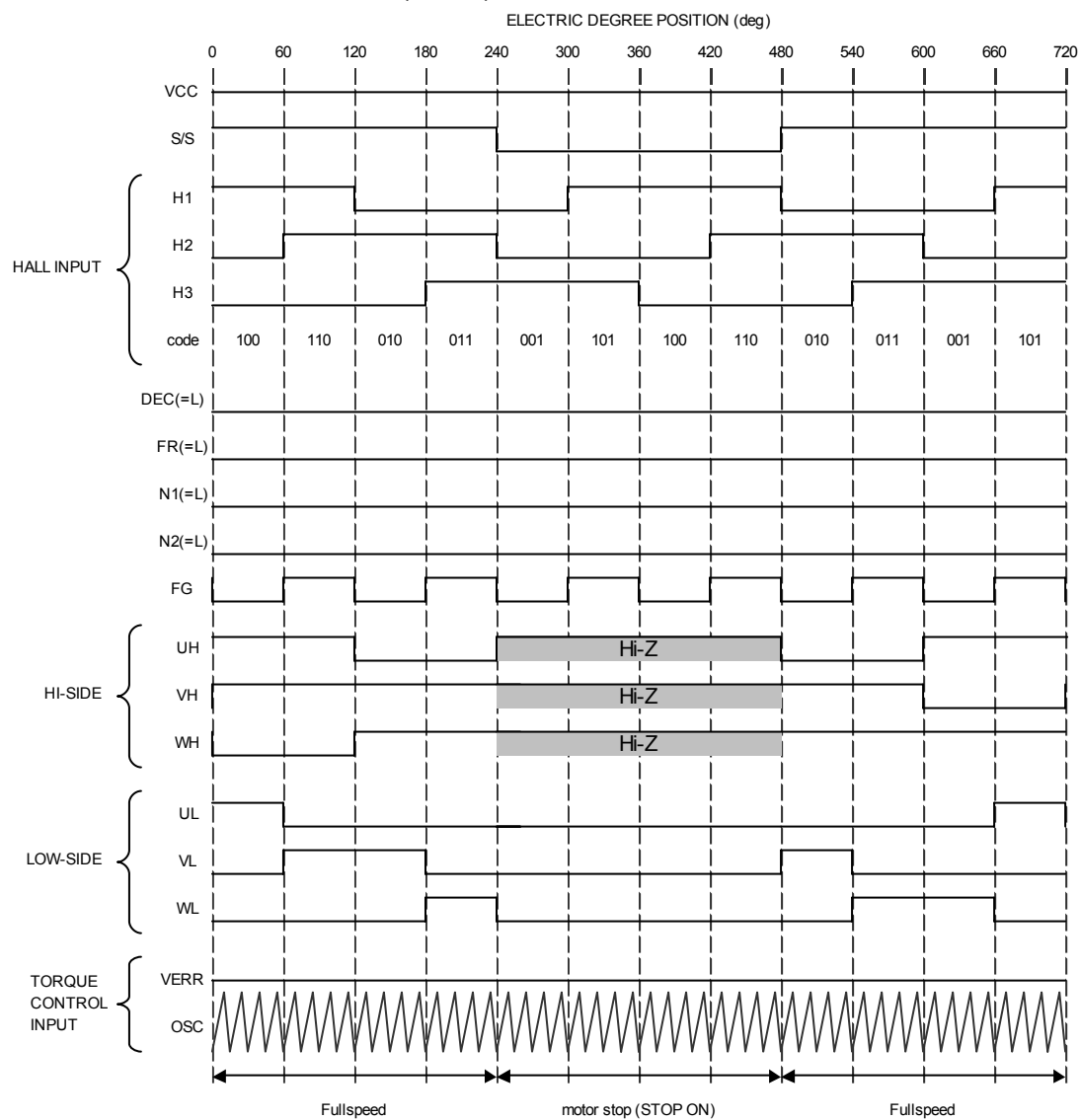
4. NORMAL FUNCTION→LOCK PROTECTION→LOCK RESET



## 5. NORMAL FUNCTION→LOW VOLTAGE PROTECTION→NORMAL FUNCTION

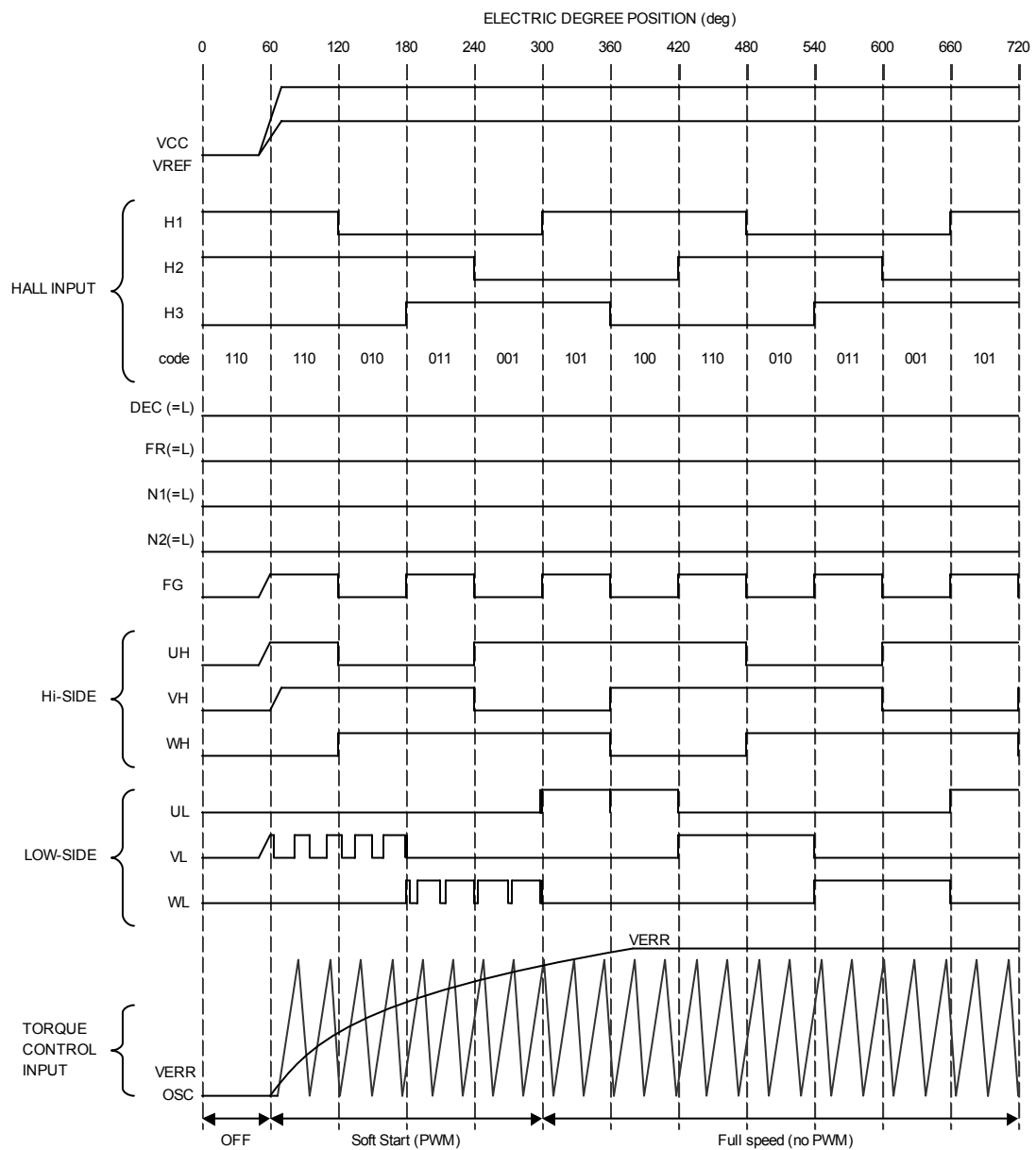


6. NORMAL FUNCTION→STOP FUNCTION (S/S=H)→NORMAL FUNCTION



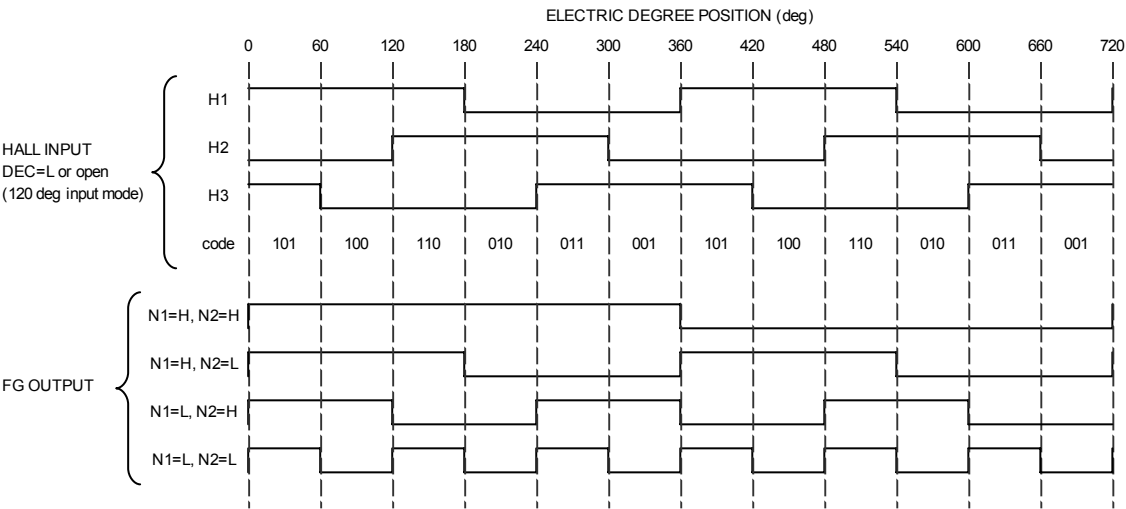


## 7. SOFT START FUNCTION

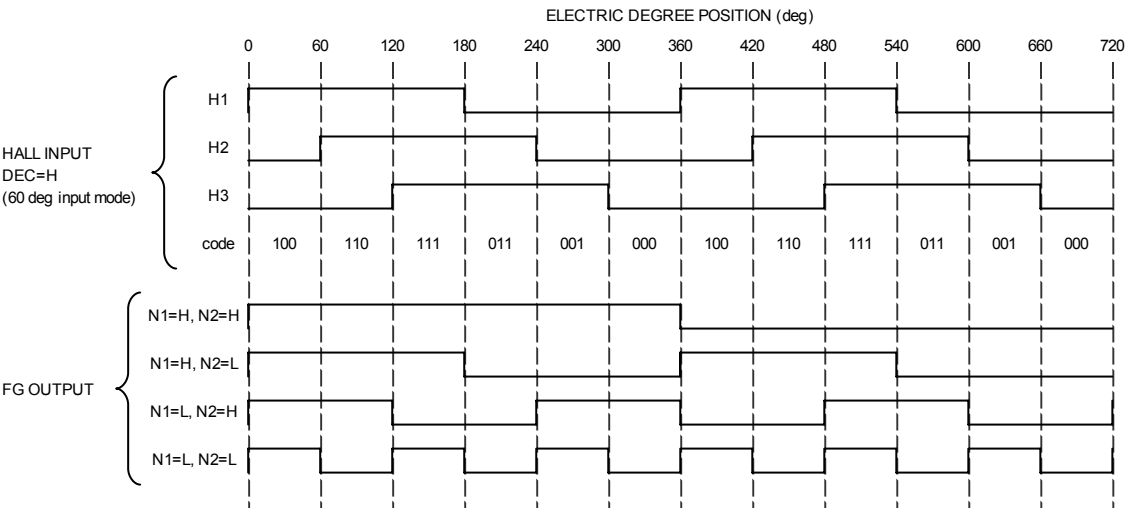


8. FG OUTPUT TIMING CHART

OUTPUT TIMING CHART 1 (120 deg Input Mode)



OUTPUT TIMING CHART 2 (60 deg Input Mode)



\* When the status of N1/N2 is H/H or L/H, FG output is not synchronized with Hall input, because FG output is produced by using a frequency divider.

## FUNCTION DESCRIPTION

### ◆ Lock Protection Block – Detect/Reset Time

Lock Protection can be done by charging/discharging to the capacitor  $C_{CT}$ . Lock Protection Detect time ( $t_{DCt}$ ) and Reset time ( $t_{RCt}$ ) are determined by the value of either  $Ct$  charging current ( $I_{CHGCT}$ ) or  $Ct$  discharging current ( $I_{DCHGCT}$ ) and the value of the external capacitor  $C_{CT}$ . To adjust Detect/Reset Time, change the value of  $C_{CT}$ . The calculation formula for Detect/Reset Time can be described in equation below: adjustment range for  $C_{CT}$  is  $0.1\mu F$  to  $10\mu F$ .

|             | Symbol    | Formula                                      | Comments |
|-------------|-----------|----------------------------------------------|----------|
| Detect Time | $t_{DCt}$ | $t_{DCt} \cong 4.6 \cdot 10^6 \cdot C_{CT}$  |          |
| Reset Time  | $t_{RCt}$ | $t_{RCt} \cong 0.46 \cdot 10^6 \cdot C_{CT}$ |          |

Figure1: Lock Protection Detect/ Reset Time Calculating Formula

When the motor is rotating, electric charge of  $C_{CT}$  capacitor discharging is produced repeatedly by input from hall signal. However, when we set the motor to low speed using the speed control application, input time from hall signal is longer, with this,  $Ct$  voltage level will increase and malfunction can be expected. When this occurs, it is recommended to add  $Ct$  discharge circuit by using FG signal output. Please refer to typical application circuit 2.

### ◆ Reference Voltage Block – How to use VREF

When using VREF pin, make sure that it is not oscillating.  
Use the recommended VCC operational condition.

### ◆ Hall Amp Block - Capacitor

Input from hall signal requires more than that of the Hall Input Sensitivity ( $\Delta V_{MIH} = 100mV$ ).

Taking measures in keeping noise immunity, when using FG output, FG jitter can be expected. When this occurs, it is recommended to add capacitors more than  $0.01\mu F$  between Hall input pins.

### ◆ Hall Amp Block – How to use Hall IC

Hall input pins H1-, H2- and H3- are biased to  $V_{REF}/2$ .

To keep Hall IC Output voltage within the Hall Input voltage range ( $V_{ICMIH}$ ), it needs to add 2 pieces of biased resistor for every H1+, H2+ and H3+ pins.

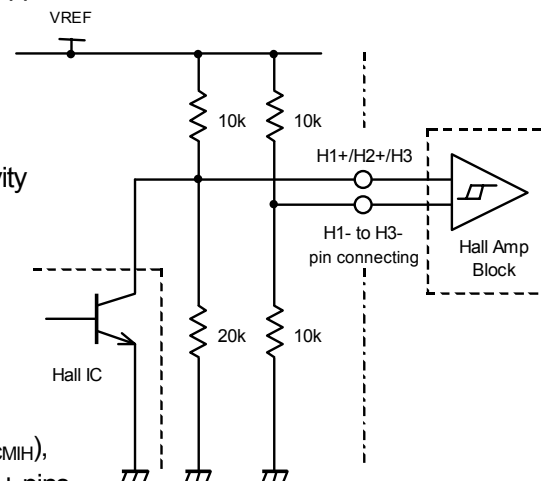


Figure2: Hall IC application

### ◆ Oscillation Block - Oscillation Frequency

OSC pin produce Oscillating wave by charging/discharging to the capacitor  $C_{OSC}$ . Oscillating frequency ( $f_{OSC}$ ) is modulated by  $C_{OSC}$ , and determined by charging time ( $t_{CHGOSC}$ ) and discharging time ( $t_{DCHGOSC}$ ). The oscillation frequency depends on  $t_{CHGOSC}$  in great deal compare to  $t_{DCHGOSC}$ , so that the calculation formula for oscillation frequency can be described in equation below: adjustment range for  $C_{OSC}$  is  $330pF$  to  $2200pF$ .

|                       | Symbol    | Formula                                 | Comments |
|-----------------------|-----------|-----------------------------------------|----------|
| Oscillation Frequency | $f_{OSC}$ | $F_{OSC} \cong 28 \cdot 10^6 / C_{OSC}$ |          |

Figure3: Oscillation Frequency Calculating Formula

### ◆ FR Dead Time Block – Dead Band Time

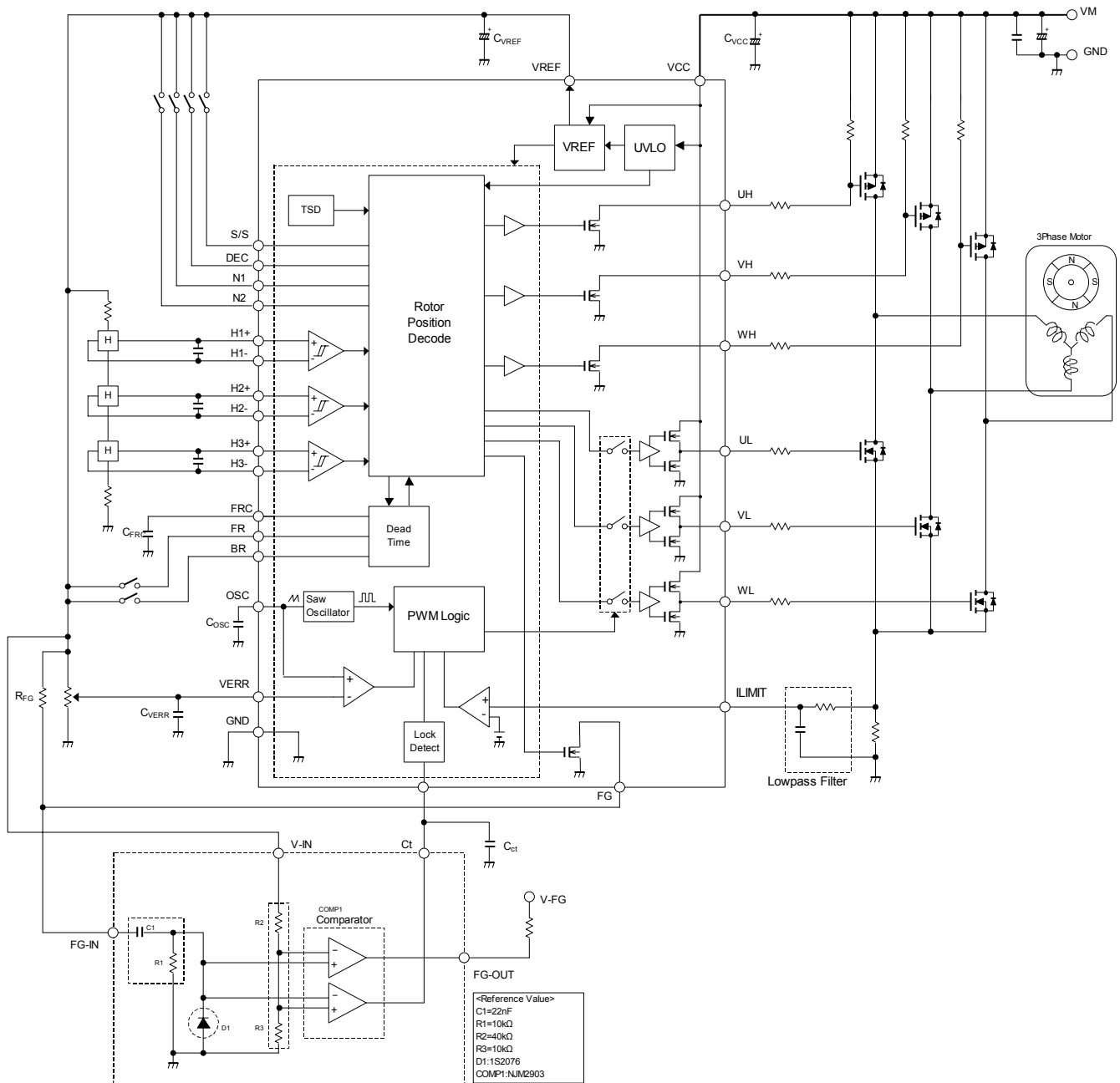
FR Dead band time is divided in two types depending on giving conditions.

The two dead band time are determined by the value of either FRC charged current or FRC discharge current  $I_{DCHGFRC}$ , and the value of an external capacitor. To adjust the dead band time, change the value of  $C_{FRC}$ . FR dead band time can be expressed as following: adjustment range for  $C_{FRC}$  is more than  $1pF$ .

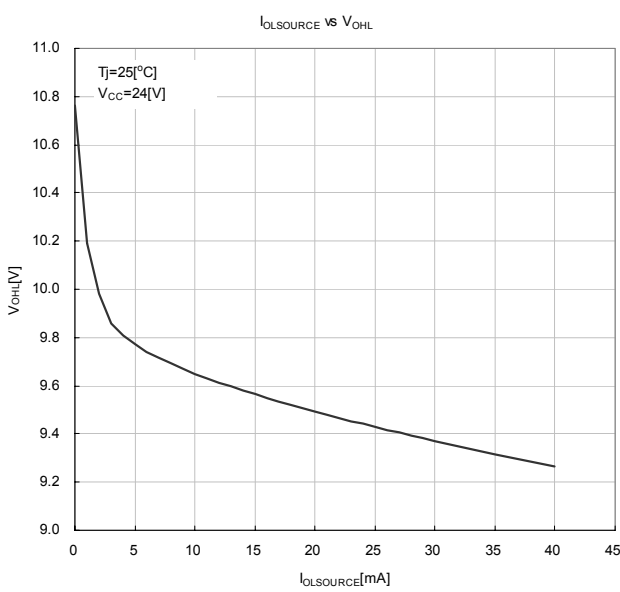
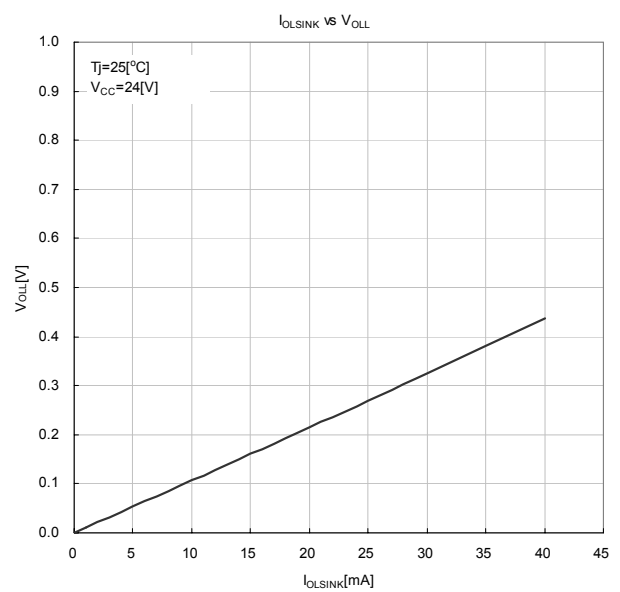
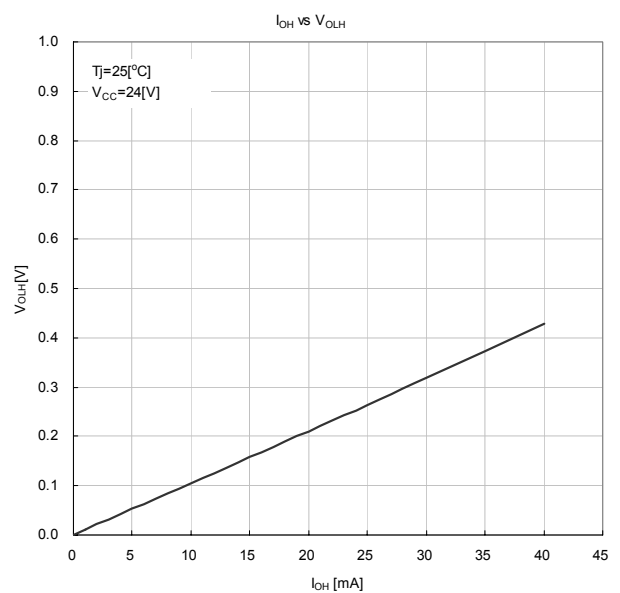
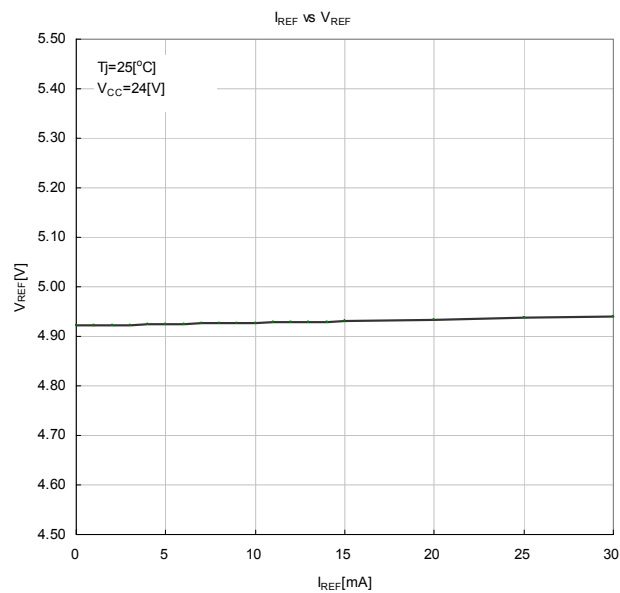
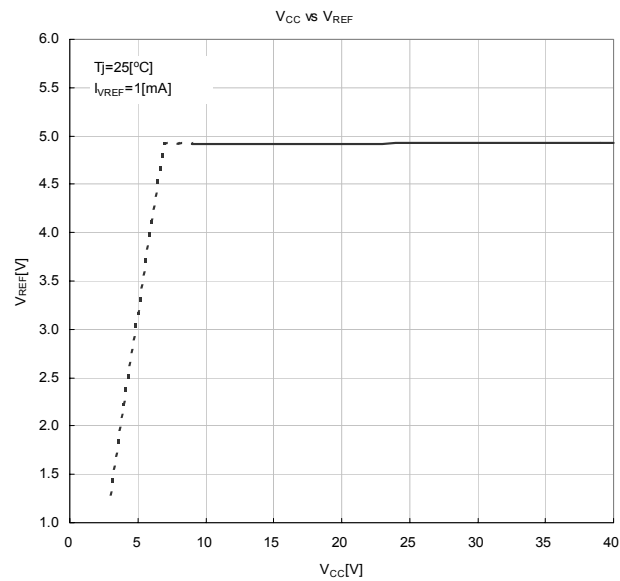
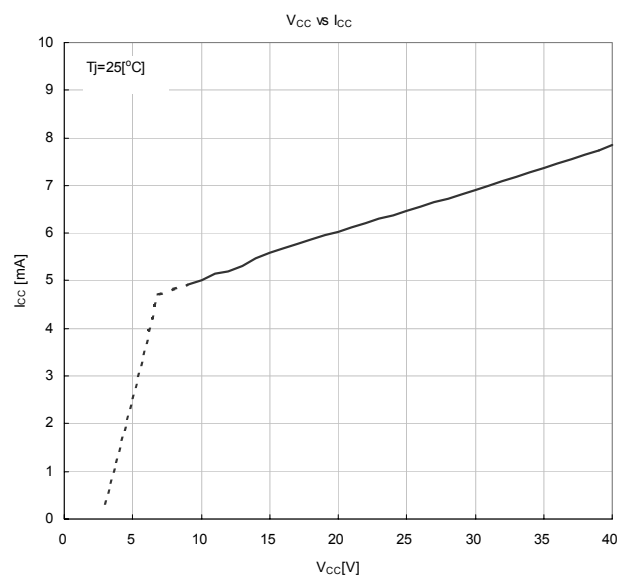
|                    | Symbol      | Formula                                        | Comments          |
|--------------------|-------------|------------------------------------------------|-------------------|
| FR Dead Band Time1 | $t_{DFRC1}$ | $t_{DFRC1} \cong 140 \cdot 10^3 \cdot C_{FRC}$ | FR : H → L (open) |
| FR Dead Band Time2 | $t_{DFRC2}$ | $t_{DFRC2} \cong 140 \cdot 10^3 \cdot C_{FRC}$ | FR : L (open) → H |

Figure4: Dead Band Time Calculating Formula

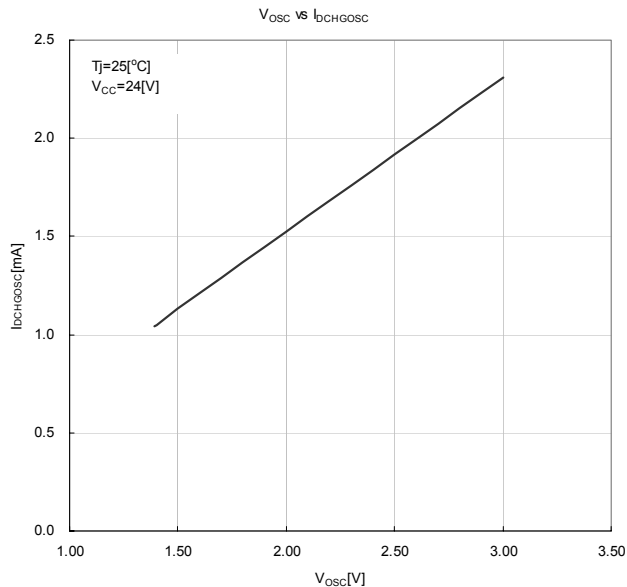
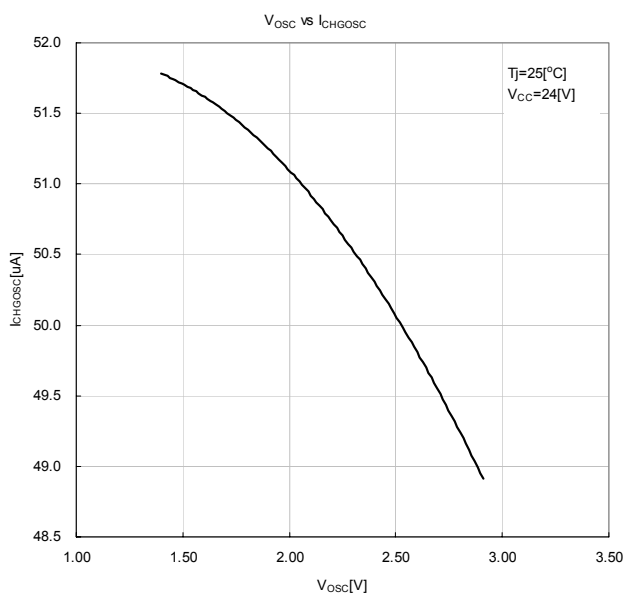
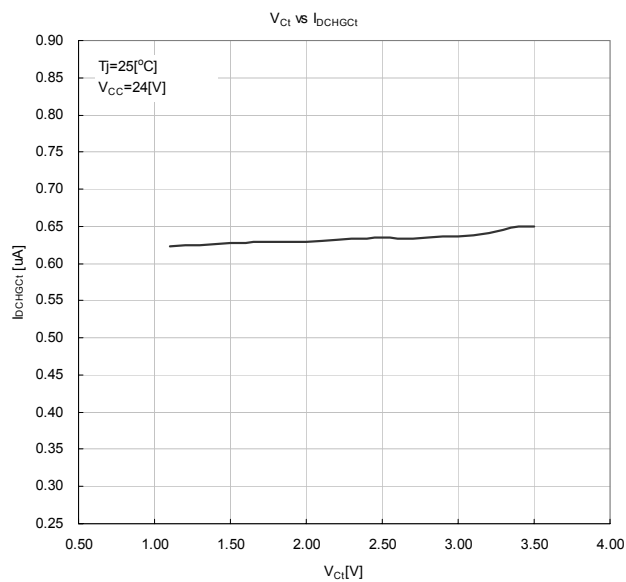
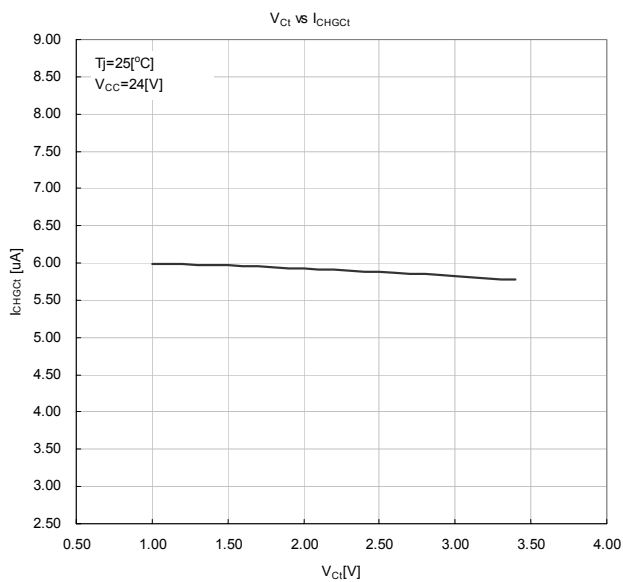
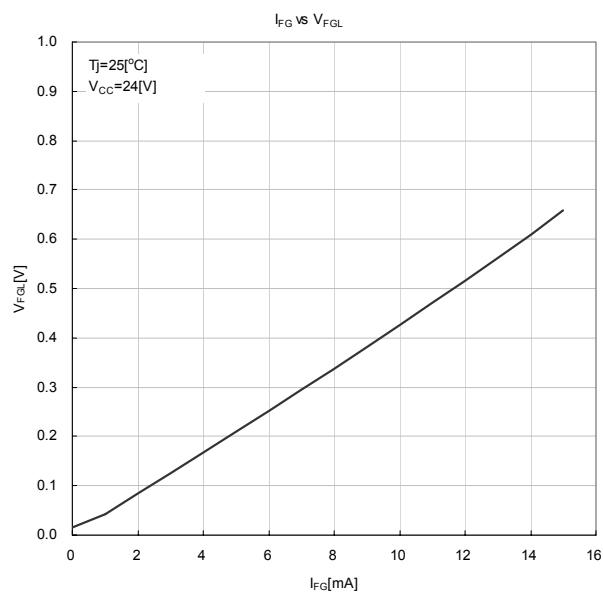
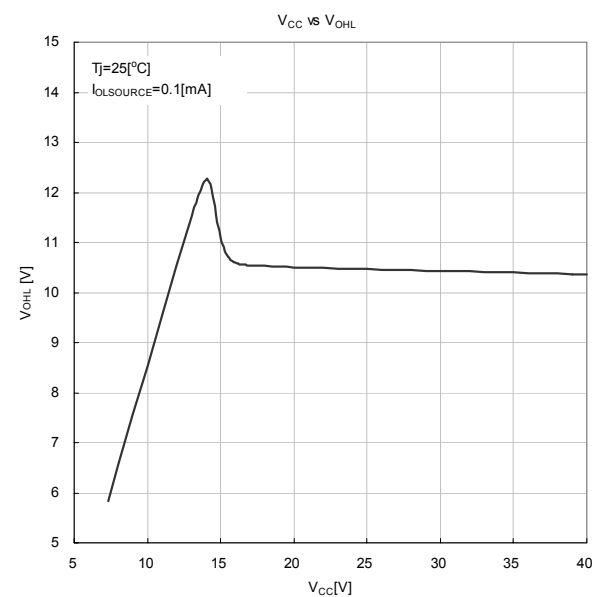




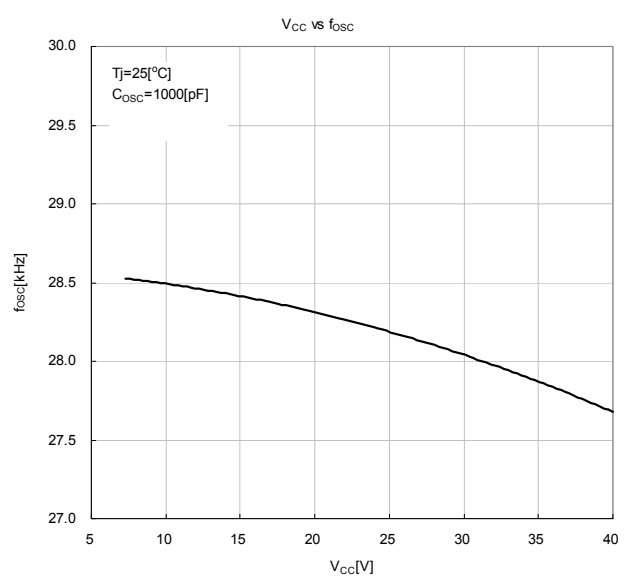
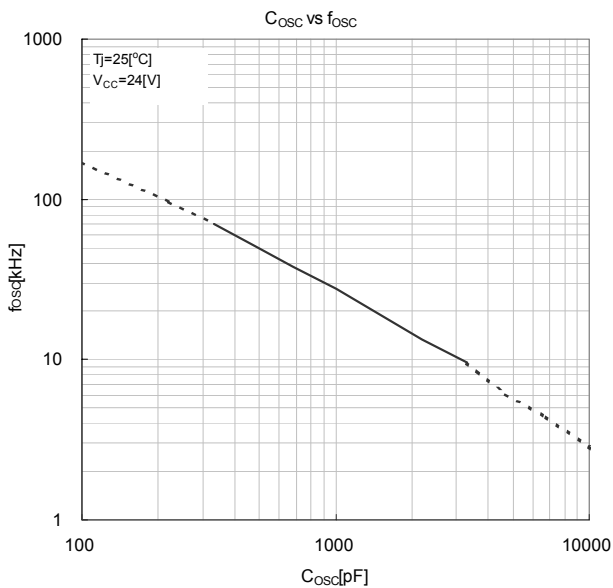
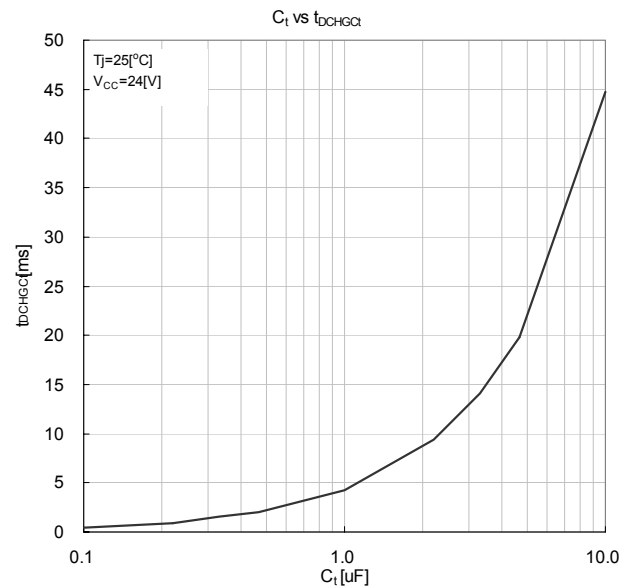
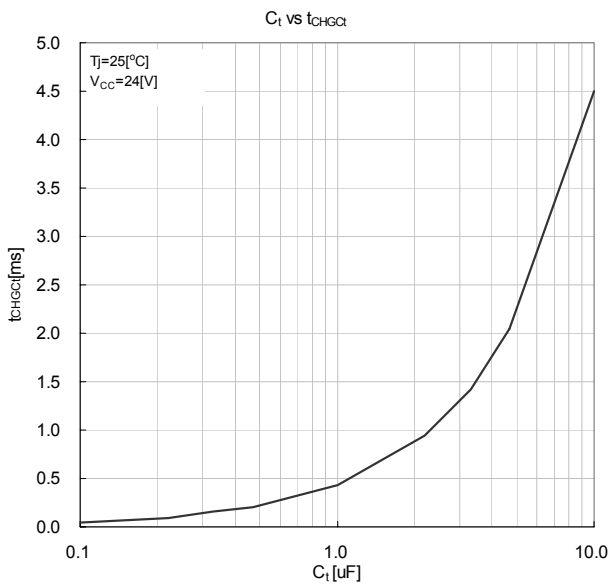
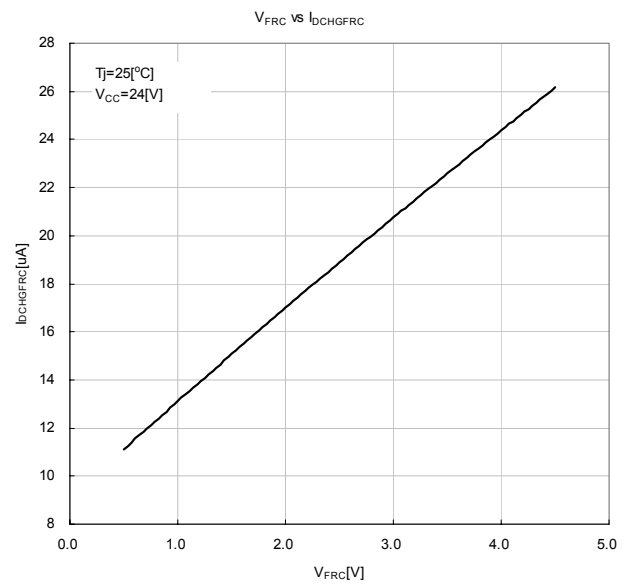
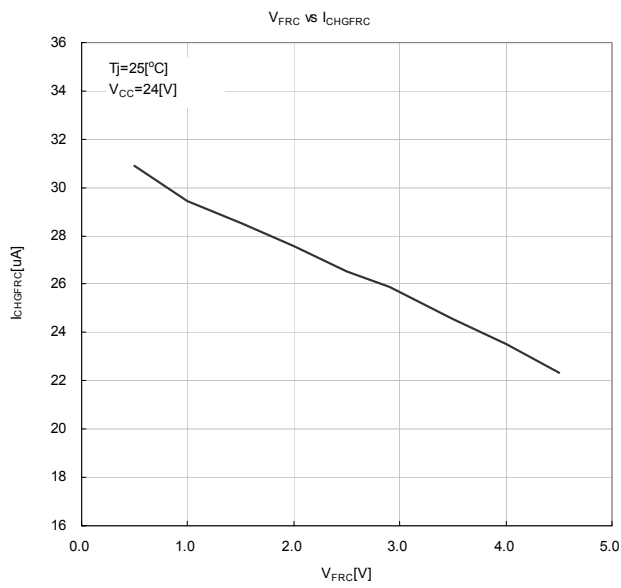
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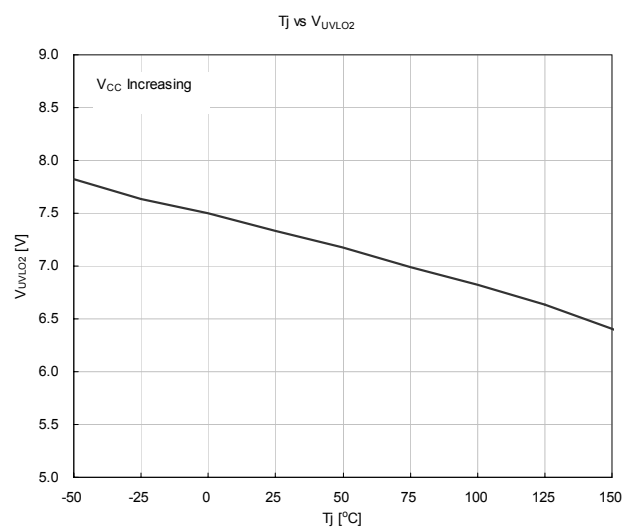
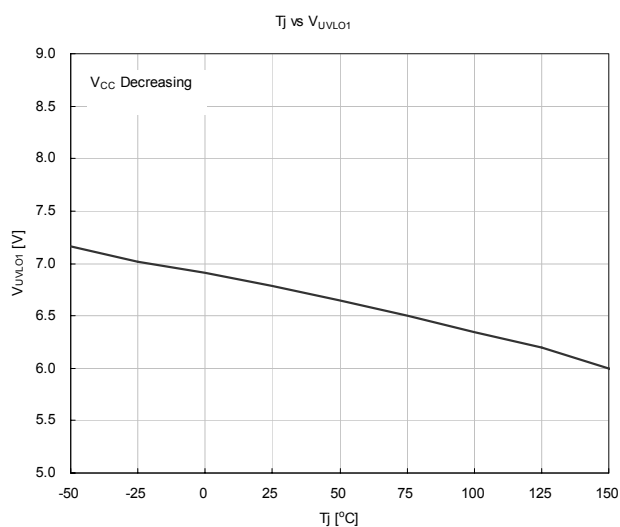
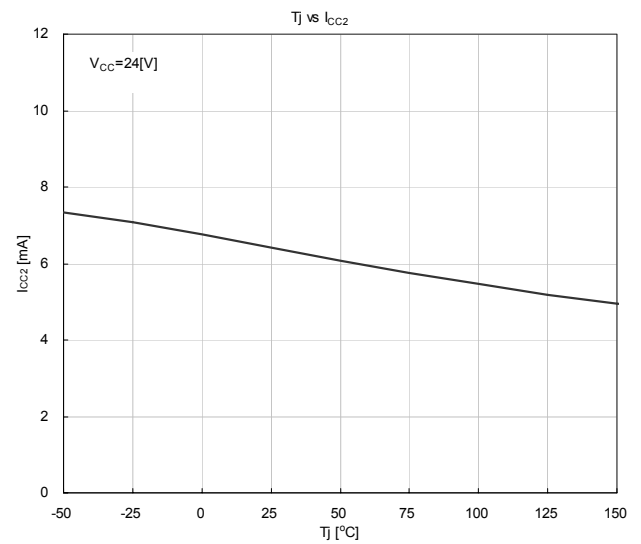
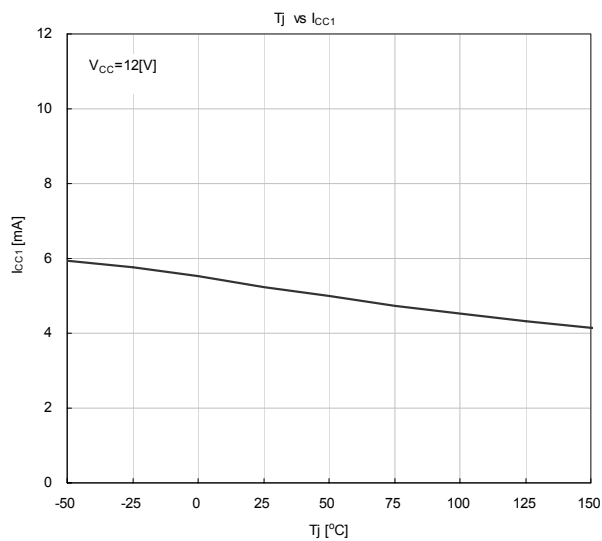
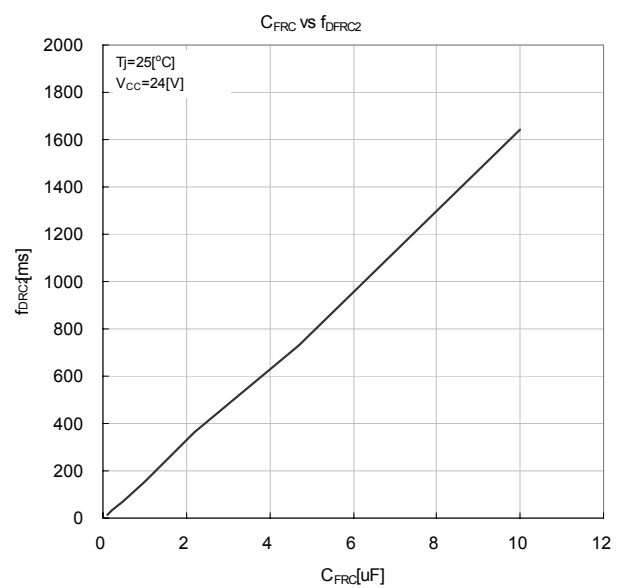
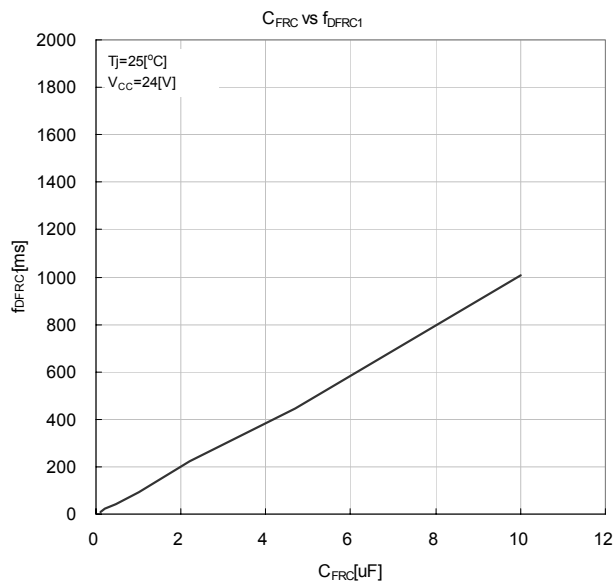


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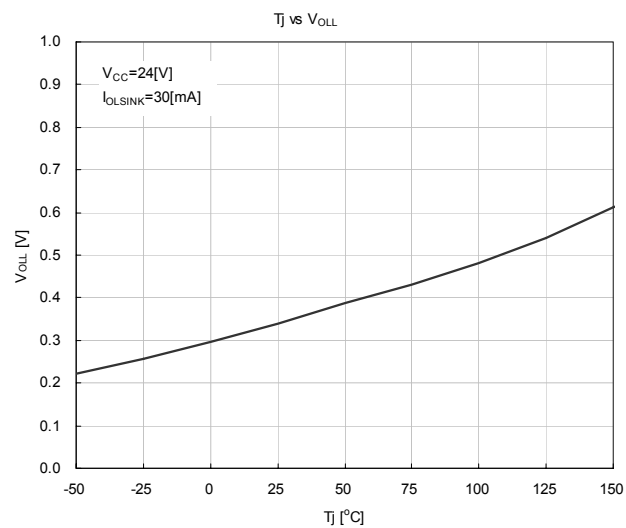
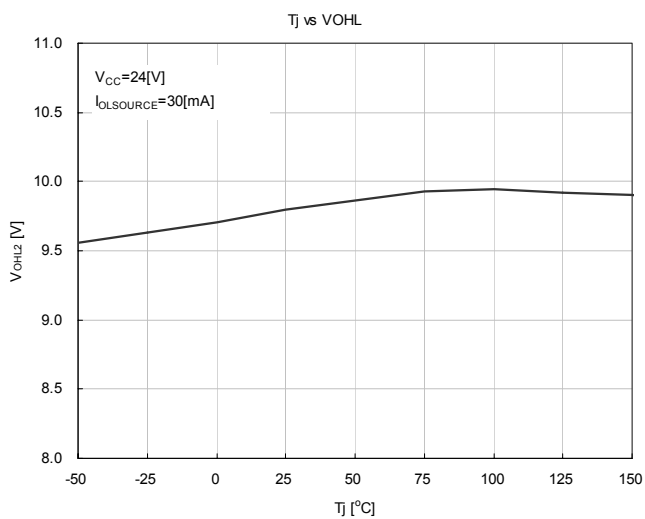
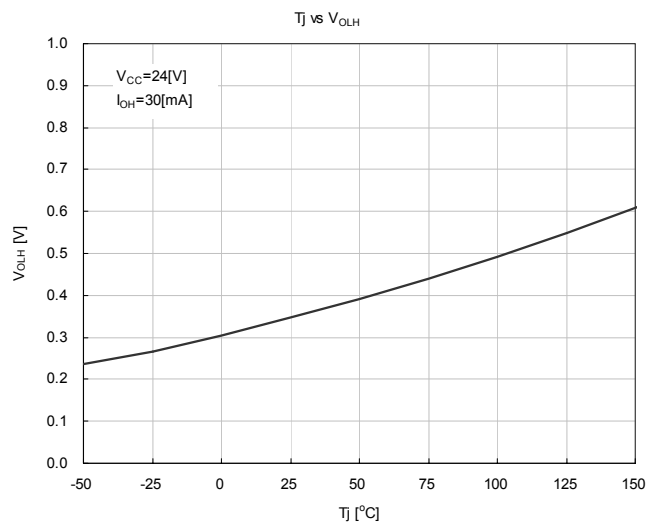
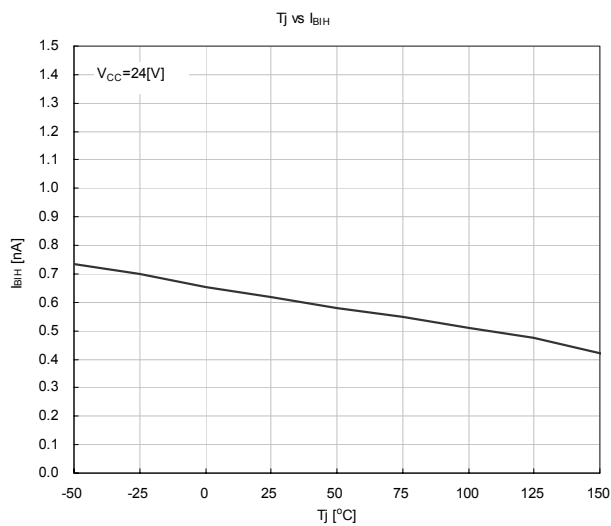
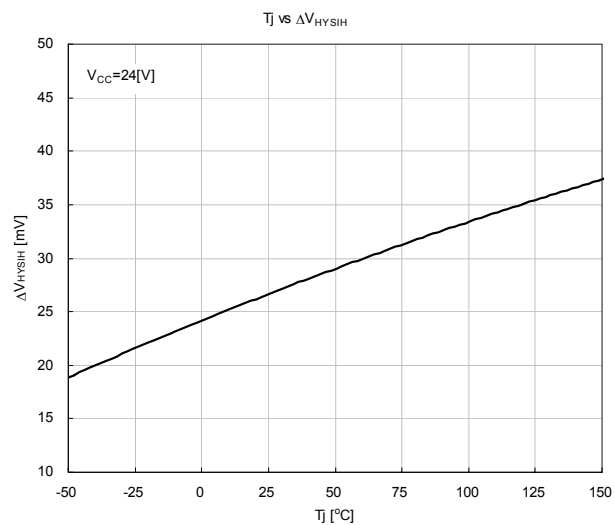
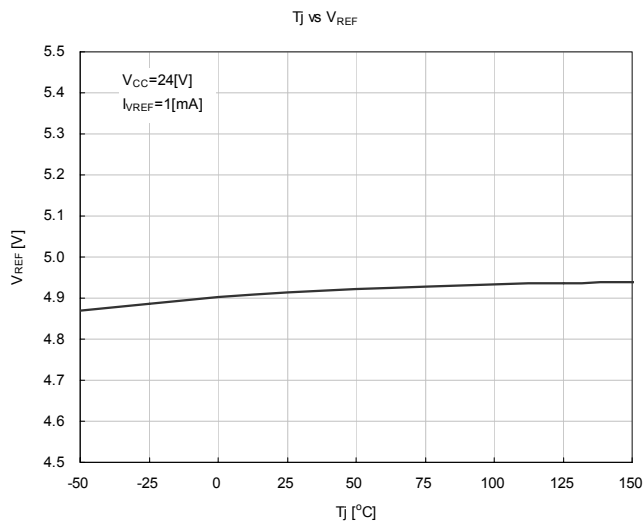




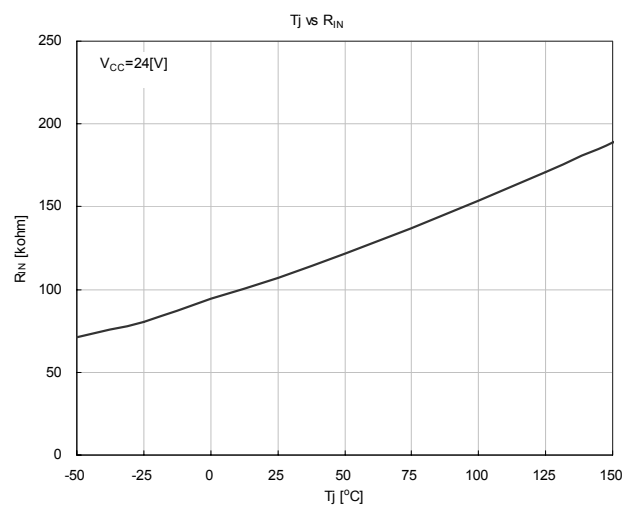
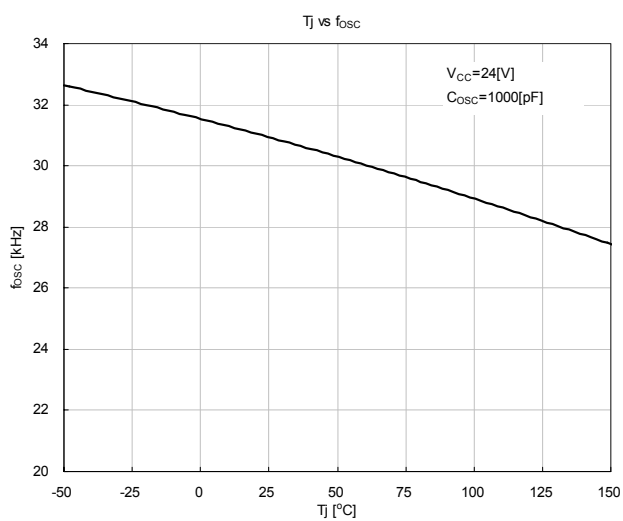
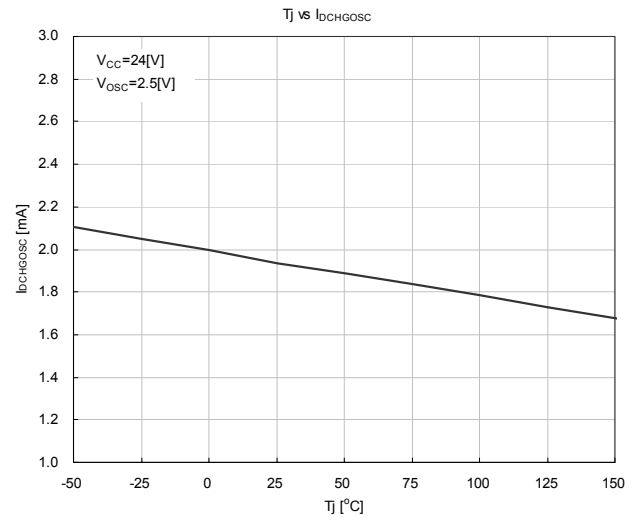
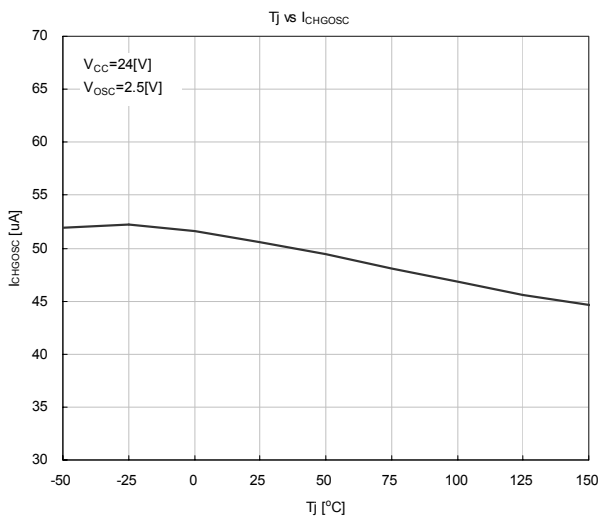
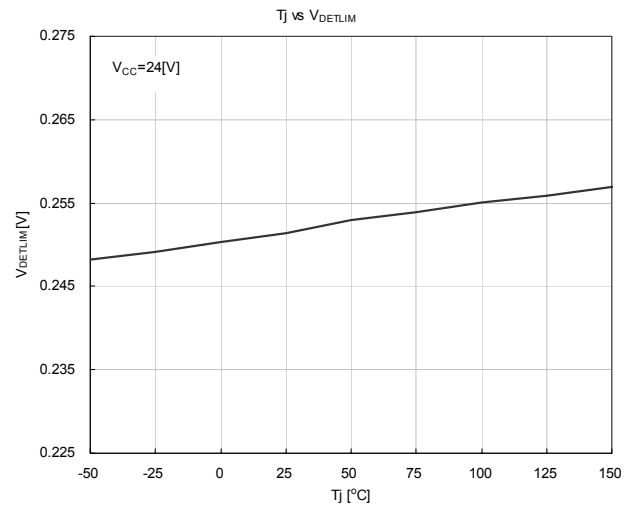
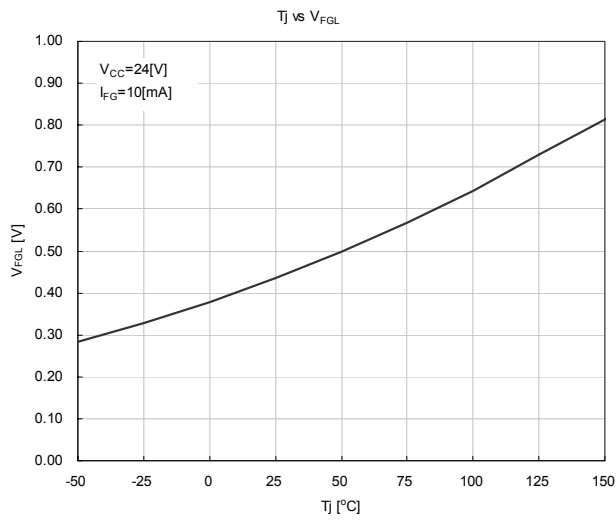
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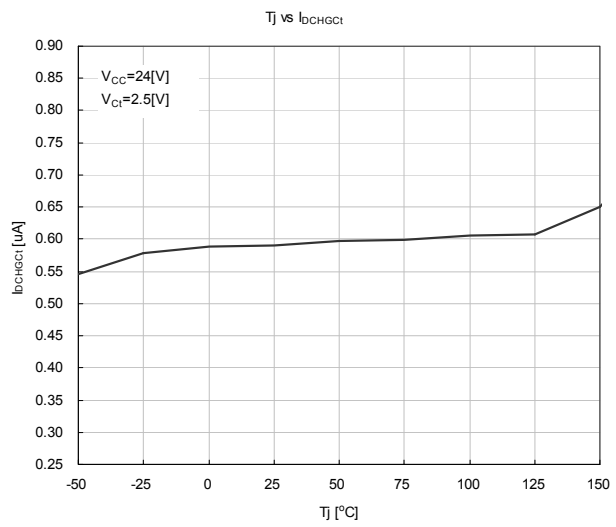
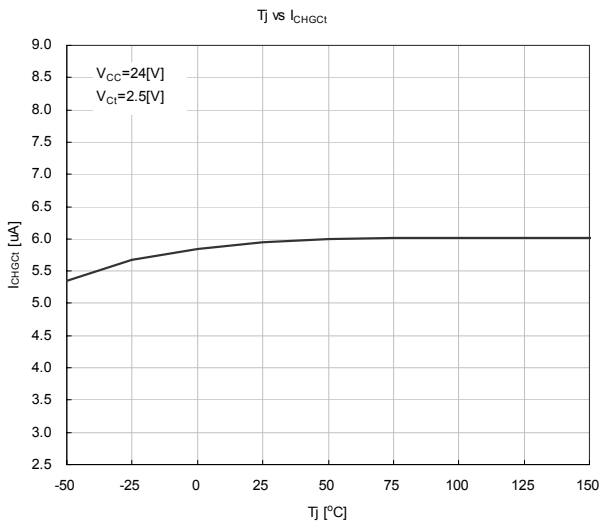
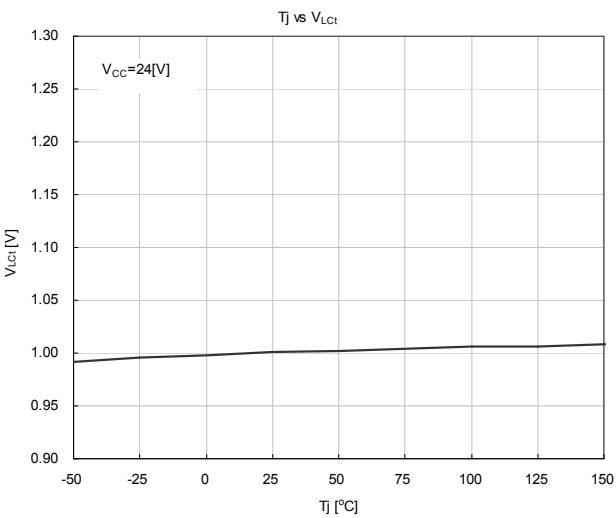
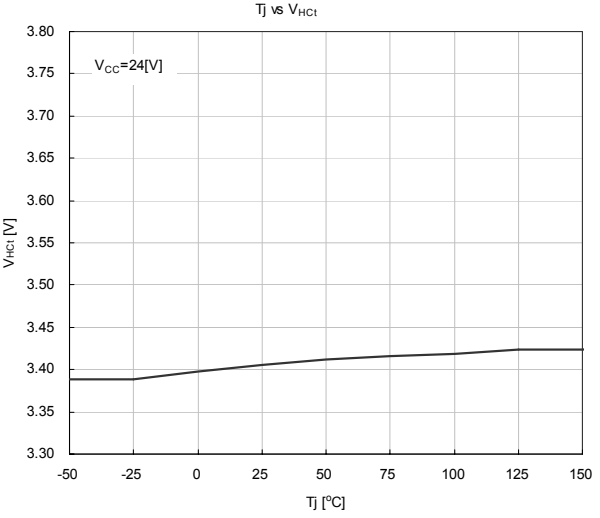
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