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Datasheet

Automotive Motor Driver Series

Three-phase Brushless Motor Driver for Automotive

BD16852EFV-C

General Description

BD16852EFV-C is a Motor driver with power DMOS FET built in.
It is mounted with 120° commutation sensor less drive which does not require a hall device as a location detection sensor.
All output protections have self-diagnostic function and self-recovery function, and it can simplify the system configuration. Also, each output protection states can be judged easily by the protect alarm signal output function. It improves traceability of the set.

Features

- AEC-Q100 Qualified*(Note 1)*
- SMD Package with Heat Sink
- Built in Driver to Power DMOS FET
- 120° Commutation Sensor Less Drive
- DC Voltage Input Variable Speed Control
- Quick Start
- Start-up Torque Support
- 3 Mode Lead Angle Selection
- Current Limit
- Soft Start
- Rotation Pulse Signal Output
- Output Protection Alarm Signal Output
- Output Protection (Motor Lock (Low Speed, High Speed), Over Current, Over Voltage, Thermal Shutdown)
- Under Voltage Lock Out

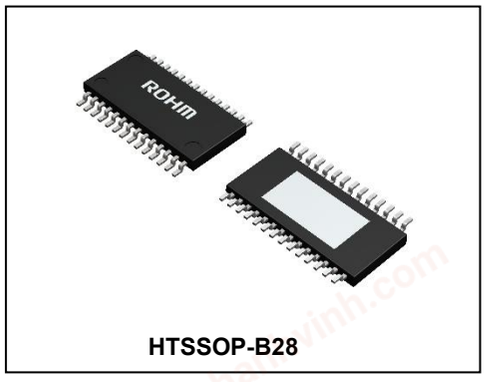
(Note 1) Grade 1

Key Specifications

- Operating Supply Voltage Range: 5.5 V to 18 V
- Junction Temperature Range -40 °C to +150 °C
- Sum of High Side and Low Side of Motor Drive Output ON-Resistance: 0.4 Ω (Typ)

Package

	W (Typ) x D (Typ) x H (Max)
HTSSOP-B28	9.7 mm x 6.4 mm x 1.0 mm

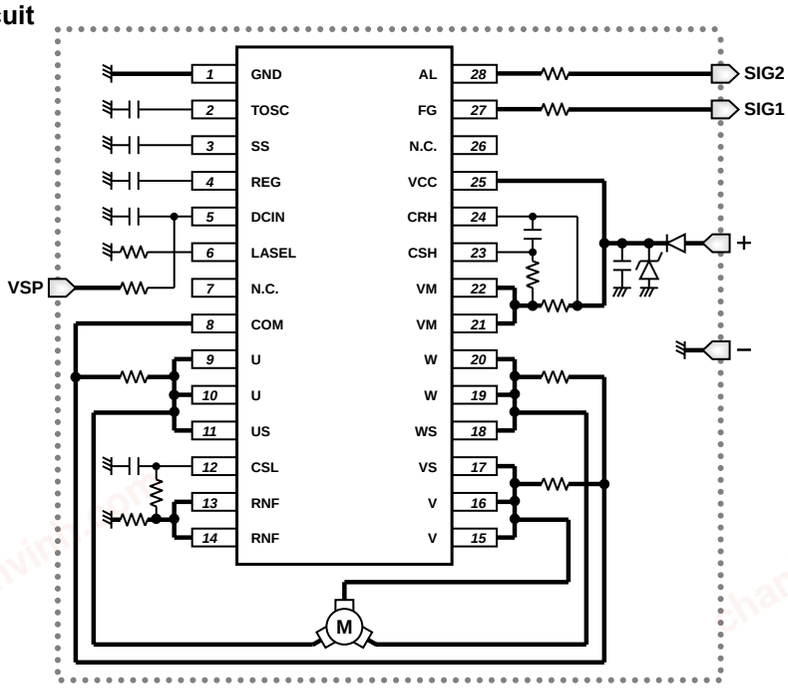


HTSSOP-B28

Application

- Automotive Pump, Fan Motor, etc

Typical Application Circuit



○Product structure : Silicon integrated circuit ○This product has no designed protection against radioactive rays.

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Absolute Maximum Ratings (Ta = 25 °C)

Parameter		Symbol	Rating	Unit
Input Voltage	VCC	V_{CC}	-0.3 to +40	V
	VM	V_M	-0.3 to +40	V
	SS, DCIN, LASEL	V_{SS}, V_{DCIN}, V_{LASEL}	-0.3 to V_{REG}	V
	TOSC, CSL, RNF	V_{TOSC}, V_{CSL}, V_{RNF}	-0.3 to +3	V
	CSH, CRH	V_{CSH}, V_{CRH}	-0.3 to V_M *(Note 1)*	V
			V_M-7 to V_M *(Note 2)*	V
	US, VS, WS	V_{US}, V_{VS}, V_{WS}	-0.3 to +40	V
	COM	V_{COM}	-0.3 to +40	V
Output Voltage	REG	V_{REG}	-0.3 to +7	V
	U, V, W	V_U, V_V, V_W	-0.3 to +40	V
	FG	V_{FG}	-0.3 to +20	V
	AL	V_{AL}	-0.3 to +20	V
Output Current	REG	I_{REG}	-10 to 0	mA
	U, V, W	I_U, I_V, I_W	±2.0 *(Note 3)*	A
		I_{UCL}, I_{VCL}, I_{WCL}	±3.2 *(Note 3)(Note 4)*	A
	FG	I_{FG}	0 to +10	mA
	AL	I_{AL}	0 to +10	mA
Maximum Junction Temperature		Tjmax	150	°C
Storage Temperature Range		Tstg	-55 to +150	°C

For parameters involving current, positive notation means inflow of current to the IC while negative notation means outflow of current from the IC.

Caution 1: Operating the IC over the absolute maximum ratings may damage the IC. The damage can either be a short circuit between pins or an open circuit between pins and the internal circuitry. Therefore, it is important to consider circuit protection measures, such as adding a fuse, in case the IC is operated over the absolute maximum ratings.

Caution 2: Should by any chance the maximum junction temperature rating be exceeded the rise in temperature of the chip may result in deterioration of the properties of the chip. In case of exceeding this absolute maximum rating, design a PCB with thermal resistance taken into consideration by increasing board size and copper area so as not to exceed the maximum junction temperature rating.

(Note 1) When V_M is less than 7 V.
(Note 2) When V_M is 7 V or more.
(Note 3) However, it must not exceed the allowable (Pd) and Area of Safe Operation (ASO).
(Note 4) The output current value of the inrush current limit at the power on, variable speed control input, and output protection recovery.

Recommended Operating Conditions

Parameter	Symbol	Min	Typ	Max	Unit
Operating Supply Voltage (VCC)	V_{CC}	5.5	12.0	18.0	V
Operating Supply Voltage (VM) *(Note 1)*	V_M	V_{CC}	V_{CC}	V_{CC}	V
Operating Temperature	Topr	-40	+25	+125	°C

(Note 1) It means single power supply.

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Thermal Resistance(Note 1)

Parameter	Symbol	Thermal Resistance (Typ)		Unit
		1s(Note 3)	4s(Note 4)	
HTSSOP-B28				
Junction to Ambient	θja	84.5	23.0	°C/W
Junction to Top Characterization Parameter(Note 2)	ψjt	7	3	°C/W

(Note 1) Based on JESD51-2A (Still-Air). The BD16852EFV-C chip is used.
(Note 2) The thermal characterization parameter to report the difference between junction temperature and the temperature at the top center of the outside surface of the component package.
(Note 3) Using a PCB board based on JESD51-3
(Note 4) Using a PCB board based on JESD51-5, 7

Layer Number of Measurement Board	Material	Board Size
Single	FR-4	114.3 mm x 76.2 mm x 1.57 mmt

Top	
Copper Pattern	Thickness
Footprints and Traces	70 µm

Layer Number of Measurement Board	Material	Board Size	Thermal Via(Note 5)	
			Pitch	Diameter
4 Layers	FR-4	114.3 mm x 76.2 mm x 1.6 mmt	1.20 mm	Φ0.30 mm

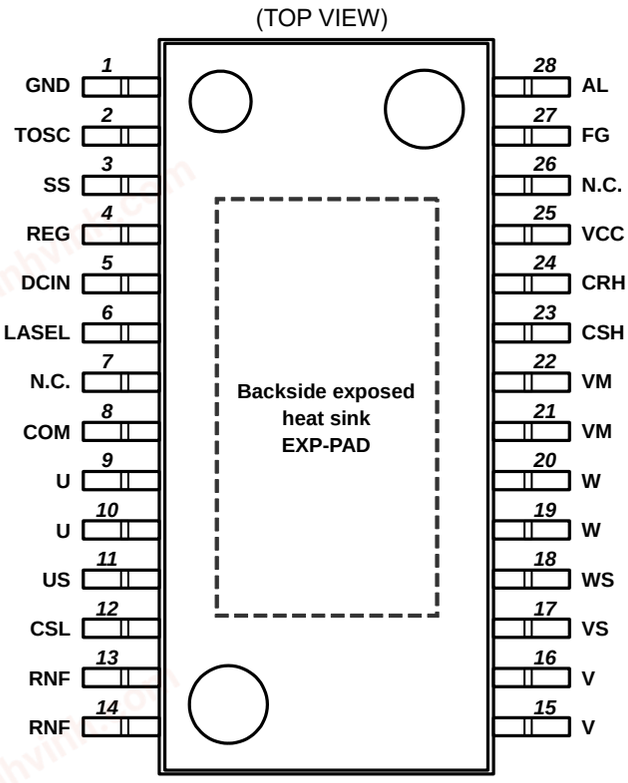
Top		2Internal Layers		Bottom	
Copper Pattern	Thickness	Copper Pattern	Thickness	Copper Pattern	Thickness
Footprints and Traces	70 µm	74.2 mm x 74.2 mm	35 µm	74.2 mm x 74.2 mm	70 µm

(Note 5) This thermal via connects with the copper pattern of all layers.

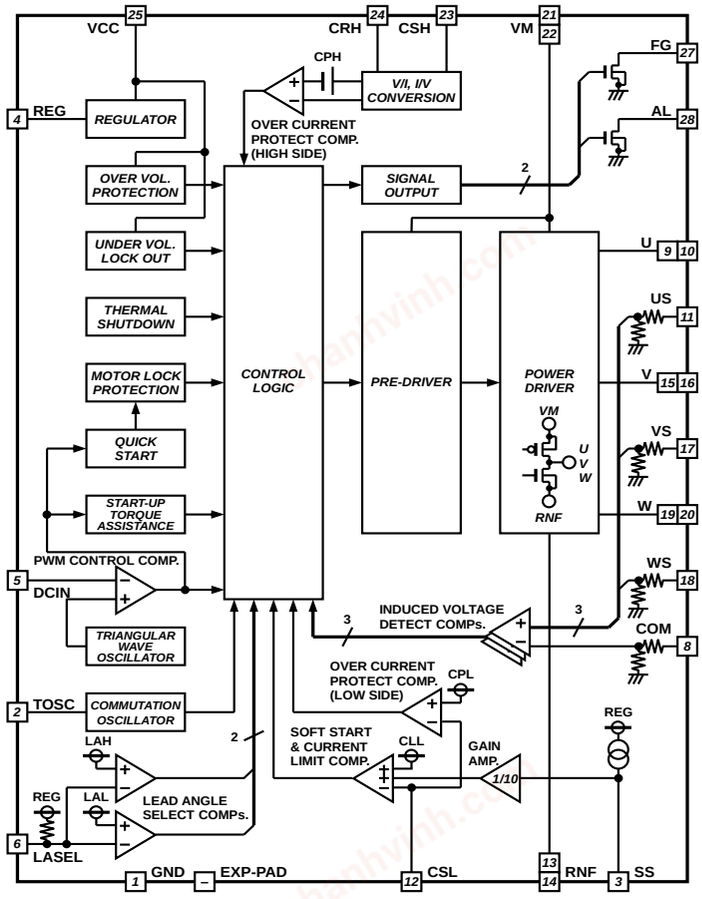
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Pin Configuration



Block Diagram



Pin Description

P/No.	Pin Name	Function	P/No.	Pin Name	Function
1	GND	Ground (signal ground)	15	V	V phase motor drive output(Note 2)
2	TOSC	Forced commutation OSC setting	16	V	V phase motor drive output(Note 2)
3	SS	Soft start time setting	17	VS	V phase detection voltage input
4	REG	Reference voltage (5 V) output	18	WS	W phase detection voltage input
5	DCIN	Variable speed control DC voltage input	19	W	W phase motor drive output(Note 2)
6	LASEL	Lead angle selection input	20	W	W phase motor drive output(Note 2)
7	N.C.	No connection(Note 1)	21	VM	Motor drive power supply(Note 2)
8	COM	Motor midpoint detection voltage input	22	VM	Motor drive power supply(Note 2)
9	U	U phase motor drive output(Note 2)	23	CSH	High side over current protection detect voltage input
10	U	U phase motor drive output(Note 2)	24	CRH	High side over current protection reference voltage input
11	US	U phase detection voltage input	25	VCC	Power supply
12	CSL	Current limit, low side over current detect voltage input	26	N.C.	No connection(Note 1)
			27	FG	Rotation pulse signal output
13	RNF	Motor drive output current detection (Motor drive ground)(Note 2)	28	AL	Output protection alarm signal output
14	RNF	Motor drive output current detection (Motor drive ground)(Note 2)	–	EXP-PAD	Package rear exposed PAD(Note 3)

(Note 1) No connection pin (N.C.) is unconnected in the internal IC. But, because of unanticipated troubles such as oscillations may happen, this pin is open on board wiring pattern.
(Note 2) The motor drive related pin of the same name (VM, RNF, U, V, W) is connected into the IC but please connect the pin of the same name on board wiring pattern in order to decrease the impedance of motor drive current route.
(Note 3) The package rear exposed PAD and the ground pin adjust to same electric potential.

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Electrical Characteristics

(Unless otherwise specified Tj = -40 °C to +150 °C, V_{CC} = V_M = 5.5 V to 18 V)

Parameter	Symbol	Limit			Unit	Conditions
		Min	Typ	Max		
<Overall>						
Circuit Current (Control Part)	I_{CC}	-	5	9	mA	
Circuit Current (Motor Drive Part)	I_M	-	0.1	0.3	mA	
<Reference Voltage Output (REG) >						
Reference Voltage	V_{REG}	4.7	5.0	5.3	V	V_{CC} = V_M = 7.5 V to 18 V, I_{REG} = -5 mA
< Motor Drive Output (U, V, W) >						
Output ON Resistance 1	R_{ON1}	0.20	0.45	0.95	Ω	V_{CC} = V_M = 5.5 V, I_O = ±2 A, Tj = +25 °C, High / Low Total
Output ON Resistance 2	R_{ON2}	0.15	0.40	0.90	Ω	V_{CC} = V_M = 12 V to 18 V, I_O = ±2 A, Tj = +25 °C, High / Low Total
Output ON Resistance 3 (Reference Value)*(Note 1)*	R_{ON3}	0.10	0.35	0.85	Ω	V_{CC} = V_M = 5.5 V, I_O = ±2 A, Tj = -40 °C, High / Low Total
Output ON Resistance 4 (Reference Value)*(Note 1)*	R_{ON4}	0.10	0.30	0.80	Ω	V_{CC} = V_M = 12 V to 18 V, I_O = ±2 A, Tj = -40 °C, High / Low Total
Output ON Resistance 5 (Reference Value)*(Note 1)*	R_{ON5}	0.35	0.85	1.35	Ω	V_{CC} = V_M = 5.5 V, I_O = ±2 A, Tj = +150 °C, High / Low Total
Output ON Resistance 6 (Reference Value)*(Note 1)*	R_{ON6}	0.20	0.70	1.20	Ω	V_{CC} = V_M = 12 V to 18 V, I_O = ±2 A, Tj = +150 °C, High / Low Total
Output High Side Leak Current	I_{OLH}	-10	-	-	μA	V_O = 0 V
Output Low Side Leak Current	I_{OLL}	-	-	+10	μA	V_O = V_M
Variable Speed Control PWM ON Duty 1	D_{SPD1}	75	80	85	%	V_{DCIN} = V_{REG} x 0.28
Variable Speed Control PWM ON Duty 2	D_{SPD2}	45	50	55	%	V_{DCIN} = V_{REG} x 0.40
Variable Speed Control PWM ON Duty 3	D_{SPD3}	15	20	25	%	V_{DCIN} = V_{REG} x 0.52
Variable Speed Control PWM Frequency	f_{SPD}	18	20	22	kHz	
< Rotation Pulse Signal Output (FG) >						
Output Low Voltage	V_{FGL}	-	0.20	0.45	V	I_{FG} = +5 mA
Output Leak Current	I_{FGL}	-	0	10	μA	V_{FG} = 20 V
<Output Protection Alarm Signal Output (AL) >						
Output Low Voltage	V_{ALL}	-	0.20	0.45	V	I_{AL} = +5 mA
Output Leak Current	I_{ALL}	-	0	10	μA	V_{AL} = 20 V
<Detect Voltage Input (US, VS, WS, COM) >						
Input Offset Voltage	V_{OSOFS}	-85	-	+85	mV	V_{OSOFS} = V_{XX} - V_{COM}, (xx = US, VS, WS)
Input Leak Current	I_{OSL}	-5	0	+5	μA	V_{US} = V_{VS} = V_{WS} = V_{COM} = 0 V
Input Bias Current	I_{OSH}	0.34	0.56	0.78	mA	V_{US} = V_{VS} = V_{WS} = V_{COM} = 18 V
< Forced Commutation OSC Setting Input (TOSC) >						
High Voltage	V_{TOSCH}	2.2	2.5	2.8	V	
Low Voltage	V_{TOSCL}	0.7	1.0	1.3	V	
Charge Current	I_{CTOSC}	-70	-60	-50	μA	
Discharge Current	I_{DTOSC}	50	60	70	μA	

For parameters involving current, positive notation means inflow of current to IC while negative notation means outflow of current from IC.

(Note 1) Reference value is design value. Evaluation done during design, but not tested in production.

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Electrical Characteristics - continued

(Unless otherwise specified Tj = -40 °C to +150 °C, V_{CC} = V_M = 5.5 V to 18 V)

Parameter	Symbol	Limit			Unit	Conditions
		Min	Typ	Max		
<Variable Speed Control DC Voltage Input (DCIN) >						
Motor Drive Output Full Speed Low Setting Voltage	V_{RDCIN1}	0	V_{REG} x 0.10	V_{REG} x 0.18	V	
Motor Drive Output OFF Setting Voltage	V_{RDCIN2}	V_{REG} x 0.64	V_{REG} x 0.70	V_{REG} x 0.76	V	
Motor Drive Output Full Speed High Setting Voltage	V_{RDCIN3}	V_{REG} x 0.84	V_{REG} x 0.90	V_{REG}	V	
Input Leak Current	I_{DCINH}	-1.2	0	+1.2	µA	V_{DCIN} = V_{REG}
Input Bias Current	I_{DCINL}	-1.2	0	+1.2	µA	V_{DCIN} = 0 V
<Lead Angle Select Input (LASEL) >						
Lead Angle 7.5° Setting Voltage	V_{LASELH}	V_{REG} x 0.80	-	V_{REG}	V	
Lead Angle 15° Setting Voltage	V_{LASELM}	-	V_{REG} x 0.50	-	V	
Lead Angle 30° Setting Voltage	V_{LASELL}	0	-	V_{REG} x 0.30	V	
Input Leak Current	I_{LASELH}	-5	0	+5	µA	V_{LASEL} = V_{REG}
Input Bias Current	I_{LASELL}	-100	-50	-20	µA	V_{LASEL} = 0 V
<Current Limit, Over Current Low Side Detect Voltage Input (CSL) >						
Input Leak Current	I_{CSHL}	-1.2	0	+1.2	µA	V_{CSL} = 3 V
Input Bias Current	I_{CSLL}	-1.2	0	+1.2	µA	V_{CSL} = 0 V
Current Limit Detect Voltage	V_{CLL}	130	150	170	mV	
<Soft Start Time Setting Input (SS) >						
Charge Current	I_{CSS}	-3.0	-2.2	-1.0	µA	V_{SS} = 0 V
<Motor Lock (Low Speed, High Speed) Protect (MLP) >						
Detect Time	t_{MLPDET}	0.9	1.0	1.1	s	
Protect Time 1	t_{MLP1}	0.9	1.0	1.1	s	
Protect Time 2	t_{MLP2}	4.5	5.0	5.5	s	
< Over Current Protection (OCP) >						
High Side Detect Voltage	V_{CPH}	100	150	230	mV	V_{CPH} = V_{CRH} - V_{CSH}
Low Side Detect Voltage	V_{CPL}	220	250	280	mV	
< Over Voltage Protection (OVP) >						
Detect Voltage	V_{OVPDET}	28	30	32	V	
Hysteresis Voltage	V_{OVPHYS}	-	2	-	V	
< Thermal Shutdown (TSD) >						
Detect Temperature (Reference Value)*(Note 1)*	T_{TSDDET}	150	175	200	°C	
Thermal Shutdown Hysteresis Temperature (Reference Value)*(Note 1)*	T_{TSDHYS}	-	25	-	°C	
< Under Voltage Lock Out (UVLO) >						
Detect Voltage	$V_{UVLODET}$	4.55	4.75	4.95	V	
Hysteresis Voltage	$V_{UVLOHYS}$	-	0.25	-	V	

For parameters involving current, positive notation means inflow of current to IC while negative notation means outflow of current from IC.

(Note 1) Reference value is design value. Evaluation done during design, but not tested in production.

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Typical-Performance-Curves (Reference Data)

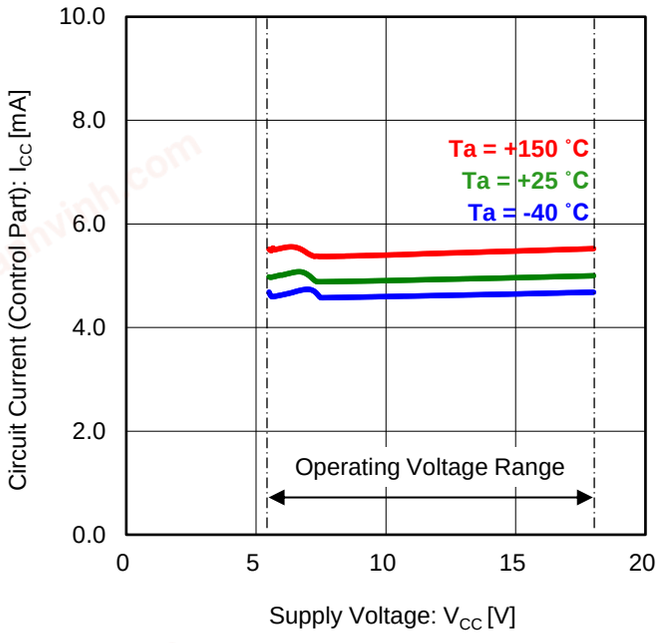


Figure 1. Circuit Current (Control Part) vs Supply Voltage

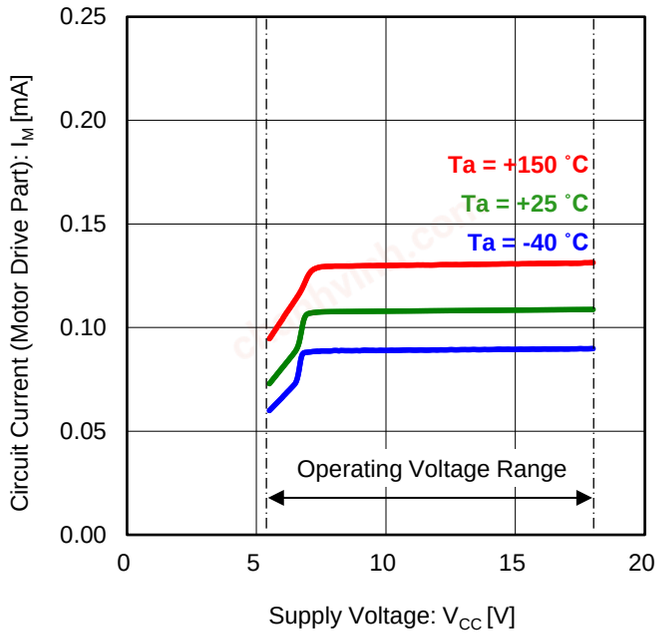


Figure 2. Circuit Current (Motor Drive Part) vs Supply Voltage

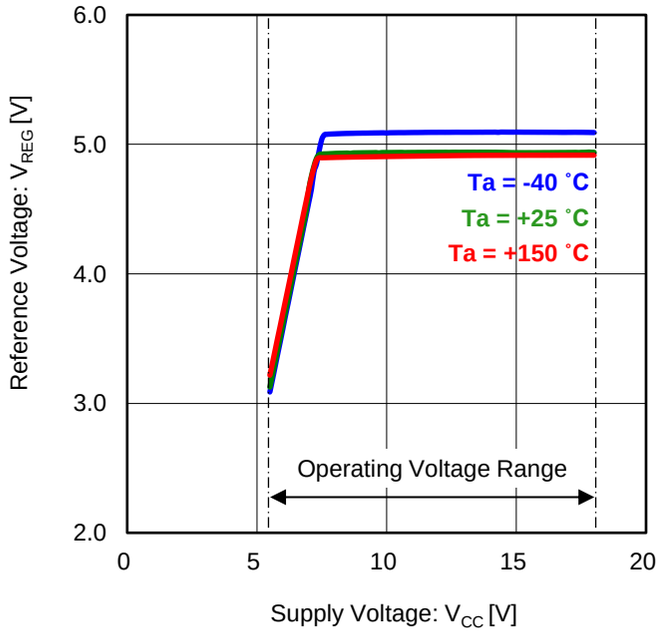


Figure 3. Reference Voltage vs Supply Voltage
I_{REG} = -5 mA

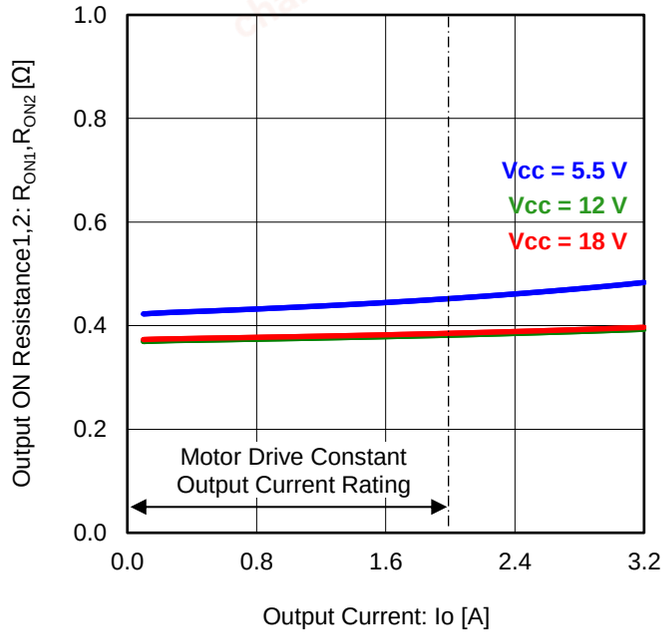


Figure 4. Motor Drive Output ON Resistance1,2 (High / Low Total) vs Motor Drive Output Current Tj = 25 °C (Supply Voltage Comparison)

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Typical-Performance-Curves - continued

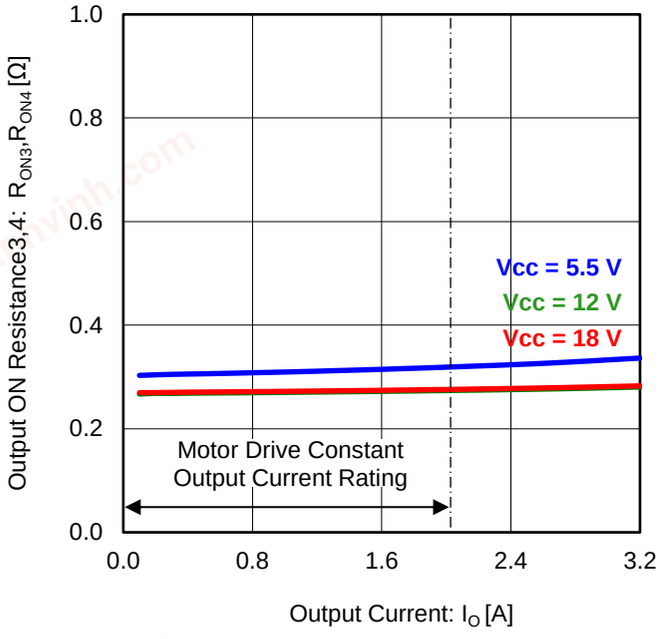


Figure 5. Motor Drive Output ON Resistance3,4
(High / Low Total)
vs Motor Drive Output Current
Tj = -40 °C (Supply Voltage Comparison)

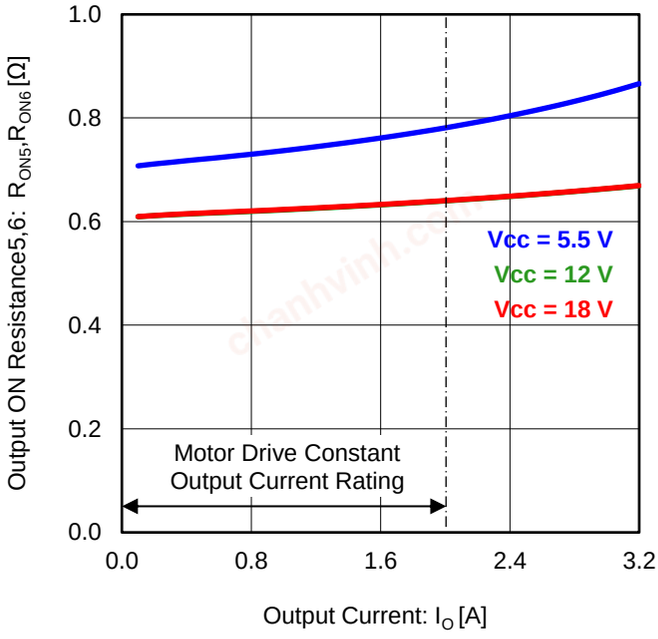


Figure 6. Motor Drive Output ON Resistance5,6
(High / Low Total)
vs Motor Drive Output Current
Tj = 150 °C (Supply Voltage Comparison)

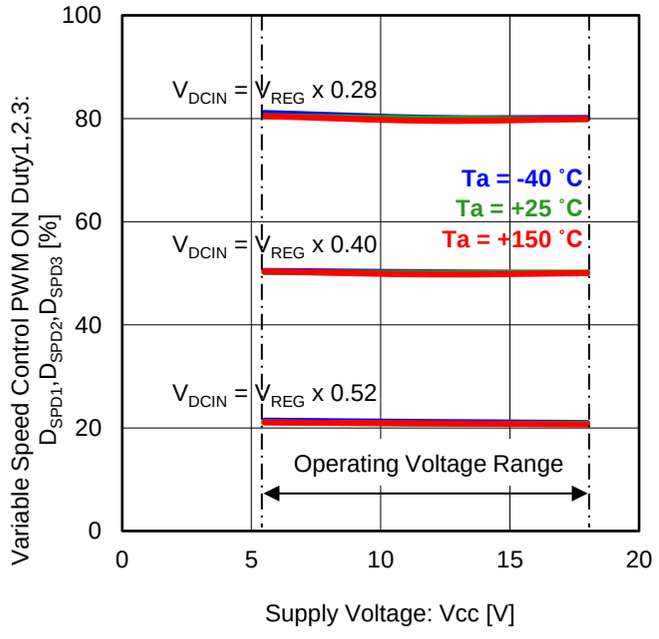


Figure 7. Variable Speed Control PWM ON Duty1,2,3
vs Supply Voltage

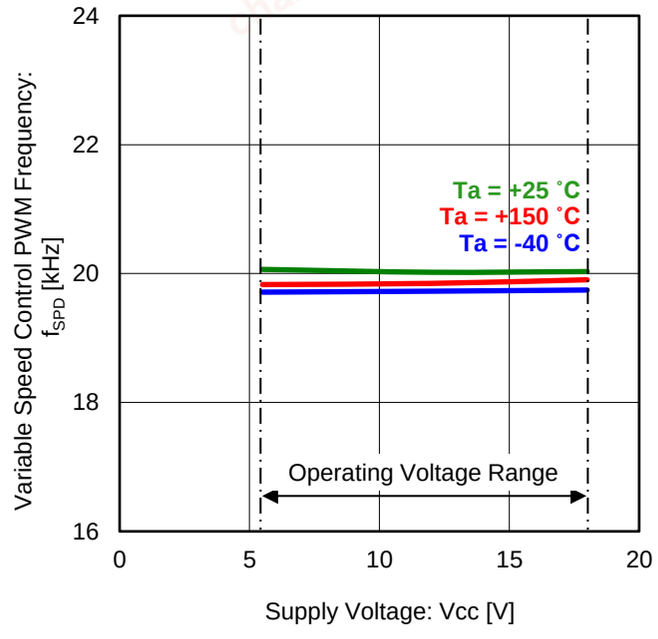


Figure 8. Variable Speed Control PWM Frequency
vs Supply Voltage

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Typical-Performance-Curves - continued

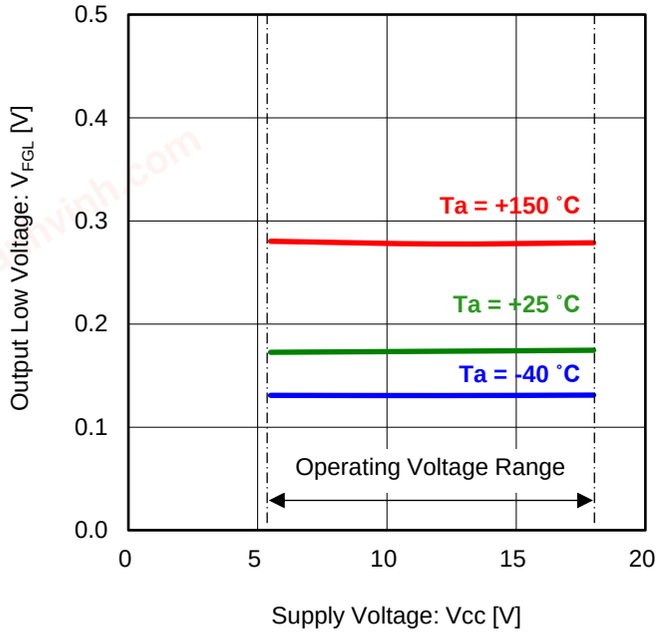


Figure 9. FG Output Low Voltage vs Supply Voltage

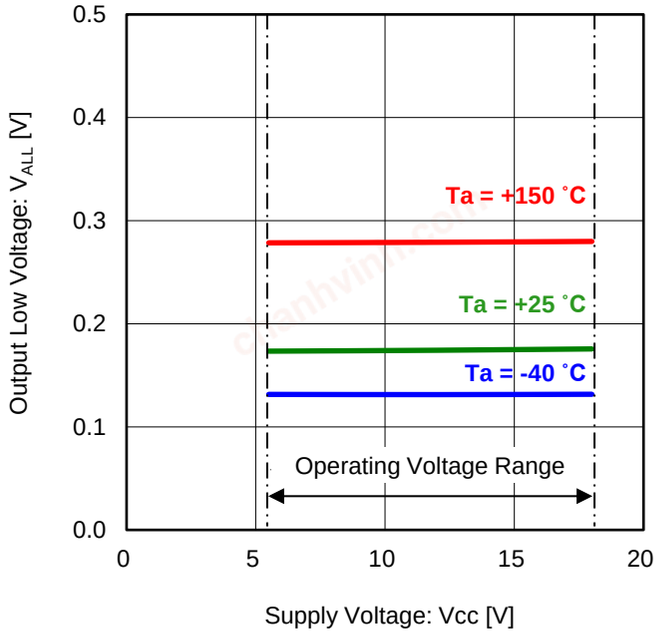


Figure 10. AL Output Low Voltage vs Supply Voltage

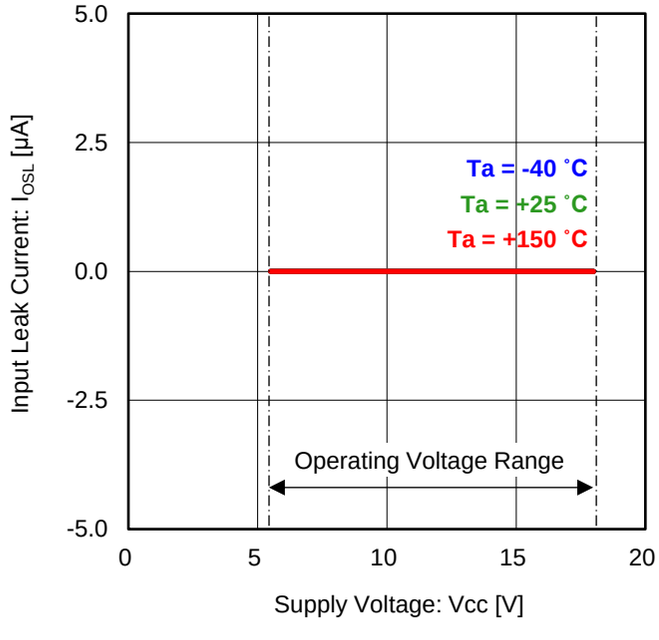


Figure 11. BEMF Comparator Input Leak Current vs Supply Voltage

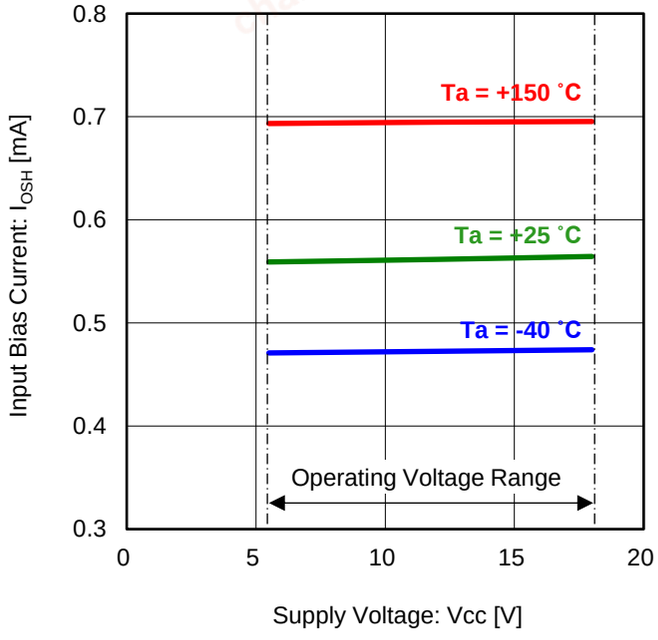


Figure 12. BEMF Comparator Input Bias Current vs Supply Voltage

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Typical-Performance-Curves - continued

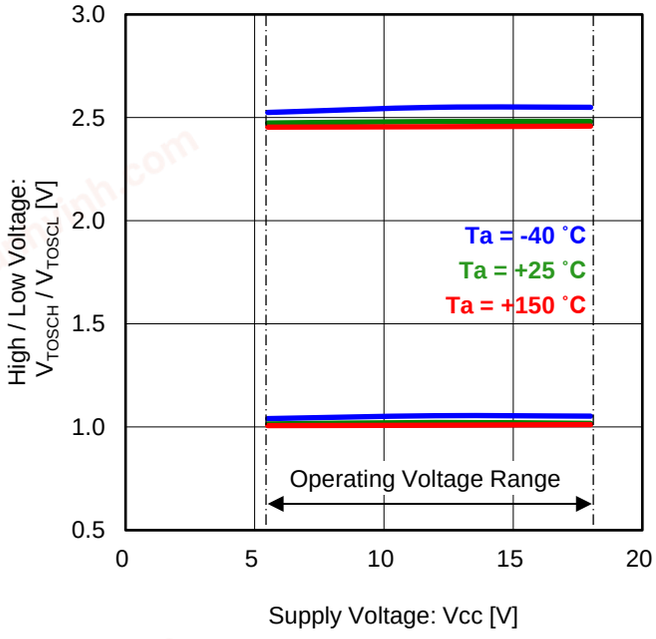


Figure 13. TOSC High / Low Voltage vs Supply Voltage

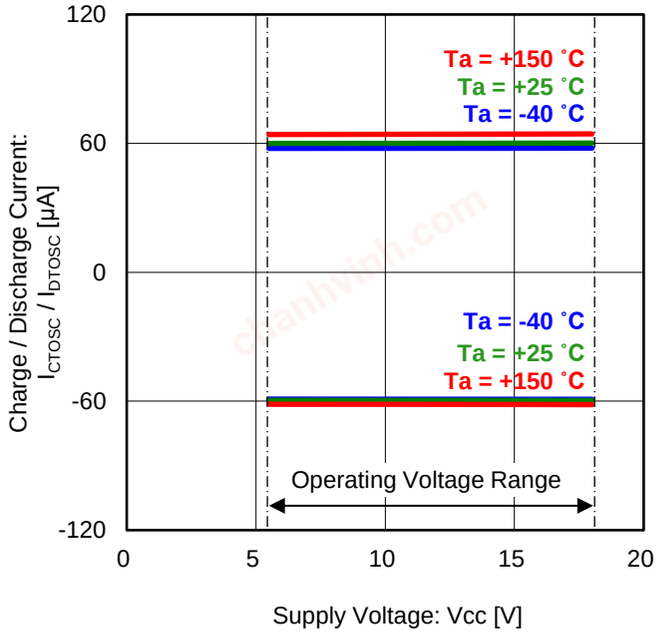


Figure 14. TOSC Charge / Discharge Current vs Supply Voltage

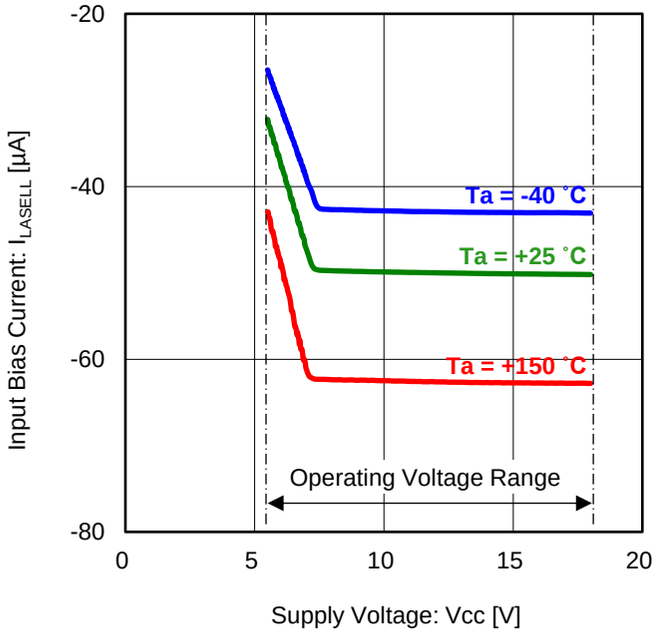


Figure 15. LASEL Input Bias Current vs Supply Voltage

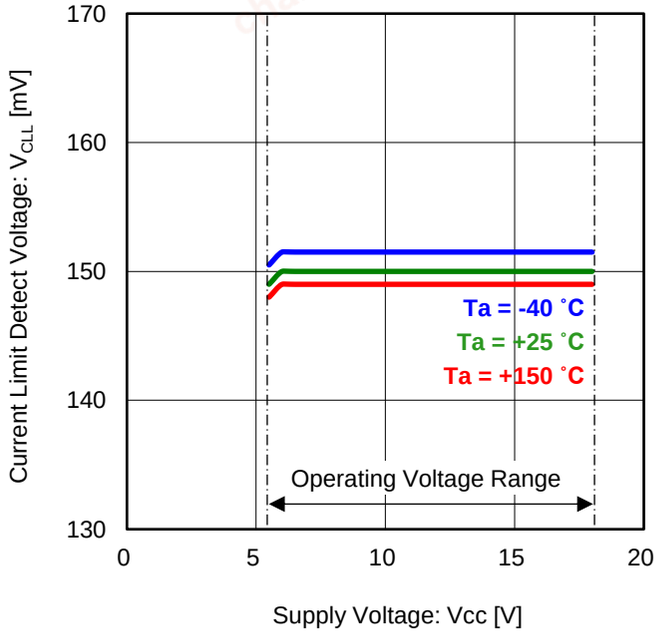


Figure 16. Current Limit Detect Voltage vs Supply Voltage

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Typical-Performance-Curves - continued

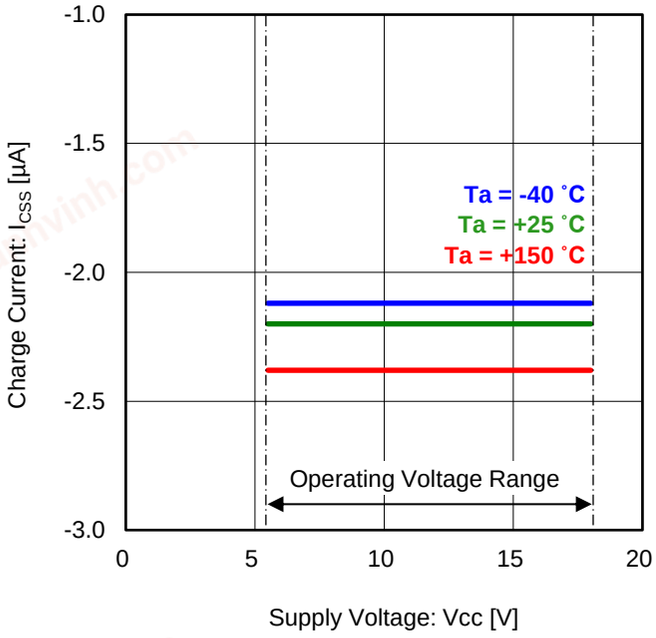


Figure 17. SS Charge Current vs Supply Voltage

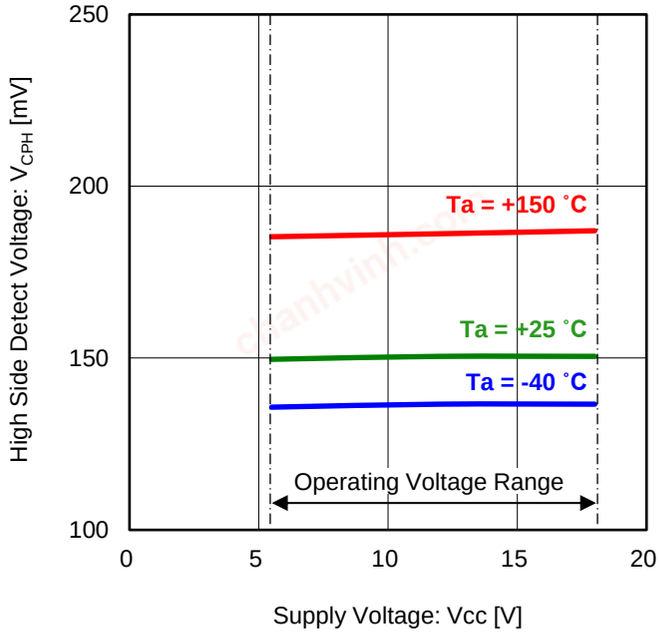


Figure 18. High Side Over Current Protection Detect Voltage vs Supply Voltage

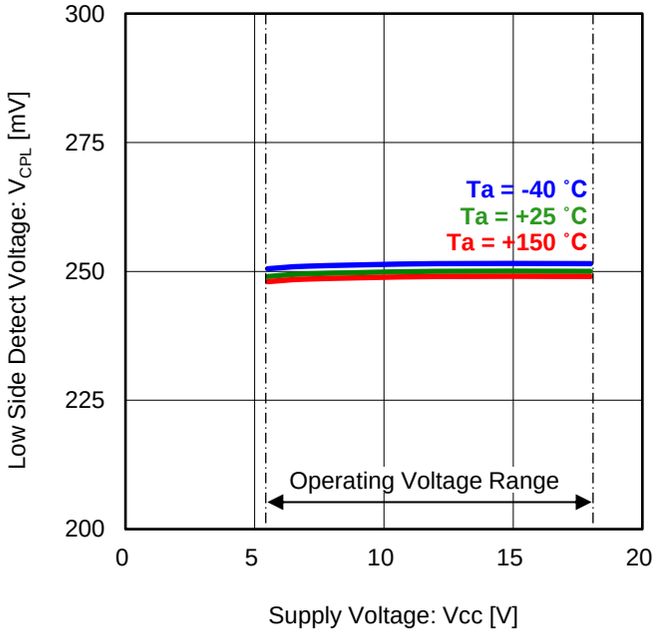


Figure 19. Low Side Over Current Protection Detect Voltage vs Supply Voltage

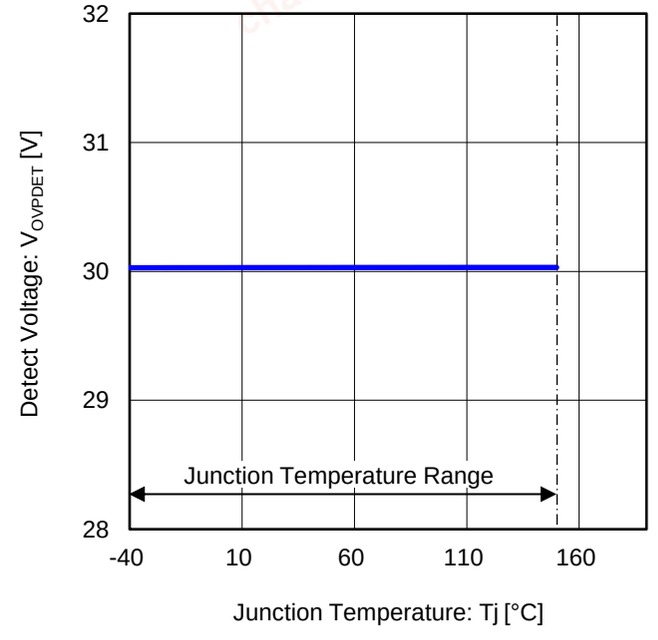


Figure 20. Over Voltage Protection Detect Voltage vs Junction Temperature

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Typical-Performance-Curves - continued

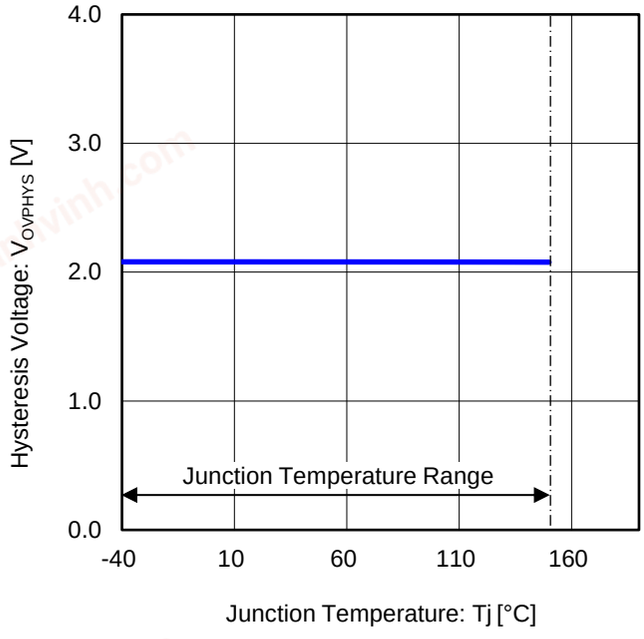


Figure 21. Over Voltage Protection Hysteresis Voltage vs Junction Temperature

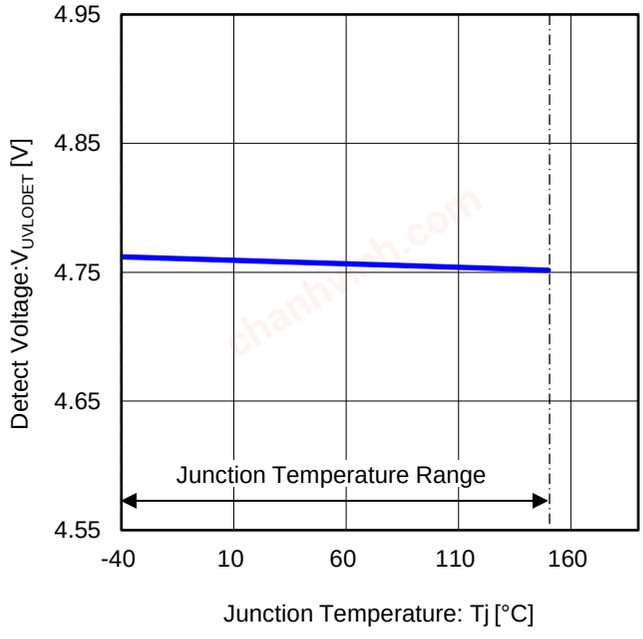


Figure 22. UVLO Detect Voltage vs Junction Temperature

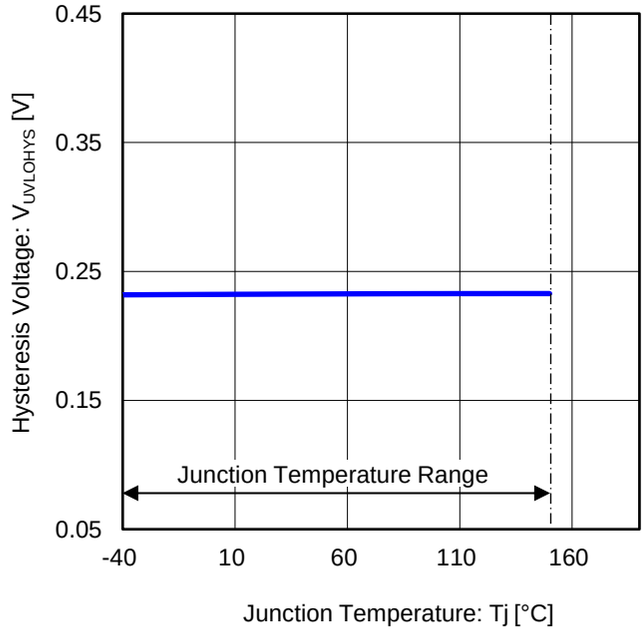


Figure 23. UVLO Hysteresis Voltage vs Junction Temperature

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Application Examples

Convert external PWM signal into DC voltage and variably controls the motor rotation speed. Example can be seen below.

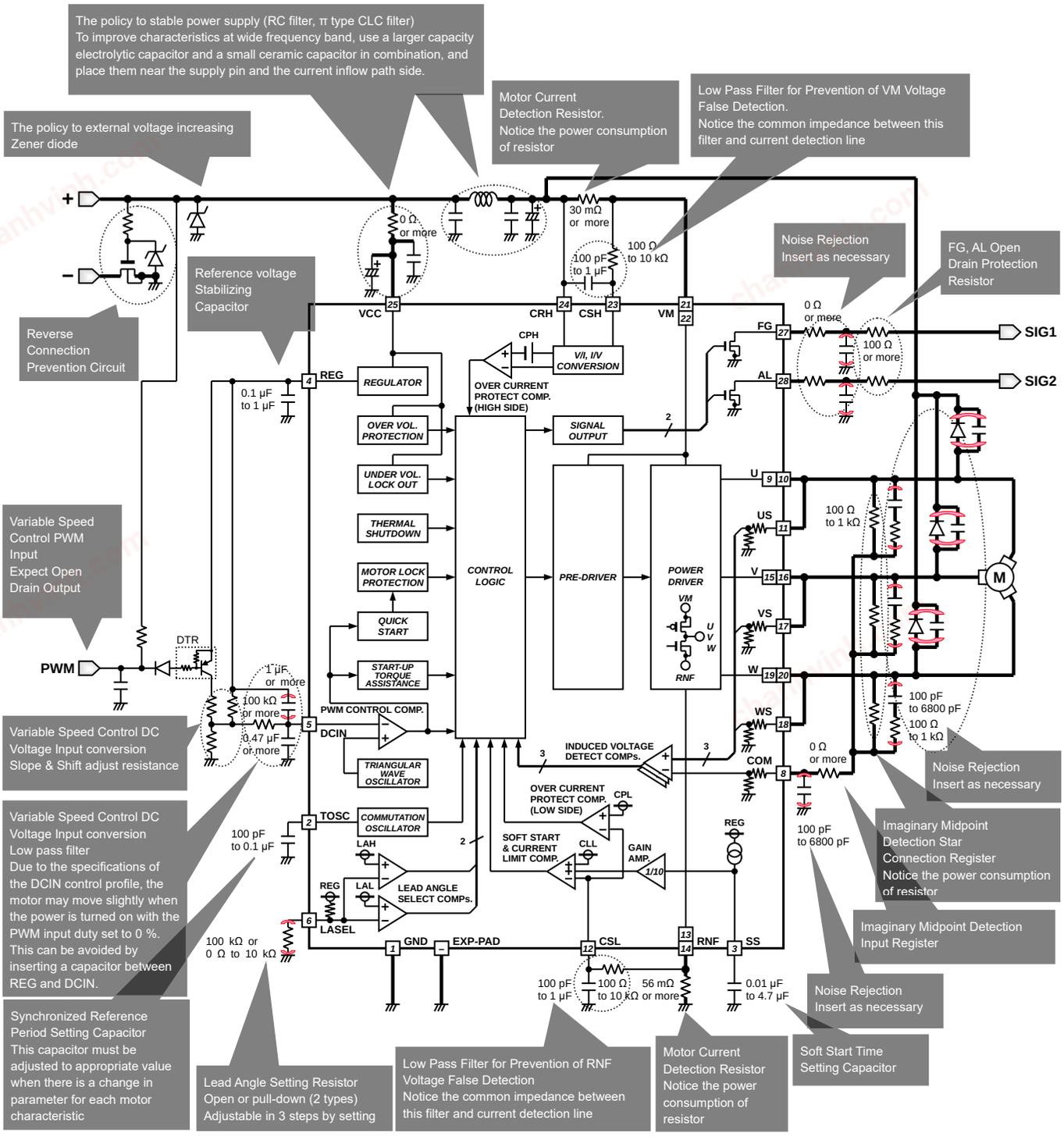


Figure 24. Variable Speed Control Application Circuit

Point of Concern for PCB Design

(1) Please wire power supply (VCC), motor drive power supply (VM), motor drive output (U, V, W) and each line of motor drive ground (RNF) briefly and thickly.
(2) Please wire a ground line (GND) briefly and thickly paying attention to the common impedance with the motor drive ground (RNF) line where a large current flows.
(3) The stable power supply filter is mounted nearby each power supply pin and inflow current route side.
(4) This noise rejection circuit is one case of EMC measure. Please take a measure depending on usage.
(5) Measures against pins connected with outside of application (+, –, PWM, SIG1, SIG2) are examples. Please take a measure depending on usage.

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Description of Blocks

1. Start-up Sequence

BD16852EFV-C is the Motor driver IC for three phase brushless DC motor without using a hall sensor for position detection. After power ON and variable speed control input, it can drive sensor less motor stably depending on the setting sequence.

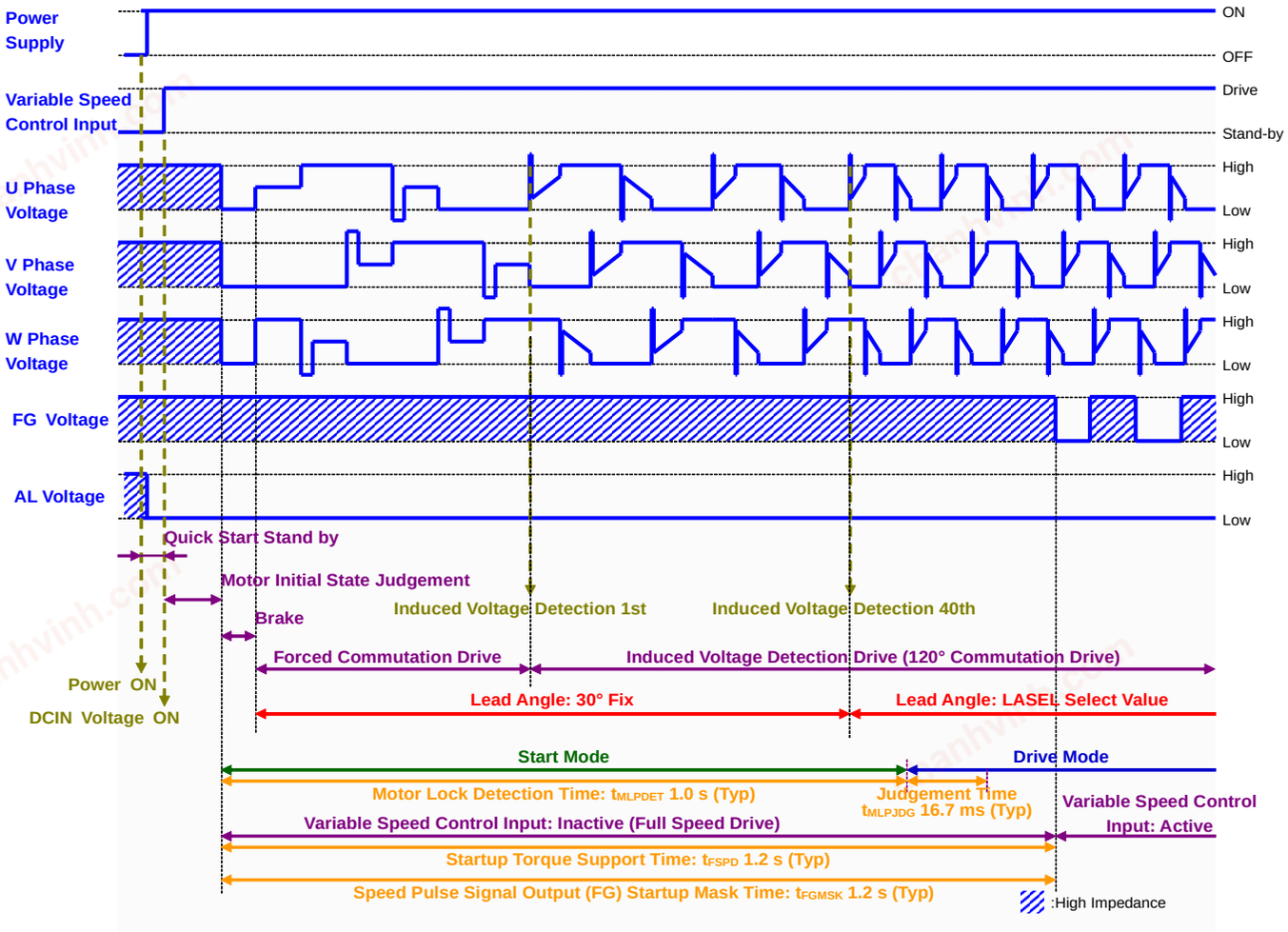


Figure 25. Start-up Sequence Summary Timing Chart (When Motor Stops)

(1) Quick Start Stand by

After the power ON, the motor drive output is OFF logic (High impedance), FG voltage is High logic and AL voltage is Low logic until the variable speed control input is ON.

(2) Motor Initial State Judge

After the power ON and variable speed control input, judge the Motor state (Forward rotation, Reverse rotation, Stop) within 12.5 ms (Typ). The transition state differs depending on the judgment.

Table 1. Motor Initial State Judgement Table

Judgement	Condition	Transmit State
Forward	Induced Voltage (Forward rotation logic) Detection	Induced Voltage Detection Drive
Reverse	Induced Voltage (Reverse rotation logic) Detection	Reverse Protection
Stop	Others	Brake

(a) Reverse Protection

When the state is judged as reverse, the motor drive outputs are all low logic (low short brake) at 1.0 s (Typ) stop it. After the reverse protection release, it transmits to Brake.

(3) Brake

When the state is judged as stop, make all motor driver outputs low logic (low short brake) at 6.5 ms (Typ) to stabilize motor and change it to forced commutation drive.

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1. Start-up Sequence - continued

(4) Forced Commutation Drive

When the motor drive output logic is forced commutation in synchronization with the reference signal inside the IC. When the induced voltage generated from the motor is detected by this forced commutation drive, the mode shifts to the induced voltage detection drive (120° commutation drive). When the induced voltage cannot be detected normally, forced commutation drive is repeated within the motor lock detect time t_{MLPDET}: 1.0 s (Typ) by the start assist described later.

(a) Forced Commutation Period

The forced commutation period is determined by the oscillation period of the TOSC pin and the range of two value inside the IC. The relationship between the oscillation period by the external capacitor connected between the TOSC pin and GND and the forced commutation period (Min and Max) is as follows.

$$t_{TOSC} = \frac{C_{TOSC} \times (|I_{DTOSC}| + |I_{CTOSC}|) \times (V_{TOSCH} - V_{TOSCL})}{(|I_{DTOSC}| \times |I_{CTOSC}|)} \text{ [s]}$$

$$t_{OSCS} = t_{TOSC} \times 20 \text{ [s]}$$

$$t_{OSCL} = t_{TOSC} \times 50 \text{ [s]}$$

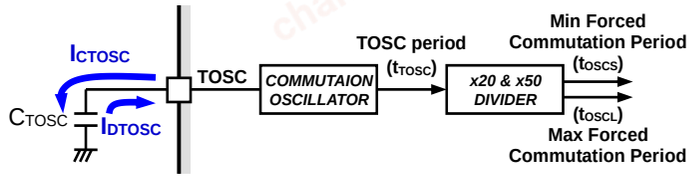


Figure 26. TOSC Capacitor and IC Internal Circuit Diagram

where:

t_{TOSC} is the TOSC Oscillation Period [s]
C_{TOSC} is the TOSC Capacitance Value [F]
I_{DTOSC} is the TOSC Discharge Current [A] (Typ 60 μA)
I_{CTOSC} is the TOSC Charge Current [A] (Typ -60 μA)
V_{TOSCH} is the TOSC High voltage [V] (Typ 2.5 V)
V_{TOSCL} is the TOSC Low voltage [V] (Typ 1.0 V)
t_{OSCS} is the Min Forced Commutation Period [s]
t_{OSCL} is the Max Forced Commutation Period [s]

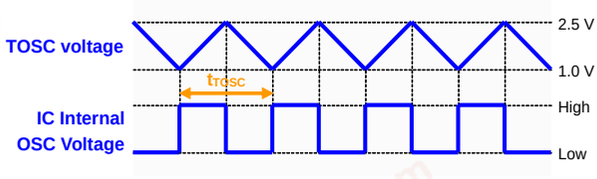


Figure 27. TOSC Timing Chart

(ex.) TOSC capacitance is 1000 pF, TOSC period is 50 μs, the min forced commutation period is 1.0 ms, the max sync. period is 2.5 ms

$$t_{TOSC} = \frac{1000 \times 10^{-12} \times (|60 \times 10^{-6}| + |-60 \times 10^{-6}|) \times (2.5 - 1.0)}{(|60 \times 10^{-6} \times -60 \times 10^{-6}|)} = 50 \times 10^{-6} \text{ [s]}$$

$$t_{OSCS} = 50 \times 10^{-6} \times 20 = 1.0 \times 10^{-3} \text{ [s]}$$

$$t_{OSCL} = 50 \times 10^{-6} \times 50 = 2.5 \times 10^{-3} \text{ [s]}$$

(b) TOSC Capacitance Value Setting

Because of the difference of motor parameter, it leads to the difference in capacitance. Please set the right value to start up the motor. Normally, the bigger the magnetic poles of the motor, the smaller the value of the capacitance. And the bigger the moment of inertia of the motor, the bigger value the value of the capacitance, too. Considering to the motor characteristic, practice the start-up test under sufficient conditions and choose the margin.

Table 2. Forced Commutation Period Table (Reference Value)

TOSC value (C_{TOSC}) [pF]	Min Period (t_{OSCS}) [ms]	Max Period (t_{OSCL}) [ms]
100	0.10	0.25
150	0.15	0.38
220	0.22	0.55
330	0.33	0.83
470	0.47	1.18
680	0.68	1.70
1,000	1.00	2.50
1,500	1.50	3.75
2,200	2.20	5.50
3,300	3.30	8.25
4,700	4.70	11.75
6,800	6.80	17.00
10,000	10.00	25.00

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(4) Forced Commutation Drive - continued

(c) Start Assist

When the induced voltage is undetected or erroneous detection after switching the motor drive output logic in forced commutation drive eight times, the forced commutation drive returns to the brake and the forced commutation drive sequence is repeated within the motor lock detect time t_{MLPDET}: 1.0 s (Typ).

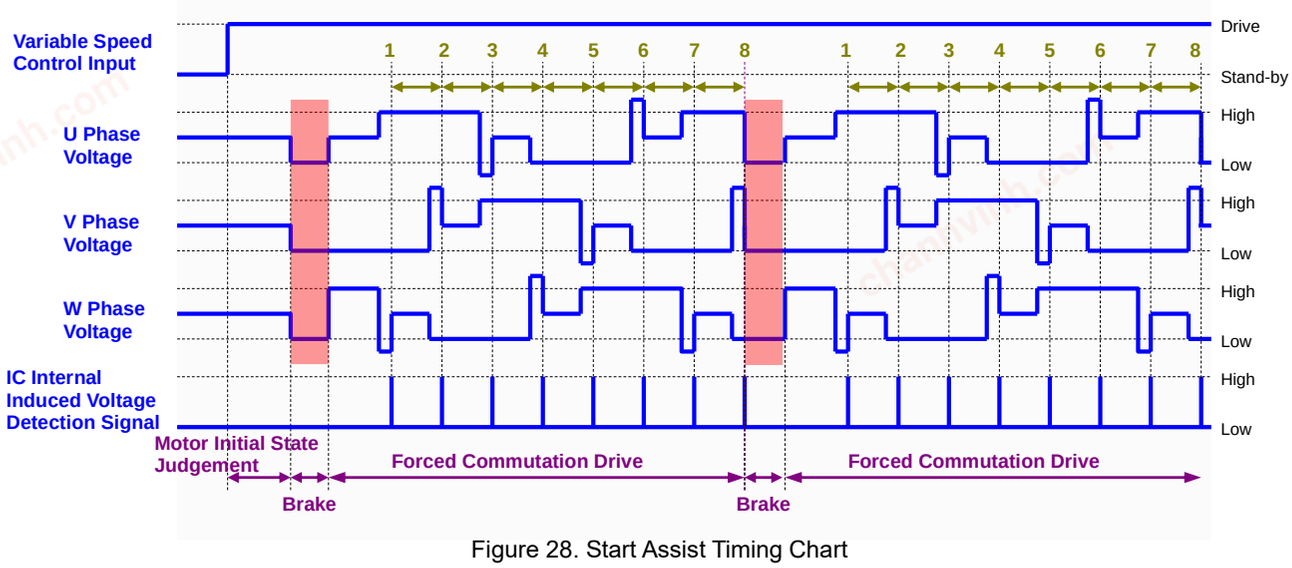


Figure 28. Start Assist Timing Chart

(5) Start Mode and Drive Mode

The Start Mode is the state from the brake to the forced commutation drive and 120° commutation drive within the motor lock detect time t_{MLPDET}: 1.0 s (Typ). The Drive Mode is the state after the motor lock judgement time t_{MLPJDG}: 16.7 ms (Typ) after passing through the motor lock detection time t_{MLPDET}.

(6) Start-up Torque Assist

If the variable speed control value from the DCIN pin is low and the start-up torque is smaller than the static friction, start-up fails.

As a countermeasure, when the variable speed control input is given or lock protection is enabled and the motor starts-up, disable the variable speed control input from the DCIN pin and drive at full speed during the start-up torque assist time t_{FSPD}: 1.2 s (Typ).

After the start-up torque assist time, the speed is gradually reduced to the variable speed control input value at a slope of -1 %/ms.

If you want to stop the motor during the start torque assist, set the variable speed control DC voltage input V_{DCIN} between V_{REG} x 0.6 or more to less than V_{REG} x 0.8.

(7) Start-up Mask Time

The FG output is high impedance, and then the signal is the same as the synchronous signal of U phase output within Start-up Mask Time t_{FGMSK}: 1.2 s (Typ).

i) Power ON (UVLO Release) and Variable Speed Control Input

ii) After Protection Release (Lock, Over Current, Over Voltage, and Thermal Shutdown)

(8) The TOSC Pin Setting

Because of board capacitance, Inner oscillator can do free running oscillation even if the TOSC pin is open but open setting is forbidden.

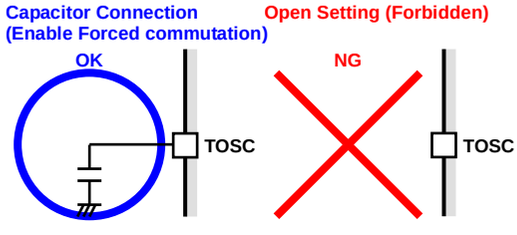


Figure 29. Forced Commutation Function Setting

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Description of Blocks - continued

2. Sensor Less Drive

(1) Induced Voltage Detection Drive (120° Commutation Drive)

Detects induced voltage and energizes every 120° electrical angle.

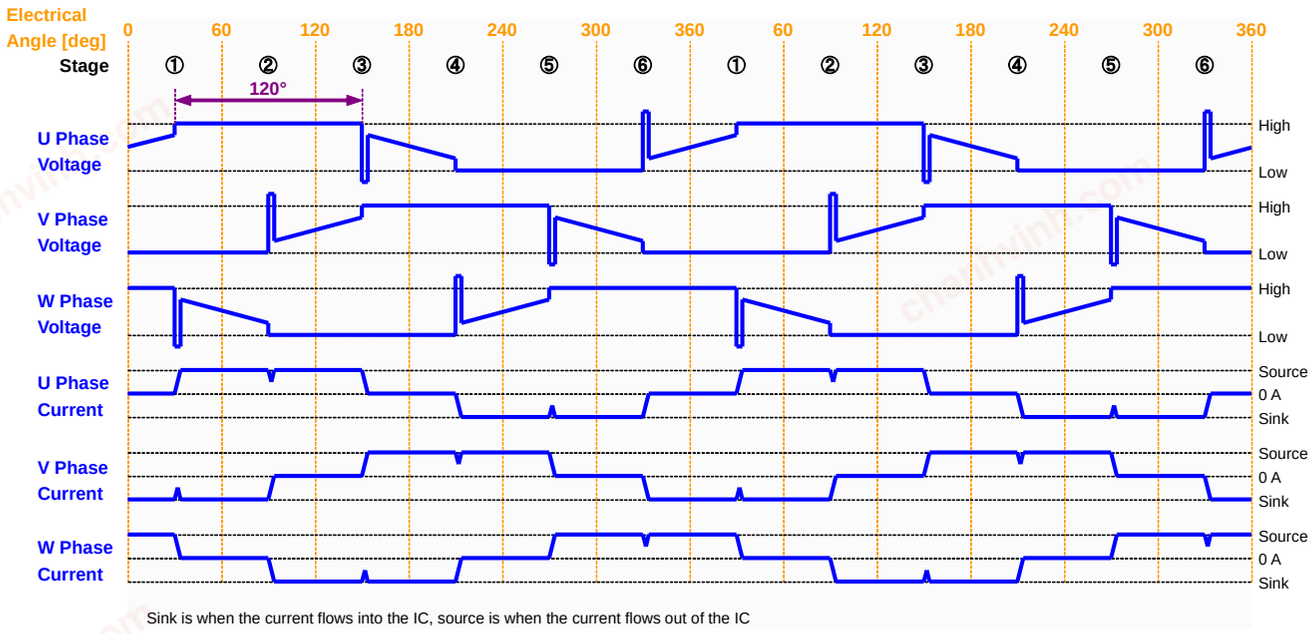


Figure 30. 120° Commutation Drive Timing Chart

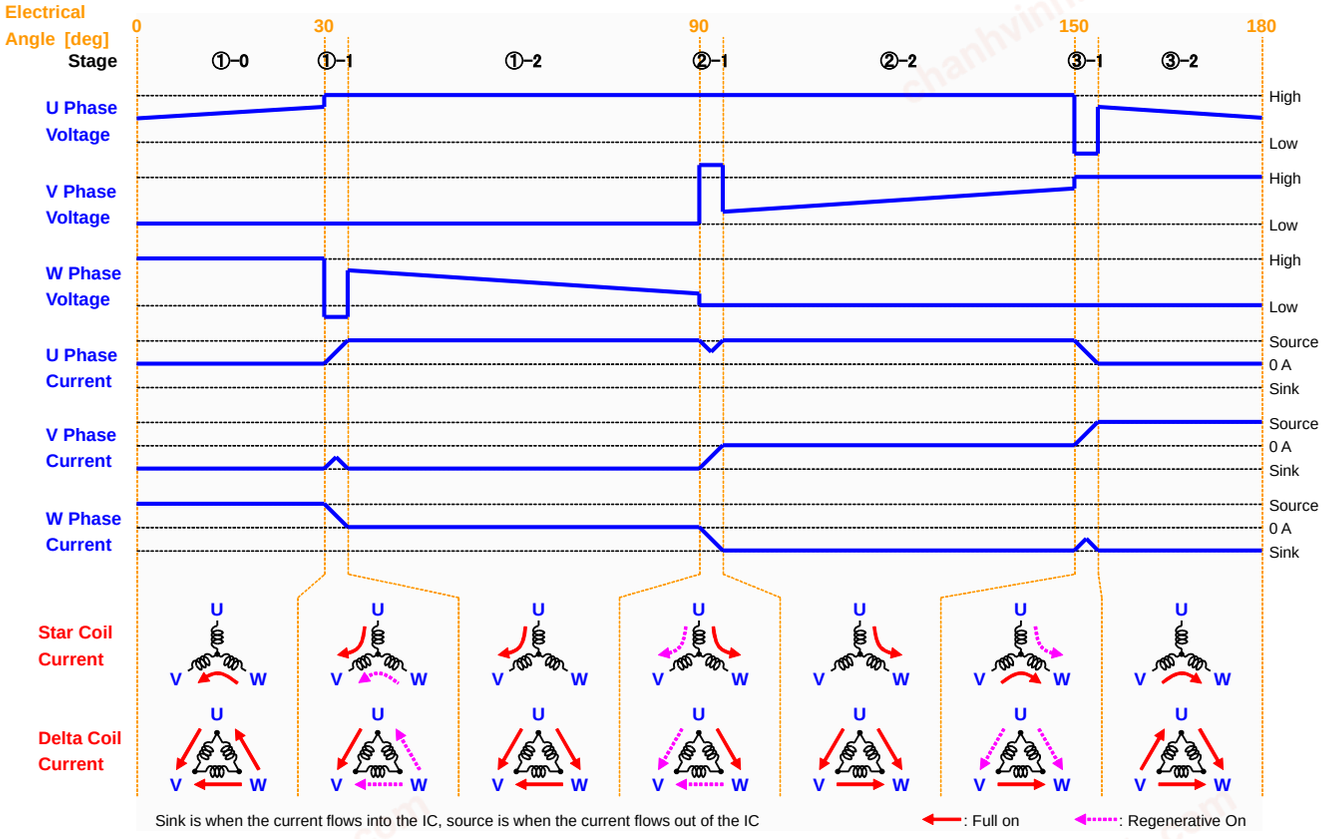


Figure 31. Motor Coil Current Change when 120° Commutation Drive

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Description of Blocks - continued

3. Variable Speed Control

(1) DC Voltage Input Variable Speed Control

Compare Variable Speed Control DC Voltage Input from the DCIN pin and Triangle Wave Voltage generated in the internal OSC circuit, and adjust speed by changing PWM duty of motor drive output (U, V, W) pin at Variable Speed Control PWM operational frequency f_{SPD}: 20 kHz (Typ).

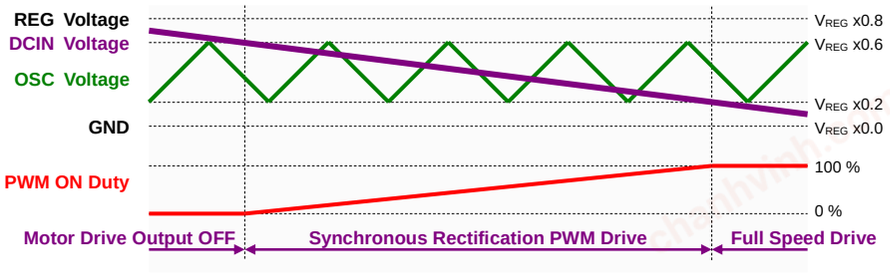


Figure 32. Variable Speed Control Input Output Timing Chart

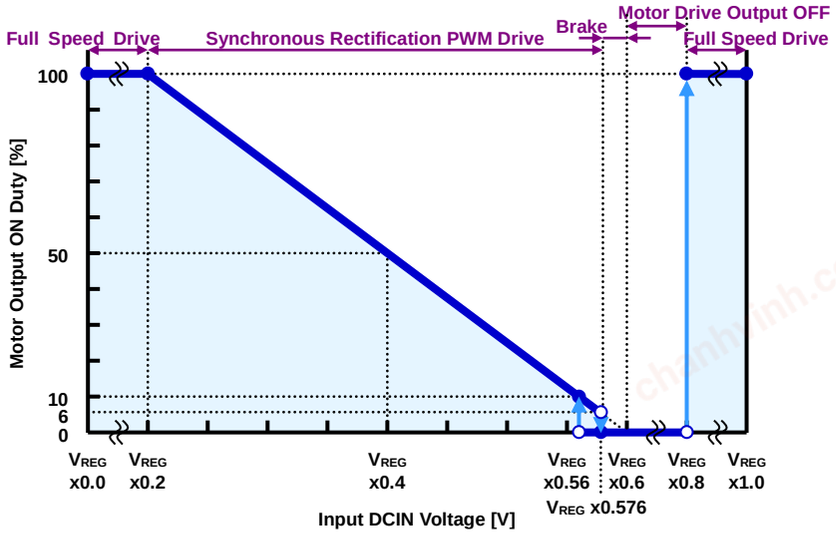


Figure 33. DCIN Control Profile

The resistor divider of the reference voltage V_{REG}: 5.0 V (Typ) generates internal OSC High voltage (V_{REG} x 0.6) and Low voltage (V_{REG} x 0.2). The PWM duty variation of motor drive output can be suppressed by configuring the variable speed control DC voltage input from the DCIN pin under V_{REG}.

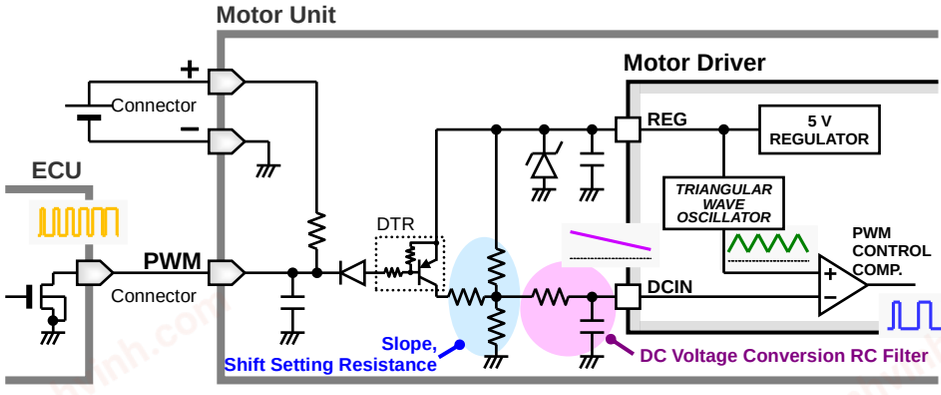


Figure 34. When Connect ECU Board and Motor Unit Board with a Connector

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(1) DC Voltage Input Variable Speed Control − continued
Various Speed Control can be realized by adjusting slope and shift setting resistance described in Figure 34.

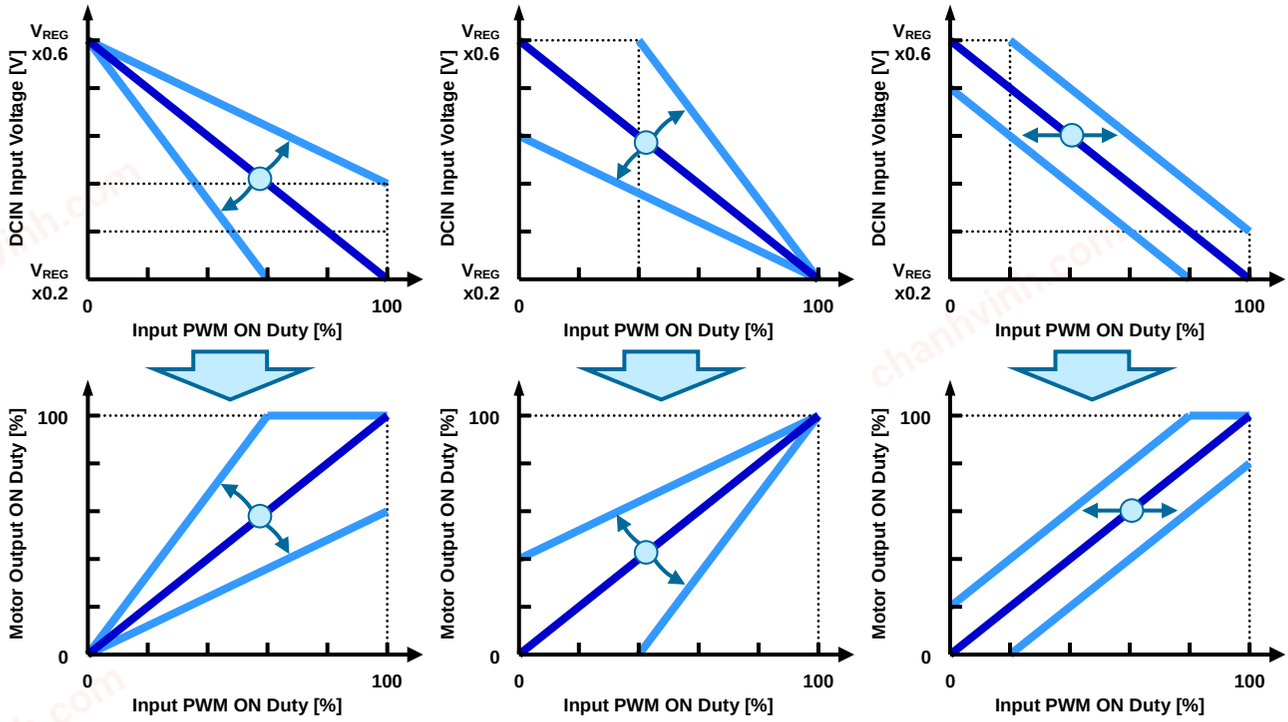


Figure 35. Example of Variable Speed Control Slope and Shift Setting

If the variable speed control input to the DCIN pin is DC voltage, it can also be used as follows:
Figure 36. It is an application that converts ambient temperature to DC voltage and control motor speed.
Thermistor that is placed nearby a heat source detects ambient temperature. In the case of NTC thermistor, motor speed increases in accordance with increase of ambient temperature.

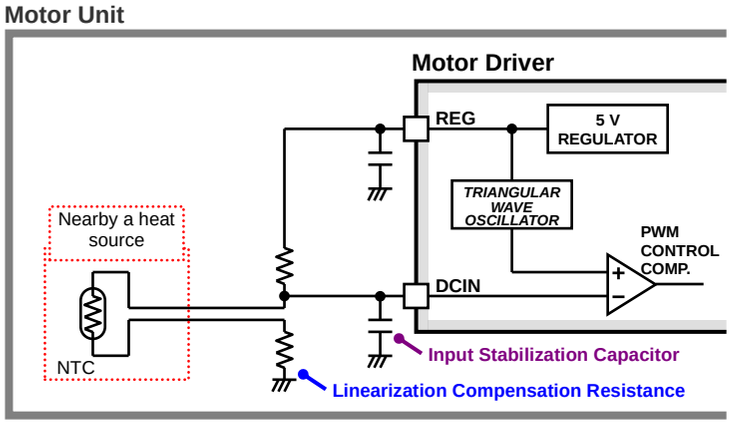


Figure 36. Temperature Control Application

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3. Variable Speed Control - continued

(2) Quick Start

Quick Start is the function to start-up immediately without the influence of the motor lock protection after the variable speed command from the DCIN pin stops motor and input the command at the timing of start-up.
When the command value continues for 90 µs (Typ) or more, it disables the motor lock protect function and keep all three phases of motor drive output high impedance logic (OFF). This state is called Quick start standby.
When inputting the command of motor drive, the start-up sequence described in Figure 25 starts, and the motor lock protection becomes enabled. Also, if the variable speed control DC voltage input V_{DCIN} is changed to V_{REG} x 0.8 or more and V_{REG} x 0.56 or less, it starts with Figure 25 start-up sequence after Quick start.

(3) Duty slope at the time of DCIN deceleration command

If the deceleration command is given to the DCIN pin during normal motor operation, a regenerative current will flow to the motor power supply because of synchronous rectification of the motor drive output.
Therefore, when the deceleration command is given, the PWM ON duty is gradually reduced at a slope of -1 %/ms.

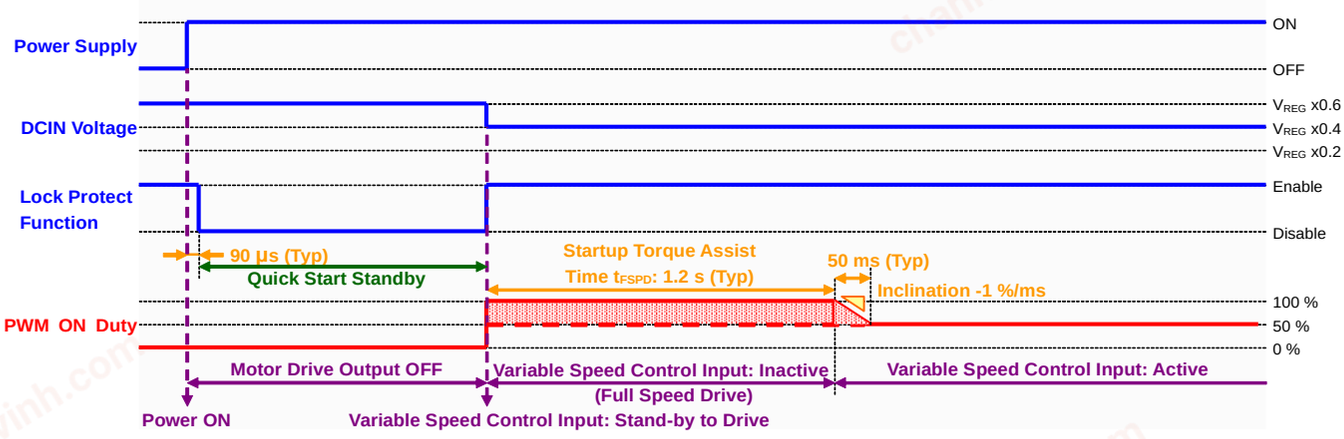


Figure 37. Quick Start Start-up Timing Chart

(4) Motor Drive Output PWM Operation

During variable speed control, set each two active motor drive output pins High, High logic or Low, Low logic (brake) depending on the variable speed control DC voltage from the DCIN pin.

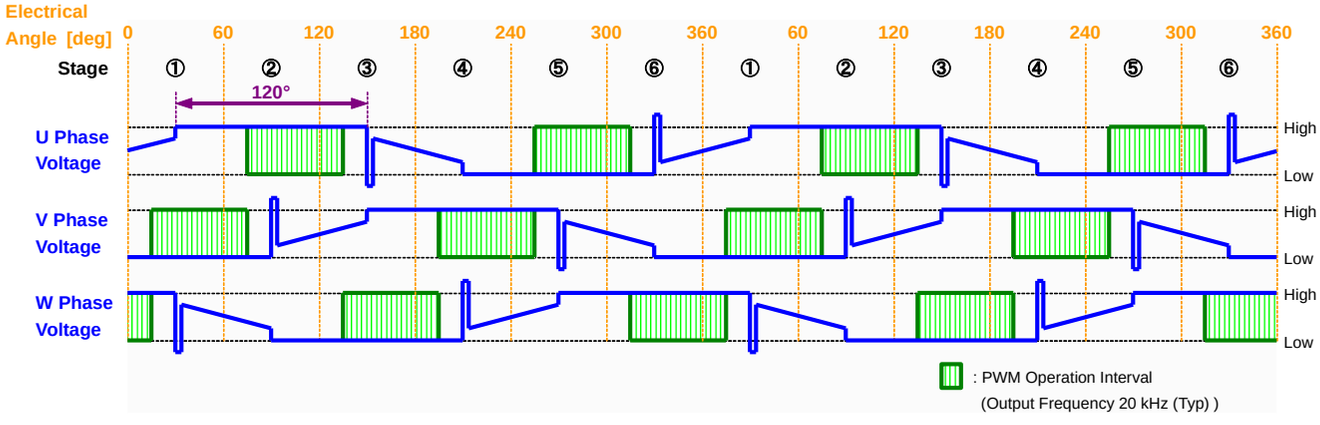


Figure 38. Variable Speed Control Motor Drive Output PWM Operation Timing Chart

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3. Variable Speed Control - continued

(5) Synchronous Rectification

When in PWM operation, in order to increase the current efficiency, the method of motor output is synchronous rectification that repeats the high and low logic.

To avoid the high and low side transistors that make up the motor drive are turned on at the same time and shoot-through current flows, high impedance section is setting at the 0.6 µs (Typ).

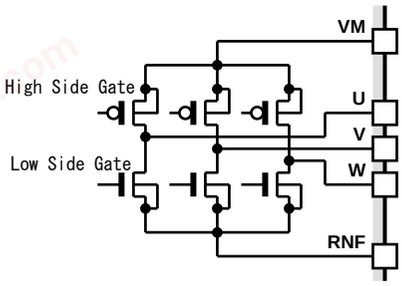


Figure 39. Motor Driver Output FET Circuit

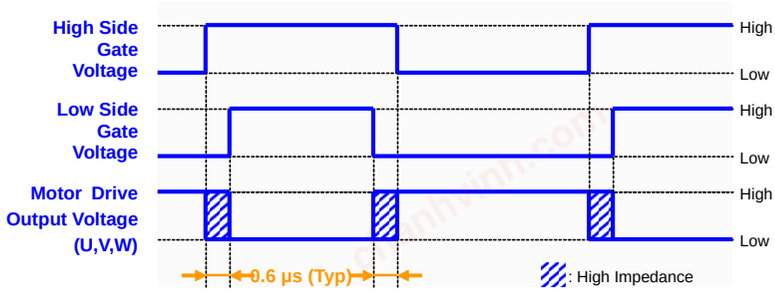


Figure 40. Synchronous Rectification Timing Chart when PWM Operation

(6) The DCIN Pin Setting

Voltage of the DCIN pin becomes unstable if it is Open. Please make sure to apply voltage into the DCIN pin when turning ON IC.

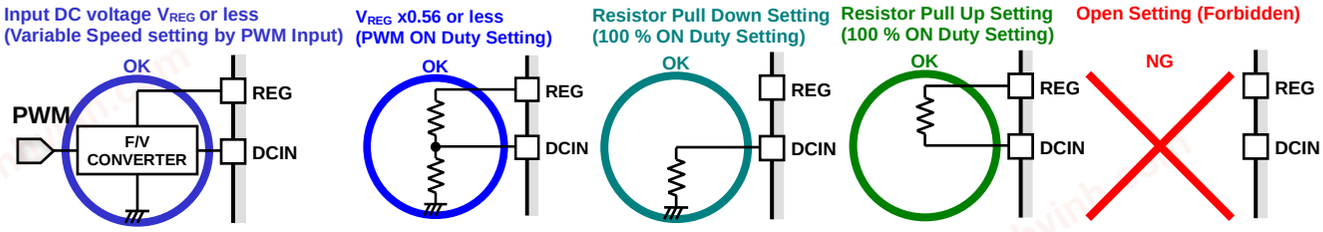


Figure 41. Variable Speed Control Command DC Voltage Function Setting

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Description of Blocks - continued

4. Lead Angle Selection

The LASEL pin can set 3 Lead Angle modes.
After the BEMF is detected a specified number of times (40 times), the selected lead angle degrees become enabled. Until 40 times, the lead angle is fixed at 30°. Please refer to Figure 25.

i) LASEL = OPEN (pull up to REG in the internal IC) High input
ii) LASEL = 1/2 x V_{REG} (pull down to GND in 100 kΩ) Middle input
iii) LASEL = GND (pull down to GND in 10 kΩ or less) Low input

LASEL	Lead Angle [deg]
H	7.5
M	15
L	30

H; High, M; Middle, L; Low

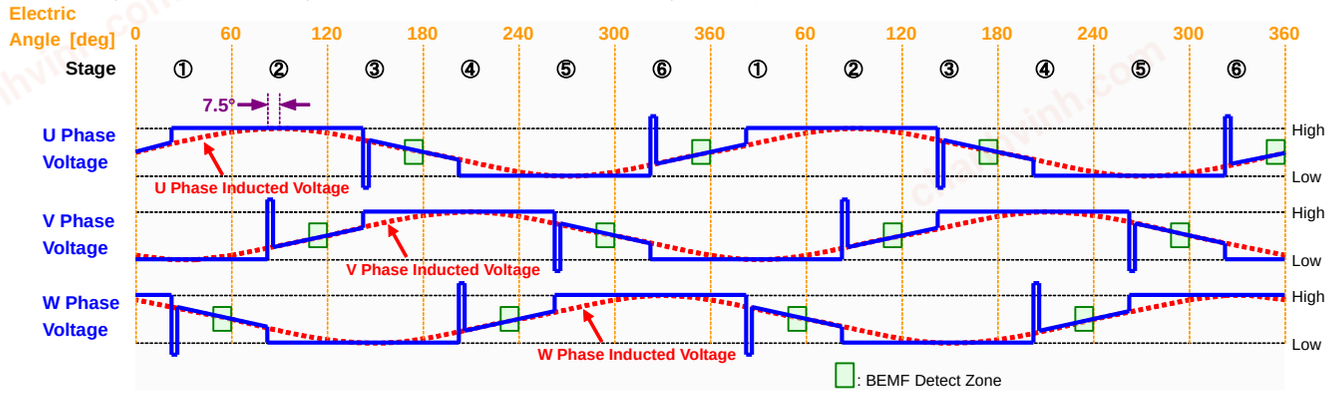


Figure 42. 7.5° Setting Timing Chart (LASEL = High)

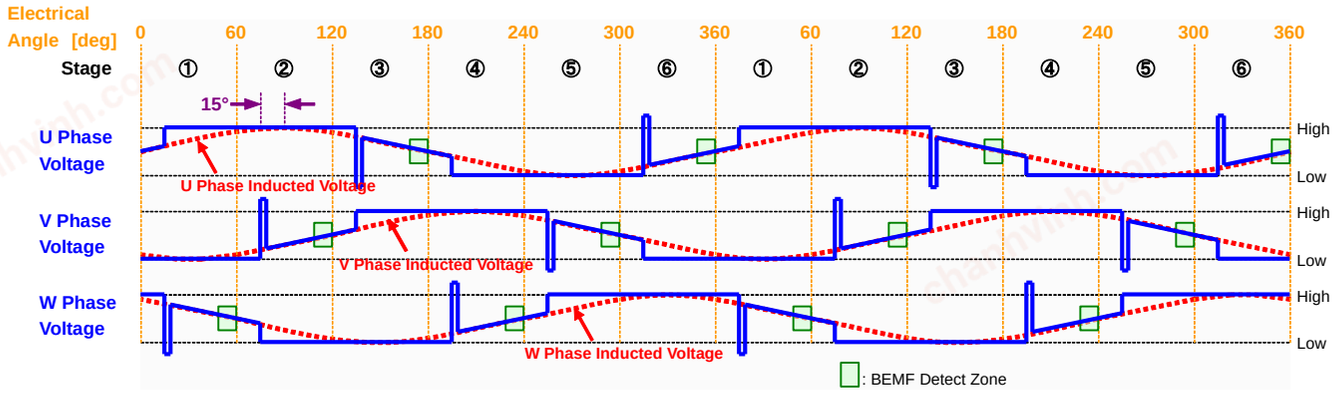


Figure 43. 15° Setting Timing Chart (LASEL = Middle)

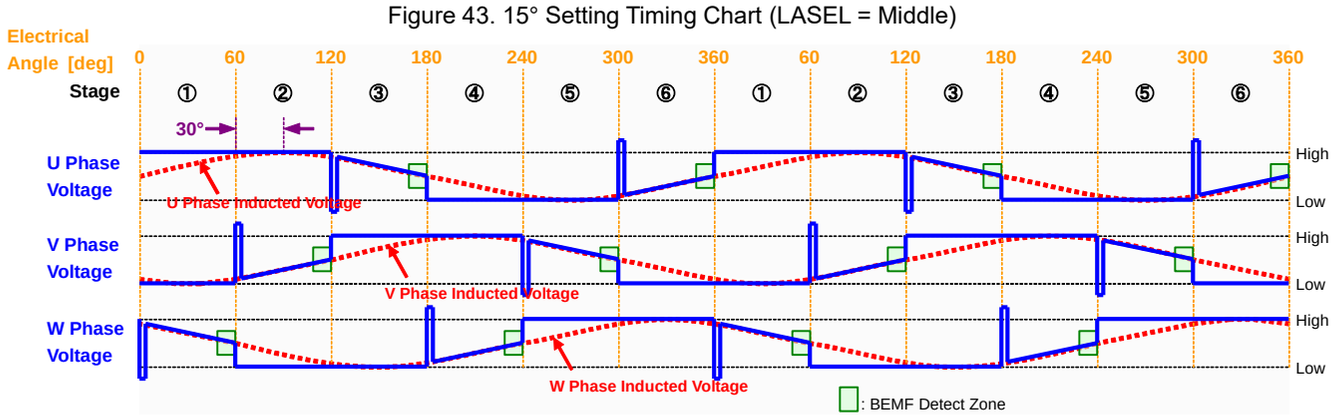


Figure 44. 30° Setting Timing Chart (LASEL = Low)

(1) The LASEL Pin Setting

The LASEL pin is pulled up to the REG pin at 100 kΩ (Typ) in IC.

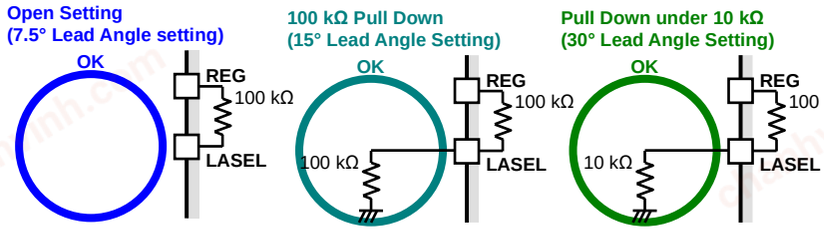


Figure 45. Lead Angle Select Function Setting

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Description of Blocks - continued

5. Current Limit

When the motor drive current flowing out from motor drive ground (RNF) is bigger than the setting value, Current Limit brakes it and turns OFF the output current.

(1) Current Limit Detection and PWM Drive

The resistor connected to the RNF pin converts motor drive current into voltage, and the voltage is inputted into the CSL pin. During the current limit detection time t_{CLLDET}: 3.2 µs (Typ), when the CSL voltage is Current Limit Detect Voltage V_{CLL}: 150 mV (Typ) or more, the current limit is triggered, and the two motor drive output pins at that time are changed to High and High logic or Low and Low logic (Brake) respectively, to turn OFF the motor drive current. After the current limit time t_{CLL}: 16 µs (Typ), if the CSL voltage is less than the current limit detection voltage V_{CLL}, releases the current limit and return the motor output. The current limit behavior is PWM drive that repeats detection (motor drive output brake) and release (motor drive output ON).

Also, as shown in Figure 46, after the current limit time t_{CLL}: 16 µs (Typ), if the motor is still in the current limit state (CSL voltage is V_{CLL} or more and less than Over Current Detect Voltage V_{CPL}: 250 mV (Typ)), returns the motor output for the current limit detect time t_{CLLDET}: 3.2 µs (Typ). Until the current limit is released, the PWM drive is repeated with the same timing.

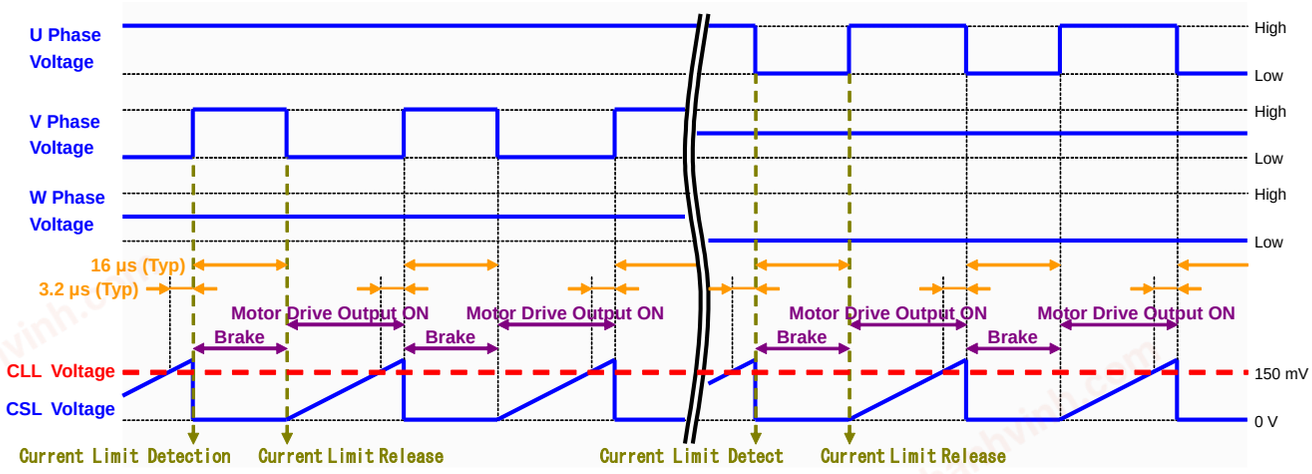


Figure 46. Current Limit PWM Operation Timing Chart 1

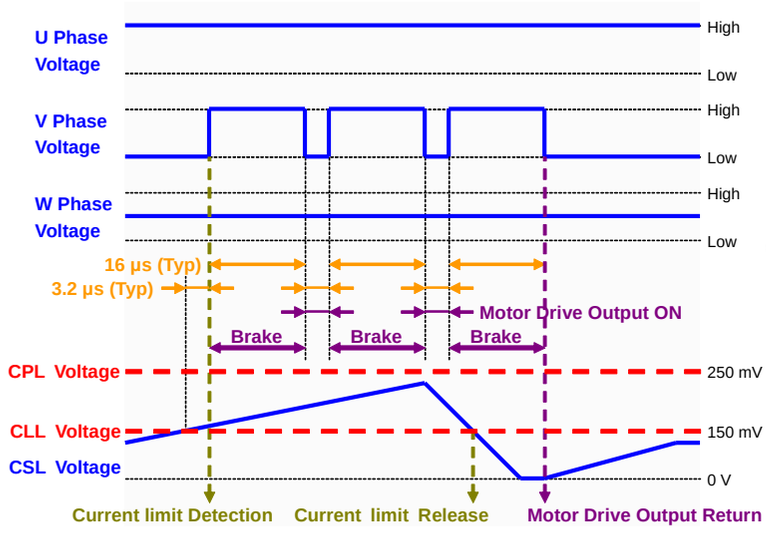


Figure 47. Current Limit PWM Operation Timing Chart 2

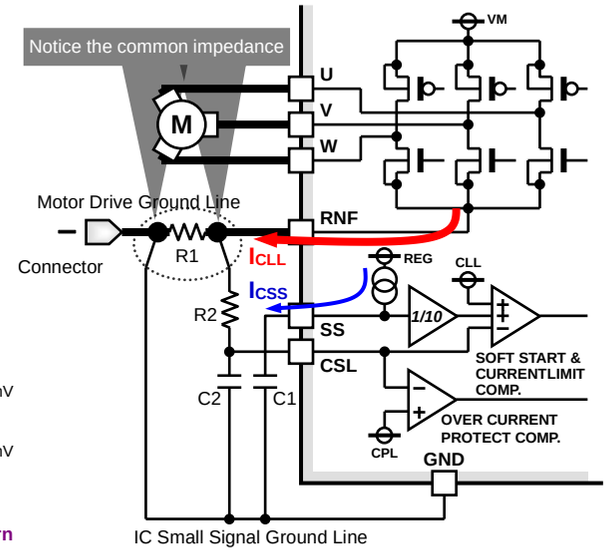


Figure 48. Separate with Small Signal Line and Motor Drive Line

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5. Current Limit - continued

(2) Current Limit Setting

In Figure 48, the setting value can be calculated according the RNF resistor of motor driver current and current detection voltage in the IC.

$$I_{CLL} = \frac{V_{CLL}}{R1} \text{ [A]}$$

where:
I_{CLL} is the Current Limit Setting Current [A]
V_{CLL} is the Current limit Detect Value [V] (Typ 150 mV)
$R1$ is the Motor Drive Current Detection Resistor [Ω]

When using current limit to restrain inrush current at the time of power ON, the variable speed control input and output protection return, according to motor drive output current I_{CL}: 3.2 A (absolute max rating) and the current limit detection voltage V_{CLL}: 150 mV (Typ), set the R1 to 56 mΩ or more.

(ex.) Motor drive current detection resistor is 56 mΩ, setting current is 2.7 A.

$$I_{CLL} = \frac{150\times10^{-3}}{56\times10^{-3}} = 2.7 \text{ [A]}$$

(3) Current Limit False Detection Measure

In Figure 48, R2 and C2 are low pass filter of RNF voltage. To prevent false detection measure of the current limit, the GND of C2 and GND of IC must be common and separate it with the GND of R1.
Notice the common impedance between IC small signal line, detection line connecting R2 and motor drive ground line connecting R1.

(4) Relationship between Current Limit Function and Soft Start Function

The detected voltage input of current limit has the common part with detected voltage input of soft start.
So, if the CSL pin is set so that the current limit function is disable, soft start function is disabled, too.

(5) Relationship between Current Limit Function and Low Side Over Current Protection Function

The detected voltage input of current limit has the common part with detected voltage input of low side over current protection function.
So, if the CSL pin is set so that the current limit function is disable, low side over current protection function is disabled, too.

(6) The CSL Pin Setting

The voltage of the CSL pin becomes unstable when it's open, if you do not need the current limit, the CSL pin must be connected to GND through resistor.

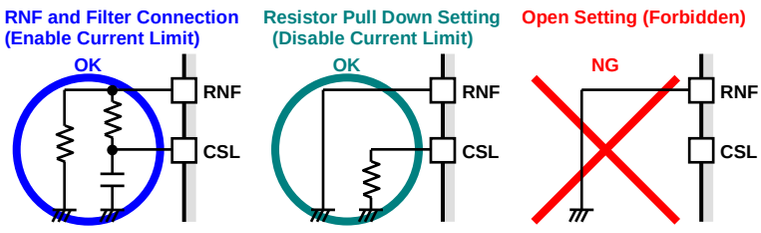


Figure 49. Current Limit Function Setting

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Description of Blocks - continued

6. Soft Start

According to the condition shown below in the motor stop, when the motor is starting, increase the rotation speed slowly and restrain inrush current.

i) Power ON (UVLO Release) and Variable speed control input
ii) Motor lock detection
iii) After protection release (Over Current Protection, Over Voltage Protection, and Thermal Shutdown)

(1) Soft Start Current Detection and PWM Operation

When the motor is starting, the current flows from the SS pin to capacitor, the voltage of the SS pin increases slowly. Compare the Current Limit Detection Voltage V_{CLL}: 150 mV (Typ) with one-tenth times voltage of the SS pin and select lower one as the threshold. It compares with CSL voltage while doing the same as a current limit PWM drive. The SS pin clamps depending on the IC internal power supply. If the power supply voltage (VCC) is 12 V, the clamp voltage V_{SSCLP1}: 3.5 V (Typ).

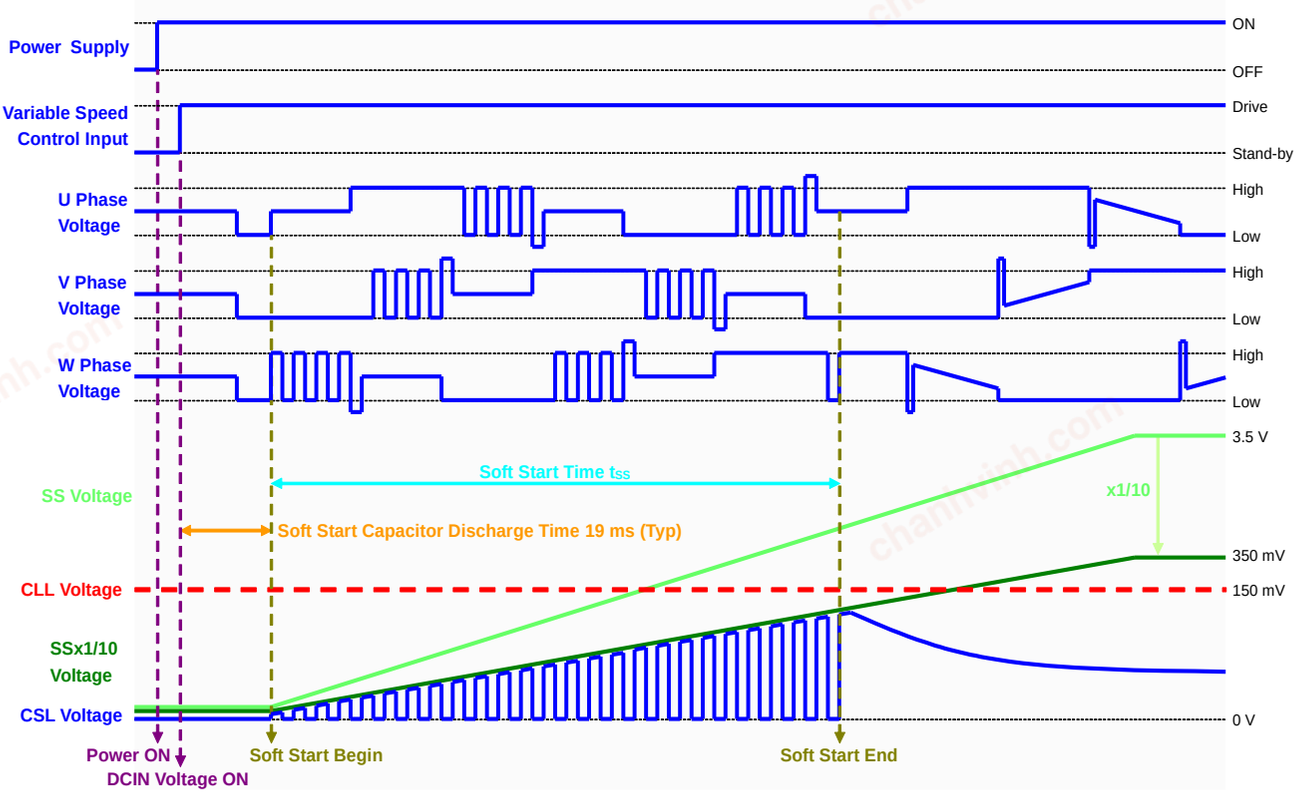


Figure 50. Soft Start PMM Operation Timing Chart when Power ON (variable speed control input)

(2) Soft Start Setting

The maximum current restricted by soft start is the Soft Start Current, and the time to reach to the set current is the Soft Start Time.
In Figure 48, it sets the soft start time by charging to SS capacitor.
But within the soft start time, if the current reaches the Current Limit Detection Voltage V_{CLL}: 150 mV (Typ), the soft start is finished.

$$t_{SS} = \frac{C1 \times I_{CUT} \times R1}{|I_{CSS}|/10} \text{ [s]}$$

where:
t_{SS} is the Soft Start Time [s]
$C1$ is the SS Capacitance Value [F]
I_{CUT} is the Soft Start Current [A]
$R1$ is the Motor Drive Current Detection Resistor [Ω]
I_{CSS} is the SS Charge Current [A] (Typ -2.2 μA)

(ex.) The soft start time is 448 ms when SS Capacitor is 2.2 μF, Soft Start Current is 0.8 A, and Motor Drive Current Detection Resistor is 56 mΩ.

$$t_{SS} = \frac{2.2\times10^{-6}\times0.8\times56\times10^{-3}}{|-2.2\times10^{-6}|/10} = 448 \times 10^{-3} \text{ [s]}$$

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6. Soft Start - continued

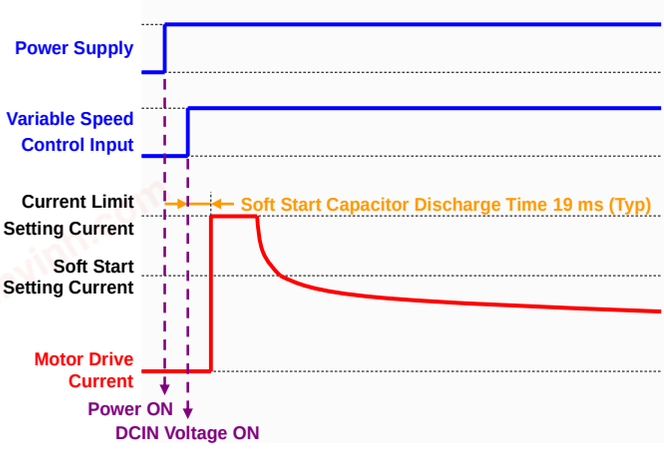


Figure 51. Motor Drive Current Characteristic when Soft Start Disable

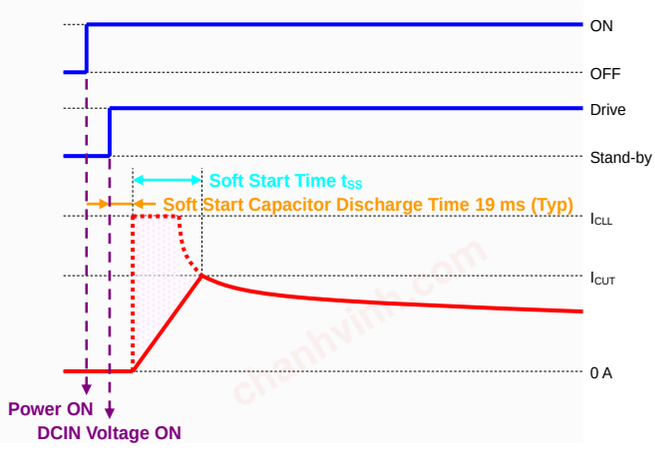


Figure 52. Motor Drive Current Characteristic when Soft Start Enable

(3) Soft Start False Detection Measure
In Figure 48, the ground of C1 and the GND pin of IC must be the common GND and separate it with the GND of R1.

(4) Relationship between Soft Start Function and Current Limit Function
Soft start detection voltage input unit share input pin with current limit detection voltage input unit above.
So, be sure to note that if set the CSL pin so that the current limiting function is disabled, the soft start function is disabled even if an arbitrary capacitor is connected to the SS pin.

(5) The SS Pin is Forbid Diversion as the Speed Control Function
The motor speed can be controlled by Inputting a variable voltage from the outside of the IC to the SS pin to control the current limit value. However, current limit function assumes that you use it as speed control function and does not design it. The motor drive output PWM frequency depends on the current limit setting value. Therefore, the SS voltage will affect the EMC performance and forbid to add the adjustable voltage into the SS pin.

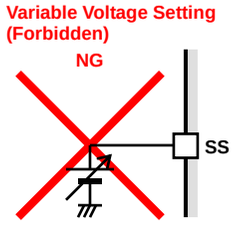


Figure 53. Variable Voltage Input to the SS pin is forbidden

(6) The SS Pin Setting
If the soft start function is disabled, the SS pin is opened.

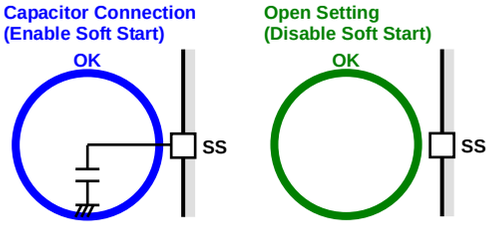


Figure 54. Soft Start Function Setting

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Description of Blocks - continued

7. Rotation Pulse Signal Output

The signal pulse that depends on the motor rotation is outputted by the FG pin. Detecting the rotation speed and judging lock state is possible. According to the condition below, during motor stop, when the motor is starting, within Startup Mask Time t_{FGMSK}:1.2 s (Typ) the FG output is high impedance, and then the signal is the same as the synchronous signal of U phase output.

i) Power ON (UVLO Release) and Variable Speed Control Input
ii) After Protection Release (Lock, Over Current, Over Voltage, and Thermal Shutdown)

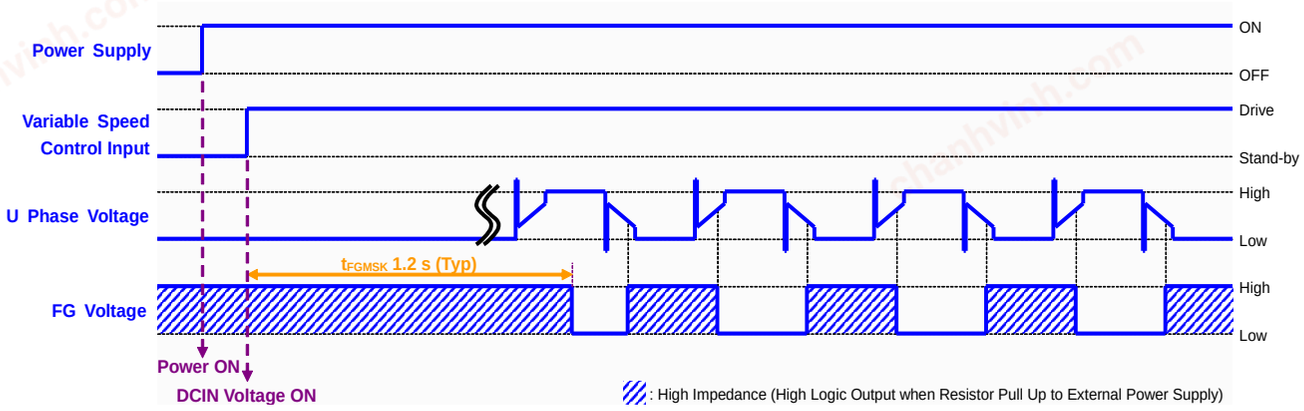


Figure 55. Rotation Pulse Signal Output (FG) Timing Chart when Power ON (Variable Speed Control Command Input)

(1) Calculate Motor Rotation Speed

The relationship between FG frequency and motor rotation speed.

$$N = \frac{2 \times f}{P} \text{ [min}^{-1}\text{]}$$

where:
N is the motor rotation speed [min^{-1}]
f is the FG output frequency [Hz]
P is the number of poles [pole]

(ex.) For 8 pole motor drive, and FG frequency is 500 Hz, the motor rotation speed at minute is 7500 min^{-1}.

$$N = \frac{2 \times 500}{8} \times 60 = 7500 \text{ [min}^{-1}\text{]}$$

(2) Reverse Rotation Detection by FG Logic

After variable speed control input, judging the motor state as reverse rotation, FG output is low logic during the reverse protection 1.0 s (Typ).

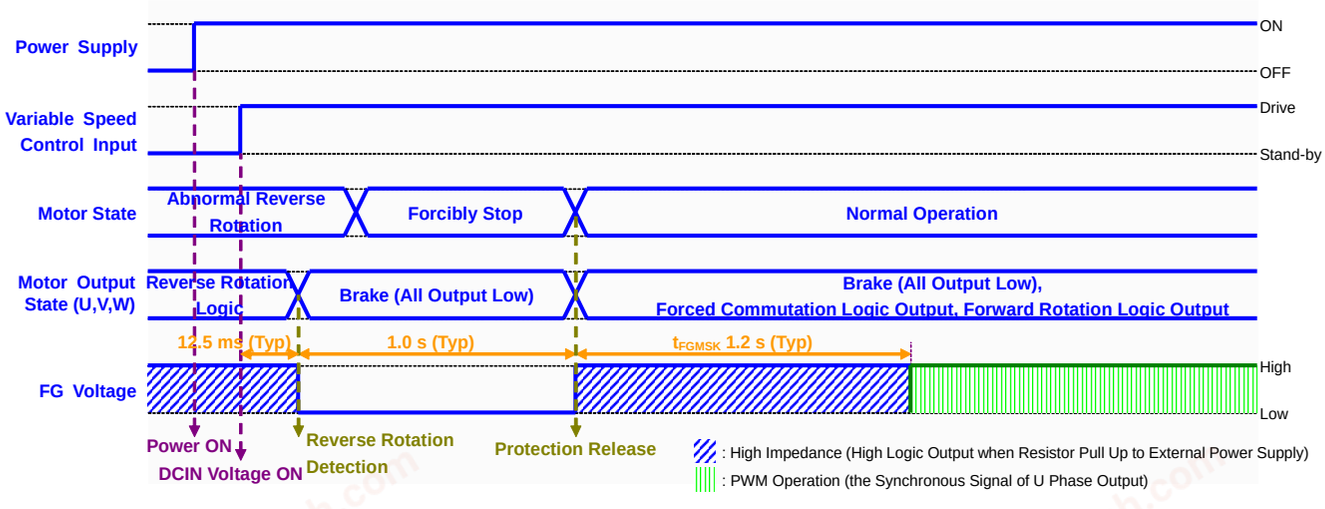


Figure 56. Motor Output State Transition and Rotation Pulse Signal (FG) Output Timing Chart when Reverse Rotation

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7. Rotation Pulse Signal Output - continued

(3) The FG Pin Setting

The FG pin is open drain output, please pull it up by resistance to external power.

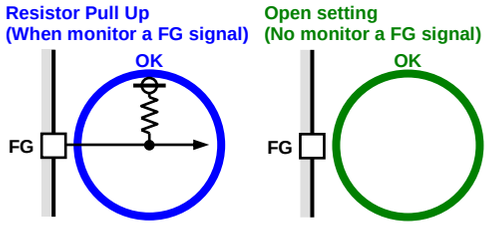


Figure 57. Rotation Pulse Signal Output Function Setting

8. Output Protection Alarm Output

The signal of output protection function state is outputted by the AL pin.
It can be used to judge the motor alarm state.
When the power on from the motor stopped state, the AL output logic is low, and maintain low during normal motor operation under variable speed control command.
When the conditions below are detected, it changes the protection related outputs ON duty (Output Frequency f_{AL}: 39 kHz (Typ)).
If the protection is released and the motor is re-starting, the AL output is fixed to the high impedance logic during the restart mask time t_{ALMSK}: 1.2 s (Typ), AL output is high impedance and then the output logic is low.
Also, please note that the output protection alarm signal is not linked to the UVLO.

Output Protection Function	AL Output ON Duty [%]
Over Voltage	12.5
Over Current	25
Thermal Shutdown	50
Motor Lock	75

i) Output Protection (Motor Lock, Over Current, Over Voltage, Thermal Shutdown)

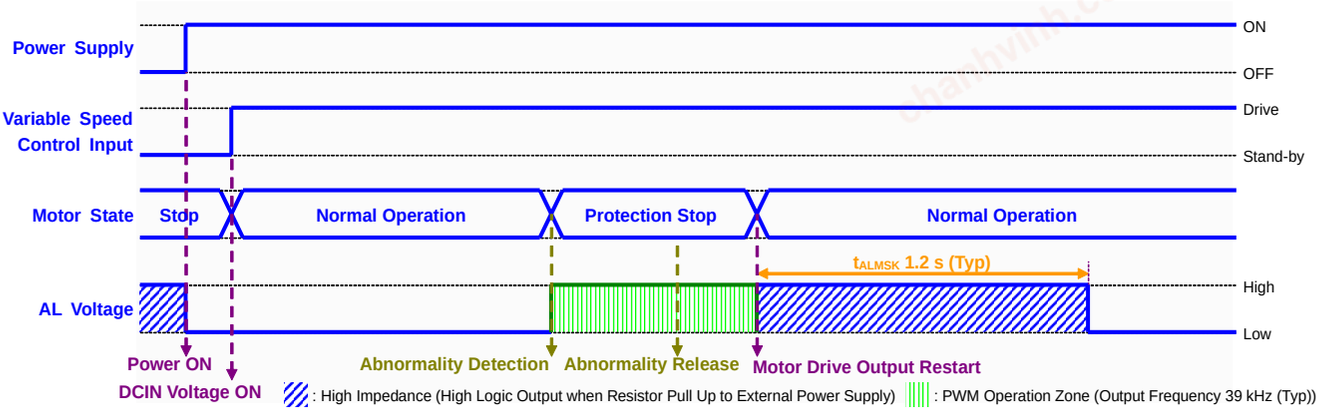


Figure 58. Output Protection Alarm Signal Output Timing Chart when Power ON (Variable Speed Control Command) and Motor Drive Output Release

(1) The AL Pin Setting

The AL pin is open drain output, please pull it up by resistance to external power.

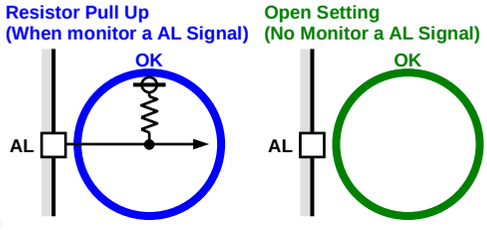


Figure 59. Output Protection Alarm Signal Function Setting

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Description of Blocks - continued

9. Output Protection

(1) Abnormal Detection and Protection Release

IC has a protection function that detects the abnormal state of the motor and the abnormal state of the IC and stops the motor. For the abnormality detection conditions and protection release conditions for each protection function, refer to the operation description below.

Table 3. Output Protection Function List

Priority	Stop Mode	Protection Condition		Motor Driver Output (U, V, W) Status		Protection Alarm (AL)
		Abnormality Detection	Protection Release	Mode	Logic	ON Duty
1	Over Voltage	VCC 30 V (Typ) or more	VCC 28 V or less	Brake	Low	12.5 %
2	Over Current	(1) High Side Detect Voltage V_{CPH} (150 mV (Typ)) ÷ High Side Current Detection Resistor (2) Low Side Detect Voltage V_{CPL} (250 mV (Typ)) ÷ Low Side Current Detection Resistor	Automatic restart after given period of time 240 ms (Typ)	Open	OFF (Hi-Z)	25.0 %
3	Thermal ShutDown	Junction Temperature 175 °C (Typ) or more	Junction Temperature 150 °C (Typ) or less	Brake	Low	50.0 %
4	Quick Start Standby	DCIN input voltage is V_{REG} x 0.6 or more and V_{REG} x 0.8 or less	DCIN input voltage is V_{REG} x 0.56 or less or V_{REG} x 0.8 or more	Open	OFF (Hi-Z)	0.0 % (Low logic)
5	Motor Lock (Startup Fault)	(1) Back electromotive voltage is not detected during the judging time 16.7 ms (Typ) (2) Abnormal rotation detection (equivalent to f_{FG}) The max rotation speed 3.3 kHz (Typ) The min rotation speed 10 Hz (Typ)	Automatic restart after given period of time 1.0 s (Typ) or 5.0 s (Typ)	Brake	Low	75.0 %

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9. Output Protection - continued

(2) The Protection Priority of Multi Abnormal state

The high priority function is available when detecting different output protection during normal operation. Over Voltage Protection is the highest priority. Therefore, when Over Voltage Protection is detected, other protection states become invalid.

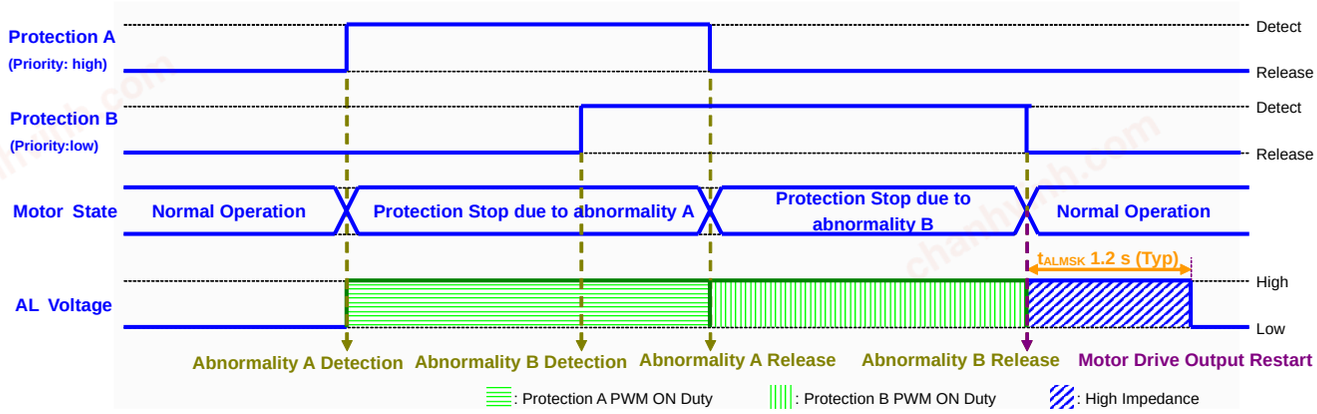


Figure 60. Protection Status When Detecting Multi Abnormalities and Output Protection Alarm Signal Output Timing Chart 1

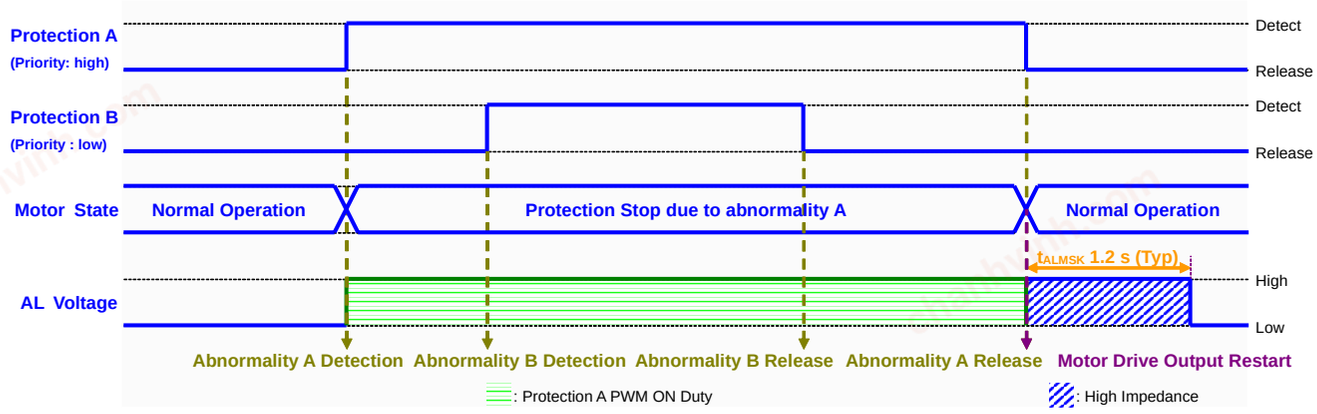


Figure 61. Protection Status When Detecting Multi Abnormalities and Output Protection Alarm Signal Output Timing Chart 2

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Description of Blocks - continued

10. Motor Lock Protection (MLP)
External factors may lead to motor lock, brake motor to turn OFF the driver current.
After setting time, the lock will be released.

(1) Motor Lock Detection and Automatic Restart during start-up mode
When the power on and the variable speed control is input in the motor locked state, the motor drive output is turned on for the time (t_{MLPDET} + t_{MLPJDG}) even if the back electromotive voltage can't be detected. After that, the all three phases of motor drive output are fixed to low logic (brake) for the protection time1 t_{MLP1} and cut off the motor current. After the protection time t_{MLP1}, the motor drive output is turned on again in the same sequence as when the variable speed control input for the time (t_{MLPDET} + t_{MLPJDG}), and it is determined whether the motor lock state continues.

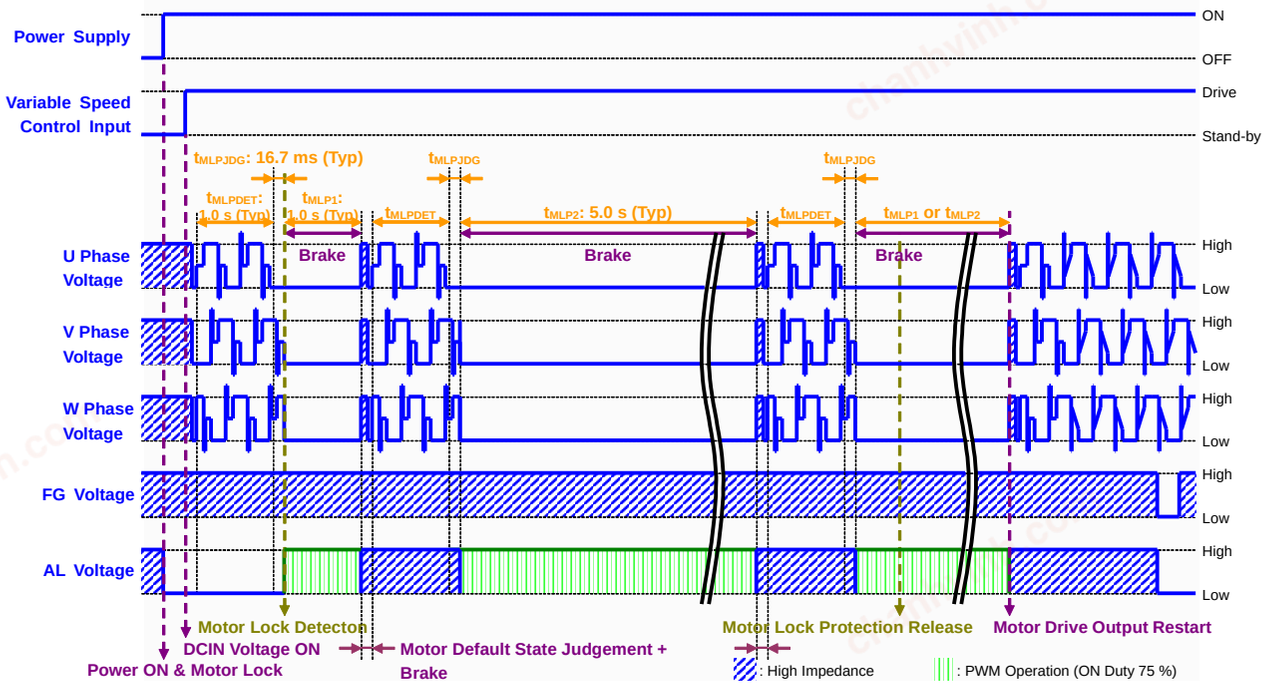


Figure 62. Motor Lock Protection Timing Chart (During the start-up mode)

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10. Motor Lock Protection (MLP) - continued

(2) Lock Protection Detection and Automatic Restart from a Normal Rotation

If the back electromotive voltage can't be detected within the judgment time t_{MLPJDG}: 16.7 ms (Typ) during the drive mode, IC judge that the motor is locked. When the lock is detected, all three phases of motor drive output are fixed to low logic (brake) for the protection time2 t_{MLP2}: 5.0 s (Typ) and cut off the motor current. After the lock protection time (t_{MLP2}), during the detection time t_{MLPDET}: 1.0 s (Typ) + judgment time t_{MLPJDG}, the motor drive output is turned on in the same sequence as when the variable speed control input, and IC judge whether the motor lock state continues. When it is judged that the motor is locked again, it is fixed to Low logic (brake) for the protection time1 t_{MLP1}: 1.0 s (Typ). The protection time while continuing to determine that the motor is locked repeats t_{MLP1} and t_{MLP2} alternately.

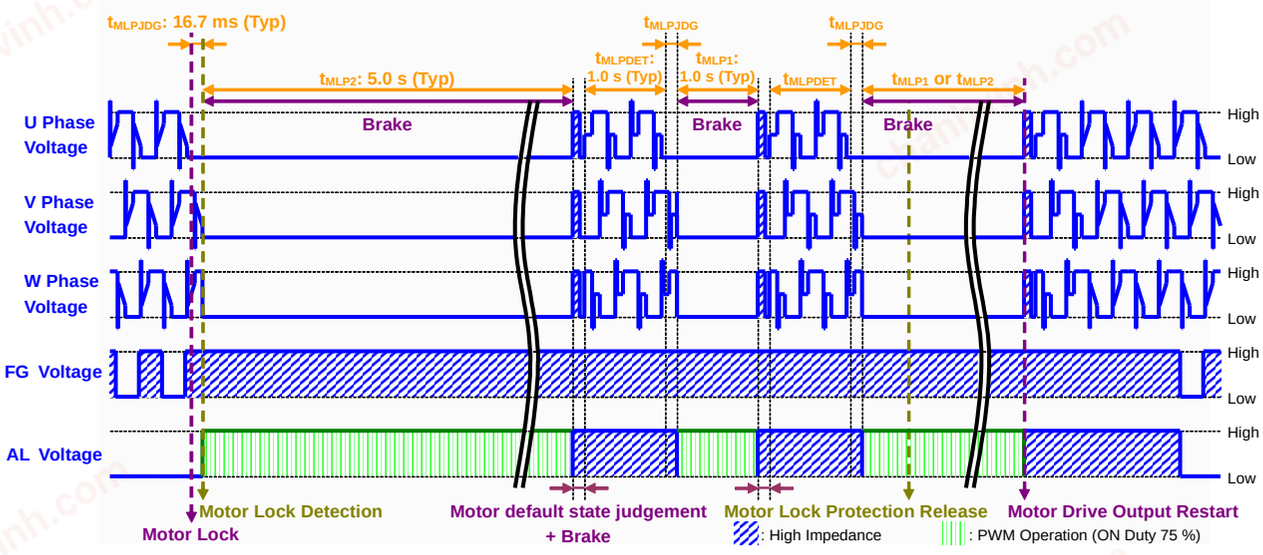


Figure 63. Motor Lock Protection Operation Timing Chart (Motor Lock during Drive Mode)

(3) Abnormal Rotation Detection and Assist Mode

To avoid unintended motor operation such as step-out due to false detection of back electromotive voltage of the short period, the false detection prevention mask is set at high rotation range.

When the motor speed is the high rotation detection frequency f_{MAXFG}: 3.3 kHz (Typ) (FG frequency conversion) or more, the motor is stopped by motor lock protection.

And in the low rotation range, when the motor speed is the low rotation detection frequency f_{MINFG}: 10 Hz (Typ) (FG frequency conversion) or less, the motor is stopped by motor lock protection.

But, if the back electromotive voltage is not detected or falsely detected even switching the motor drive output logic in forced commutation drive 8 times during the start mode (detection time t_{MLPDET}: 1.0 s (Typ)), return to brake sequence (Assist Mode).

Table 4. Relationship between Motor Pole and Max Rotation Speed List (High Speed)

Max Rotation Speed (Typ)				
Driver IC	Motor			
FG Frequency [kHz]	4 Pole [min^{-1}]	6 Pole [min^{-1}]	8 Pole [min^{-1}]	12 Pole [min^{-1}]
3.3	99,000	66,000	49,500	33,000

Table 5. Relationship between Motor Pole and Min Rotation Speed List (Low Speed)

Min Rotation Speed (Typ)				
Driver IC	Motor			
FG Frequency [Hz]	4 Pole [min^{-1}]	6 Pole [min^{-1}]	8 Pole [min^{-1}]	12 Pole [min^{-1}]
10	300	200	150	100

(4) Start-up Failure

When sensor less start-up fails from t_{MLPDET}: 1.0 s (Typ) (detection time) to t_{MLPJDG}: 16.7 ms (Typ) (judgement time), the logic of all three phases of motor drive output is fixed to Low logic (brake) for protection time1 t_{MLP1}: 1.0 s (Typ) and block the motor drive current. After t_{MLP1}, turn the motor driver output ON with the same sequence as the time of variable speed control input (t_{MLPDET} + t_{MLPJDG}).

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Description of Blocks - continued

11. Over Current Protection (OCP)

Monitoring the motor drive current flow into motor drive power supply (VM) pin and flow out from motor drive ground (RNF) pin and if it exceeds the set value, the IC brakes the motor and turns off the output current.
And, the purpose of the over current protection is to prevent the destruction in case of sudden accidents. It must not operate it constantly.

(1) High Side Over Current Detection and Automatic Restart

The resistor connected to the VM pin converts motor drive current into voltage, and the voltage is inputted into the CSH pin. During the detection time t_{OCPDET}: 6.4 µs (Typ), when the CRH-CSH voltage is the high side detection voltage V_{CPH}: 150 mV (Typ) or more with reference to the CRH pin, the high side over current detection is triggered, all three phases of motor drive output are fixed to high impedance logic (OFF) for a certain period of time to cut off the motor drive current. After the protection time t_{OCP}: 240 ms (Typ), if the CRH-CSH voltage is less than V_{CPH}, releases the high side over current protection and returns the motor drive output. Also, after the protection time t_{OCP}, if it is still in over current state (when CRH-CSH voltage is V_{CPH} or more), returns the motor drive output for the detection time t_{OCPDET}: 6.4 µs (Typ) for detecting motor drive current following a motor initial state judgement and brake. Until the high side over current protection is released, the intermittent operation is repeated at the same timing.

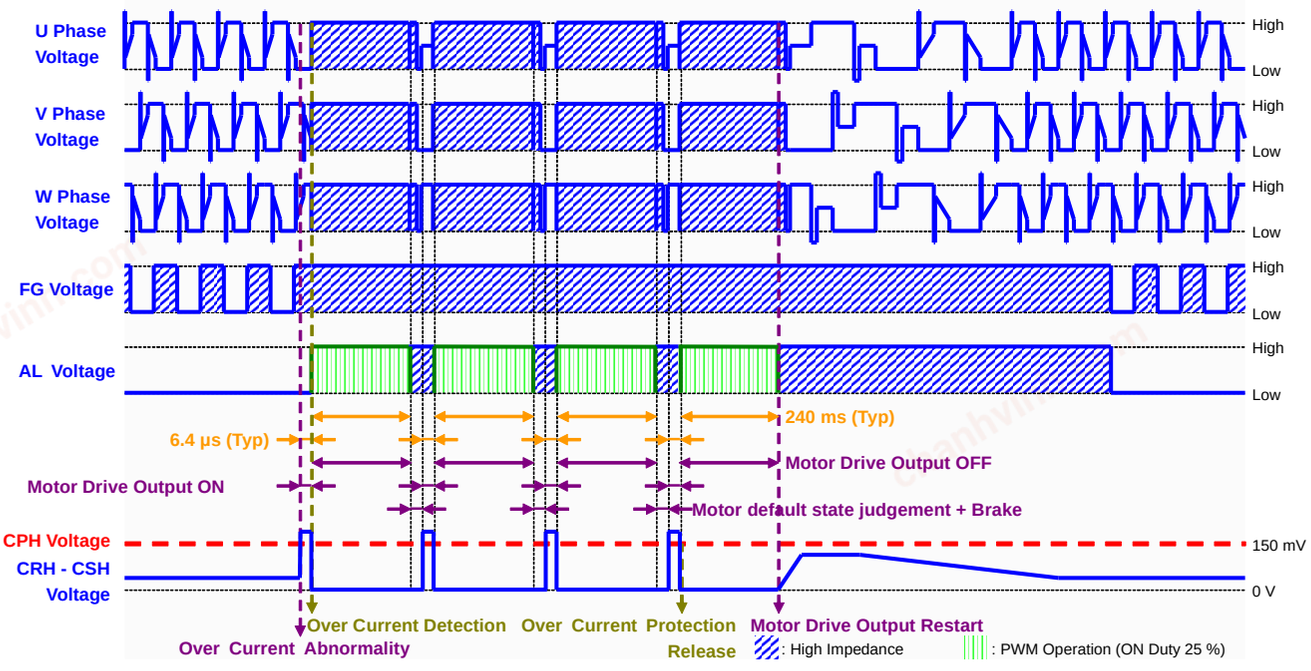


Figure 64. High Side Over Current Protection Timing Chart

(2) High Side Over Current Protection Current Setting

In Figure 65, the setting value can be calculated according to the VM resistor of motor driver current and high side over current protection voltage in the IC.

$$I_{CPH} = \frac{V_{CPH}}{R4} \text{ [A]}$$

where
I_{CPH} *is the* High Side Over Current Protection Detection Current [A]
V_{CPH} *is the* High Side Over Current Protection Detection Voltage [V] (Typ 150 mV)
R4 is the High Side Motor Drive Current Detection Resistor [Ω]

According to electrical characteristics (current limit setting voltage, high side over current protection voltage), please set R4 to be 30 mΩ or more.

(ex.) If high side motor drive output current detection resistance value is 30 mΩ, the high side over current protection detection current value is 5.0 A.

$$I_{CPH} = \frac{150\times10^{-3}}{30\times10^{-3}} = 5.0 \text{ [A]}$$

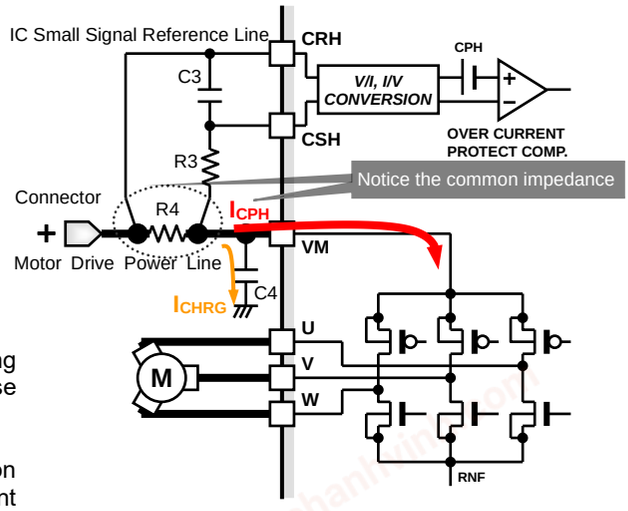


Figure 65. Separate with Small Signal Line and Motor Drive Line

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11. Over Current Protection (OCP) - continued

(3) High Side Over Current Detection Measure

In Figure 65, R3 and C3 are low pass filter of VM voltage. In order to prevent the false detection measure of over current, notice that the power supply reference line (C3 and CRH) and the current detection line (R3) have a common impedance of Motor drive power line (R4). And, if VM voltage stabilizing capacitor is connected like C4, depending on its capacitance value, false detection on the high side over current protection may occur due to transient charging current such as starting up.

(4) High Side Over Current Protection Function and Current Limit Function Parallel Use

When you use current limit together with high side over current protection, please select current detection resistor of each function, to avoid the high side over current protection setting current exceeding the current limit setting current. If you reverse each setting value, high side over current protection operates earlier than current limit, for rush current in motor starting up. In this case, motor may not start up normally.

But even if you select correct setting value, depending on the low pass filter component value of motor drive current detection route, motor may not start up normally. Please select component value after having evaluated enough, so that characteristics do not have a problem.

In Table 6, if R1 (low side motor drive current detection resistor) is 56 mΩ, I_{CLL} (current limit setting current) is 3.0 A maximum when taking V_{CLL} (current limit detection voltage) electrical characteristics into consideration. In this case, R4 (high side motor drive current detection resistor) value where I_{CPH} (high side over current setting current) always exceeds I_{CLL} is 30 mΩ when taking electrical characteristics of V_{CPH} (high side over current detection voltage) into consideration. And, when R1 setting value is 100 mΩ, R4 settable range is from 30 mΩ to 51 mΩ.

Table 6. Current Detection Resistor Setting Table

Current Limit Function			High Side Over Current Protection Function		
Low Side Motor Drive Current Detection Resistor R1 [mΩ]	Setting Current I_{CLL} [A]		High Side Motor Drive Current Detection Resistor R4 [mΩ]	Detection Current I_{CPH} [A]	
	Current Limit Detect Voltage V_{CLL} 150 mV (Typ)	Current Limit Detect Voltage V_{CLL} 170 mV (Max)		High Side Over Current Detection Voltage V_{CPH} 100 mV (Min)	High Side Over Current Detection Voltage V_{CPH} 150 mV (Typ)
51	Forbidden Setting		27	Forbidden Setting	
56	2.7	3.0	30	3.3	5.0
62	2.4	2.7	33	3.0	4.6
68	2.2	2.5	36	2.8	4.2
75	2.0	2.3	39	2.6	3.9
82	1.8	2.1	43	2.3	3.5
91	1.7	1.9	47	2.1	3.2
100	1.5	1.7	51	2.0	2.9

Table 7. Current Detection Resistor, Recommend Table (Reference Data)

		High Side Motor Drive Current Detection Resistor R4 [mΩ]							
		27	30	33	36	39	43	47	51
Low Side Motor Drive Current Detection Resistor R1 [mΩ]	51	NG	NG	NG	NG	NG	NG	NG	NG
	56	NG	OK	NG	NG	NG	NG	NG	NG
	62	NG	OK	OK	NG	NG	NG	NG	NG
	68	NG	OK	OK	OK	NG	NG	NG	NG
	75	NG	OK	OK	OK	OK	NG	NG	NG
	82	NG	OK	OK	OK	OK	OK	NG	NG
	91	NG	OK	OK	OK	OK	OK	OK	NG
	100	NG	OK	OK	OK	OK	OK	OK	OK

OK; Enable Setting (To Check and Confirm the Above Description (4)). NG; Forbidden Setting

(5) The CRH and CSH Pins Setting

If you do not need the high side over current protection, please connected the VM pin to the CRH and CSH pins through resistor.

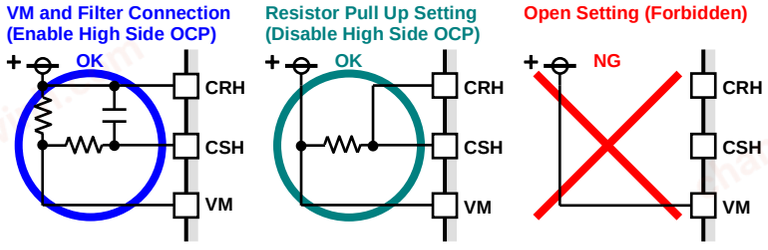


Figure 66. High Side Over Current Protection Function

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11. Over Current Protection (OCP) - continued

(6) Low Side Over Current Detection and Automatic Restart

The resistor connected to the RNF pin converts motor drive current into voltage, and the voltage is inputted into the CSL pin. During the detection time t_{OCPDET}: 6.4 µs (Typ), when the CSL voltage is the low side detection voltage V_{CPL}: 250 mV (Typ) or more, the low side current detection is triggered, all three phases of motor drive output are fixed to high impedance logic (OFF) to cut off the motor current. After the protection time t_{OCP}: 240 ms (Typ), if the CSL voltage is less than V_{CPL}, releases the high side over current protection and returns the motor drive output. Also, after the protection time t_{OCP}, if it is still in over current state (when CSL voltage is V_{CPL} or more), returns the motor output for the detection time t_{OCPDET}: 6.4 µs (Typ) for detecting motor drive current following an initial state judgement. Until the low side over current protection is released, the operation is repeated at the same timing.

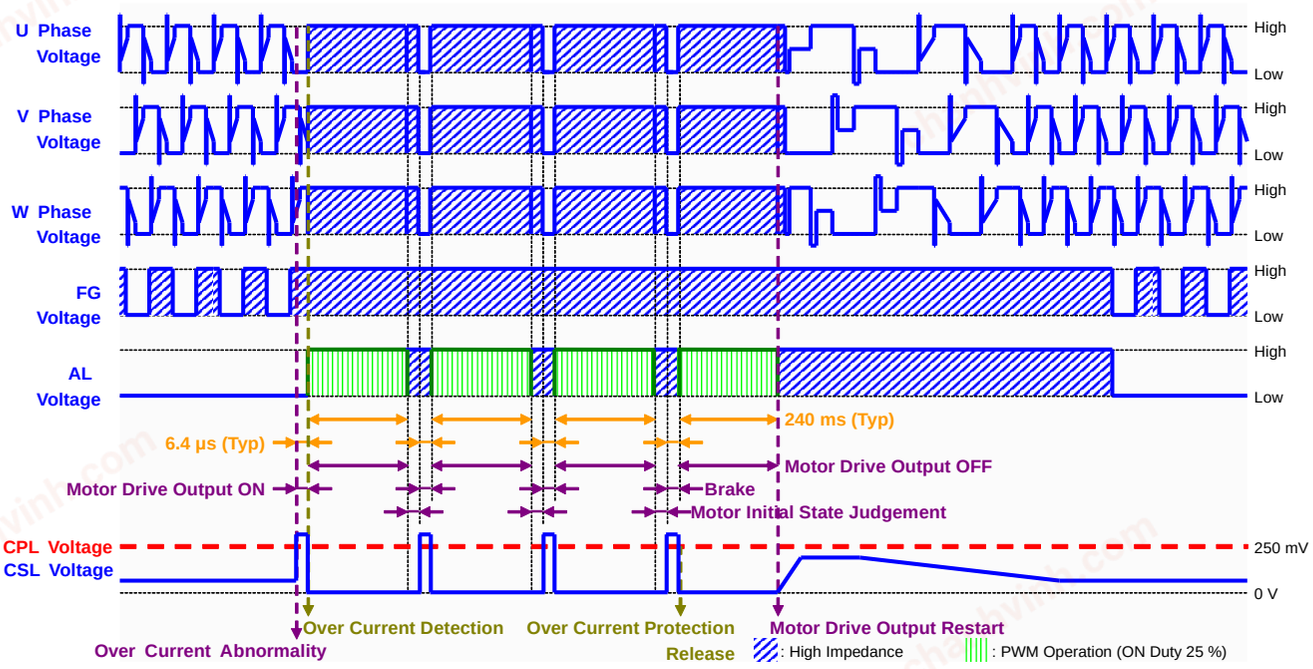


Figure 67. Low Side Over Current Protection Timing Chart

(7) Low Side Over Current Detection Current Setting

In Figure 68, the setting value can be calculated according to the RNF resistor of motor drive current and low side over current detection voltage in the IC.

$$I_{CPL} = \frac{V_{CPL}}{R1} \text{ [A]}$$

where:
I_{CPL} is the Low Side Over Current Protection Setting Current [A]
V_{CPL} is the Low Side Over Current Protection Detection Voltage [V] (Typ 250 mV)
$R1$ is the Low Side Motor Drive Current Detection Resistor [Ω]

(ex.) If the low side motor drive output current detection resistance value is 56 mΩ, low side over current protection detection current value is 4.5 A.

$$I_{CPL} = \frac{250\times10^{-3}}{56\times10^{-3}} = 4.5 \text{ [A]}$$

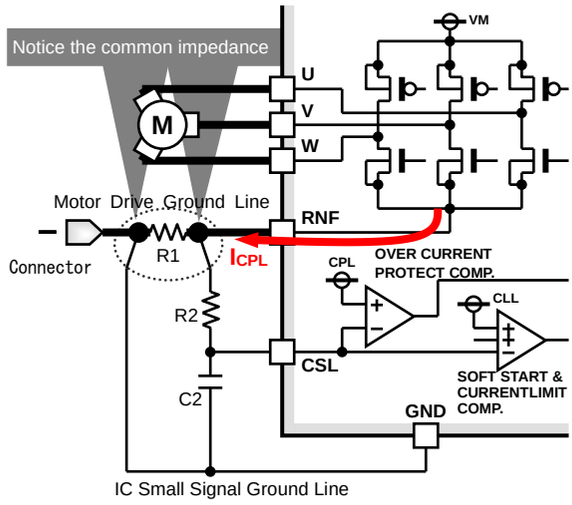


Figure 68. Separate with Small Signal Line and Motor Drive Line

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11. Over Current Protection (OCP) - continued

(8) Low Side Over Current False Detection Measure

In Figure 68, R2 and C2 are low pass filter of RNF voltage. In order to prevent the false detection measure of over current, the GND of C2 and GND of IC must be the common as IC small signal ground line. And separate it with the motor drive ground line (R1).

Notice the common impedance of IC small signal line, detection line connected to R2 and motor drive ground line connected to R1.

(9) Relationship between Low Side Over Current Protection Function and Current Limit Function

Low side over current protection detection voltage input unit share input pin with current limit detection voltage input unit above.

So, be sure to note that if set the CSL pin so that the low side over current protection function is disabled, the current limiting function is disabled.

(10) Relationship between Low Side Over Current Protection Function and Soft Start Function

Low side over current protection detection voltage input unit share input pin with soft start detection voltage input unit above.

So, be sure to note that if set the CSL pin so that the low side over current protection function is disabled, the soft start function is disabled.

(11) The CSL Pin Setting

If you do not need the low side over current protection, the CSL pin must be connected to GND through resistor.

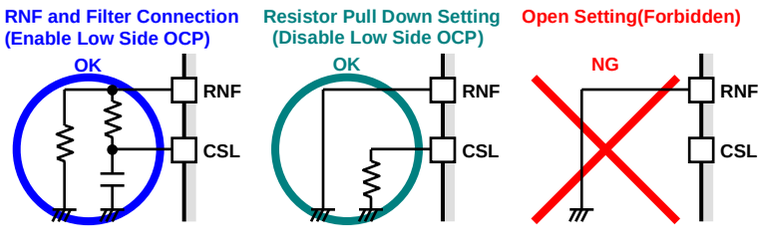


Figure 69. Low Side Over Current Protection Function

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Description of Blocks - continued

12. Over Voltage Protection (OVP)

If VCC voltage surpass a specific voltage, IC brakes and cut offs motor drive current. However, when supply voltage exceeds absolute maximum ratings, we have possibility of damaging the IC. Please do not exceed absolute maximum ratings. VCC supply pin detects over voltage. The motor drive supply (VM) pin doesn't detect over voltage because the IC is designed with the assumption that input DC voltage will be supplied using only a single power supply.

(1) Over Voltage Detection and Restart

If the operation power supply voltage is 18 V or more, when VCC power supply voltage surpass the detection voltage V_{OVPDET}: 30 V (Typ) or more during the detection time t_{OVPDET}: 1.0 µs (Typ), all three phases of motor drive output are fixed to low logic (brake), and motor current is cut off. There is hysteresis voltage V_{OVPHYS}: 2 V (Typ) between the detection voltage and release voltage. When VCC power supply voltage is 28 V or less, over voltage protection is released, and motor drive output will restart.

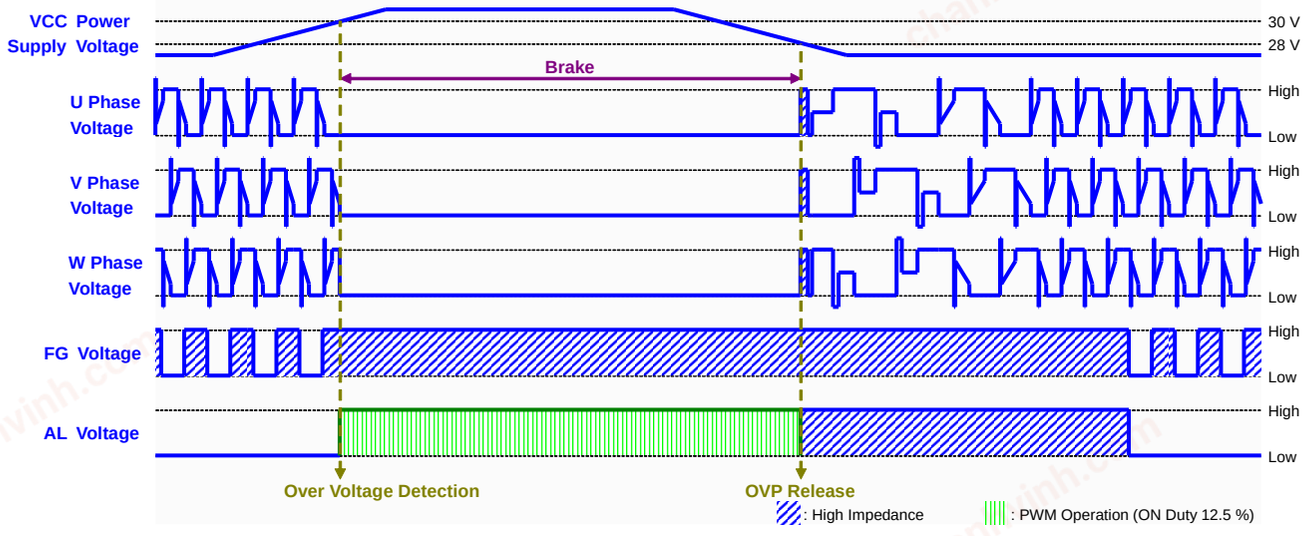


Figure 70. Over Voltage Protection Timing Chart

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Description of Blocks - continued

13. Thermal Shutdown (TSD)

In order to prevent destruction and malfunction by thermal runaway, when junction temperature surpass a specific temperature, IC brakes and to cut offs motor drive current. And TSD detect temperature and hysteresis temperature has a design value. We did evaluate it by design evaluation but was not tested in production that tests whether protection circuit is operating when we raise and lower ambient temperature. Purpose of this function is just protecting the IC from thermal runaway. IC temperature should not surpass absolute maximum ratings (junction temperature range) with the help of this function.
Please do thermal design with enough margin which does not premise the use of this function.

(1) Thermal Shutdown Detection and Restart

If the absolute maximum rated junction temperature is 150 °C or more, when IC junction temperature surpass the detection temperature T_{TSDDET}: 175 °C (Typ) during the detection time t_{TSDDET}: 1.0 µs (Typ), TSD operates and all three phases of motor drive output are fixed to low logic (brake) to cut OFF motor current. There is hysteresis temperature T_{TSDHYS}: 25 °C (Typ) between detection temperature and release temperature. When the junction temperature goes down to 150 °C (Typ) or less, protection is released, and motor drive output will restart.

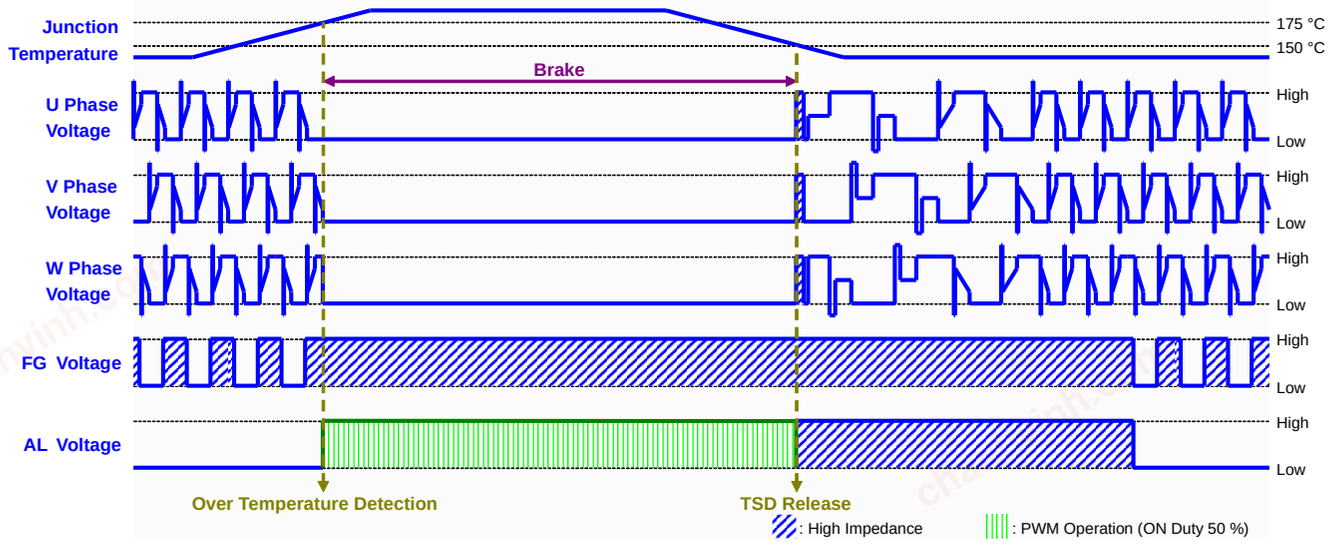


Figure 71. Thermal Shutdown Timing Chart

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Description of Blocks - continued

14. Under Voltage Lock Out (UVLO)

If the VCC voltage is less than specific voltage, reset logic circuit in the IC to prevent malfunction. Also, turn OFF motor drive output and interrupt motor driving current. VCC power supply pin detects under voltage. Motor drive power supply VM pin doesn't detect it because the IC is designed with the assumption that input DC voltage will be supplied using only a single power supply.

(1) Under Voltage Detection and Restart

If the operational power supply voltage is less than 5.5 V, when the VCC voltage is down to the detection voltage $V_{ULVODET}$: 4.75 V (Typ) or less, UVLO operates and the inner IC logic is reset. When inner logic is reset, all three phases of motor drive output are fixed to high impedance logic (OFF) to cut OFF the motor current. UVLO has hysteresis voltage $V_{UVLOHYS}$: 0.25 V (Typ). When the VCC voltage raises up to 5.0 V or more, UVLO is released, the inner logic reset is released, and motor drive output will restart.

(2) Under Voltage Lock Out Release and Output Protection Alarm Output

Be sure to note that UVLO release is not related to the output protection alarm output.

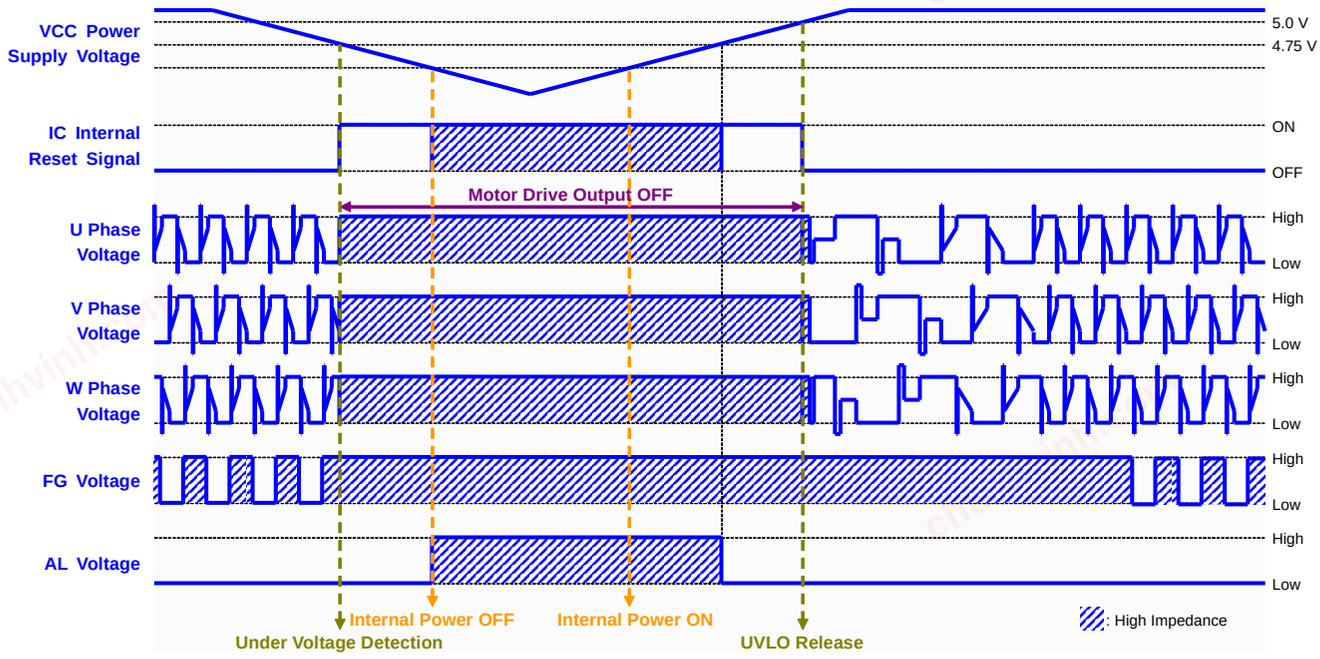


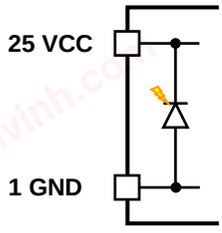
Figure 72. Under Voltage Lock Out Timing Chart

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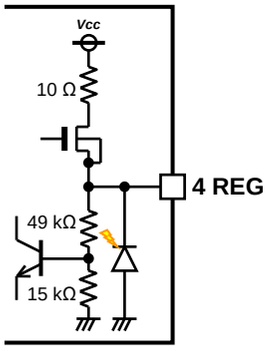
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I/O Equivalence Circuits (Resistance Values are Typical)

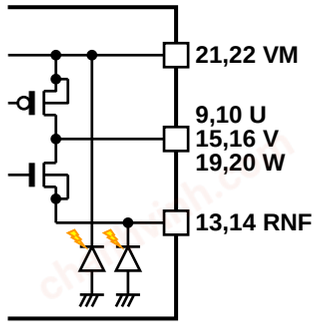
1 Power Supply
Ground



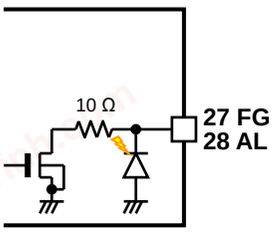
2. Reference Voltage (5 V) Output



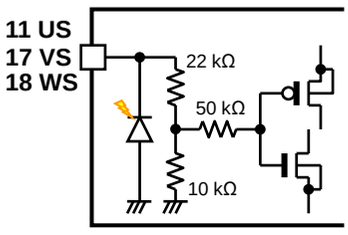
3. Motor Drive Power Supply
Motor Drive Output
Motor Drive Ground



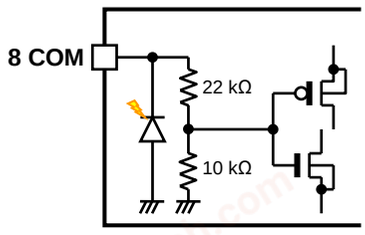
4. Rotation Pulse Signal Output
Output Protection Alarm
Signal Output



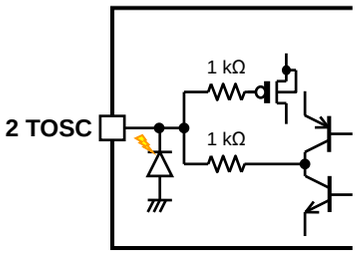
5. Motor Drive Detection
Voltage Input



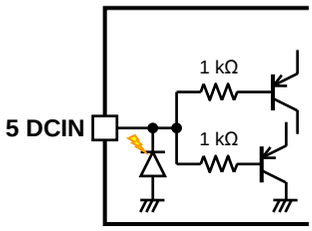
6. Motor Midpoint Detection
Voltage Input



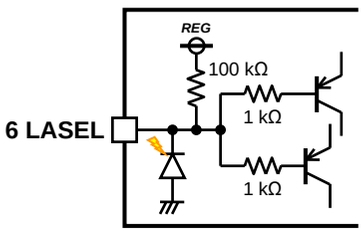
7. Forced Commutation OSC Setting



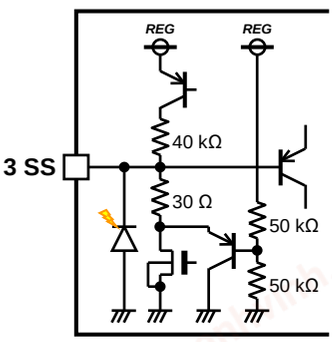
8. Variable Speed Control
Command DC Voltage Input



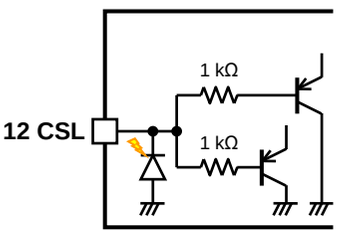
9. Lead Angle Selection Input



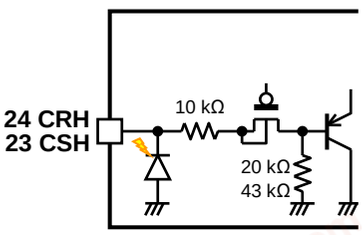
10. Soft Start Time Setting



11. Current Limit, Low Side Over
Current Detect Voltage Input



12. High Side Over Curent Protection
Reference Voltage Input
High Side Over Current Protection
Detection Voltage Input



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Heat Loss

1. Thermal Resistance

Heat generated by consumed power of IC is radiated from the mold resin or lead frame of package. The parameter which indicates this heat dissipation capability (hardness of heat release) is called thermal resistance. In the state of the substrate mounting, thermal resistance from the chip junction to the ambient environment is shown in θja [°C/W], and thermal characterization parameter from the chip junction to the top centre of the outside surface of the component package is shown in Ψjt [°C/W]. Thermal resistance is classified into the package part and the substrate part, and thermal resistance in the package part depends on the composition materials such as the mold resins and the lead frames. On the other hand, thermal resistance in the substrate part depends on the substrate heat dissipation capability of the material, the size, and the copper foil area etc. Therefore, thermal resistance can be decreased by the heat radiation measures like installing a heat sink etc. in the mounting substrate.
The thermal resistance model is shown in Figure 73, and thermal resistance formula is shown below.

$$\theta ja = \frac{Tj-Ta}{P}\ [°C/W]$$
$$\psi jt = \frac{Tj-Tt}{P}\ [°C/W]$$

where:
θja is the thermal resistance from junction to ambient [°C/W]
ψjt is the thermal characterization parameter from junction to the top centre of the outside surface of the component package [°C/W]
Tj is the junction temperature [°C]
Ta is the ambient temperature [°C]
Tt is the package outside surface (top centre) temperature [°C]
P is the power consumption [W]

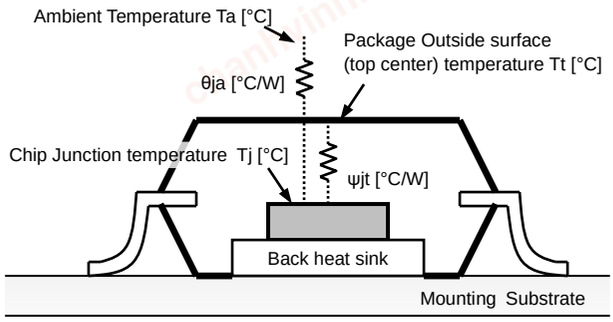


Figure 73. Thermal Resistance Model of package

Even if it uses the same package, θja and ψjt are changed depending on the chip size, power consumption, and the measurement environments of the ambient temperature, the mounting condition, and the wind velocity, etc.

2. Transient Thermal Resistance

The above thermal resistance is when DC power is applied, on the other hand the transient thermal resistance is when power is pulsating. Transient thermal resistance with specified conditions is shown in Figure 74 as a reference value when FR-4 4-layer board (114.3 mm x 76.2 mm x 1.6 mmt, backside copper foil area 74.2 mm x 74.2 mm) is mounted. However, this reference value is the actual measurement value, not a guaranteed value.

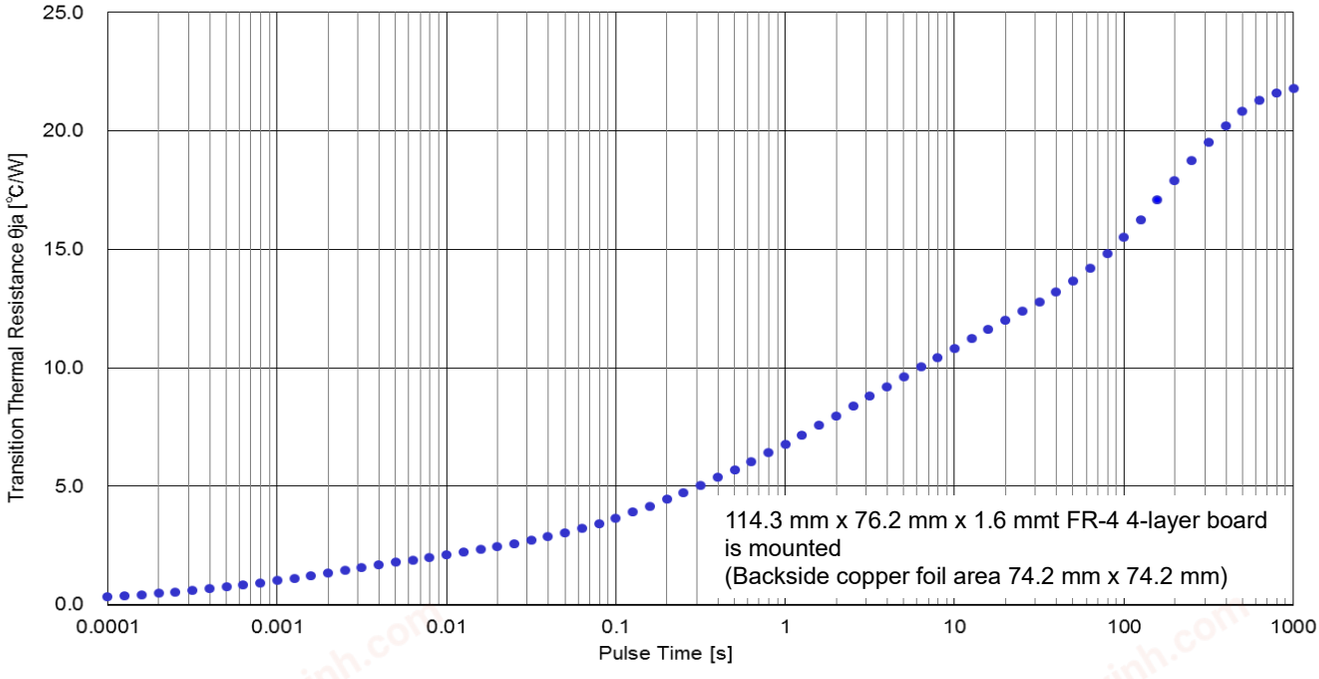


Figure 74. Transient Thermal Resistance (Reference Value)

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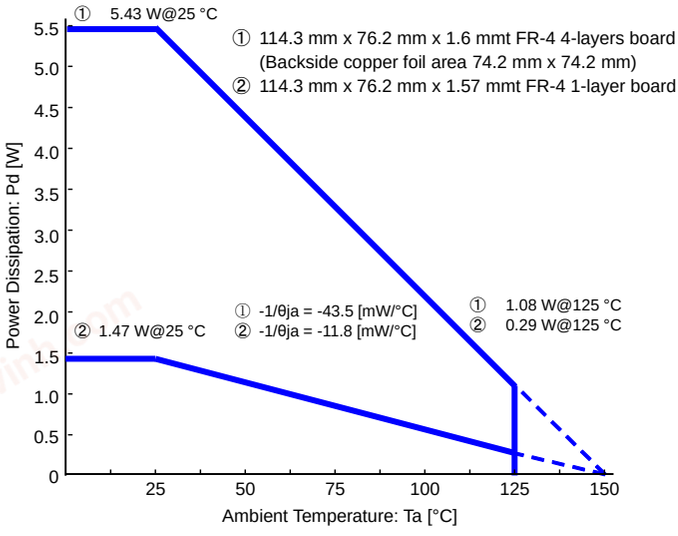
Heat Loss - continued

3. Power Dissipation

Power dissipation (total loss) is the power that can be consumed by IC at Ta = 25 °C (ambient temperature). The IC is heated when it consumes power, and the temperature of IC chip becomes higher than ambient temperature. The temperature that can be allowed by IC chip into the package is the absolute maximum rating of the junction temperature, and depends on circuit configuration, manufacturing process, etc. The Power dissipation is determined by this maximum junction temperature, the thermal resistance in the state of the substrate mounting, and the ambient temperature. Therefore, when the power dissipation exceeds the absolute maximum rating, the operating temperature range is not a guarantee. The maximum junction temperature is in general equal to the maximum value in the storage temperature range.

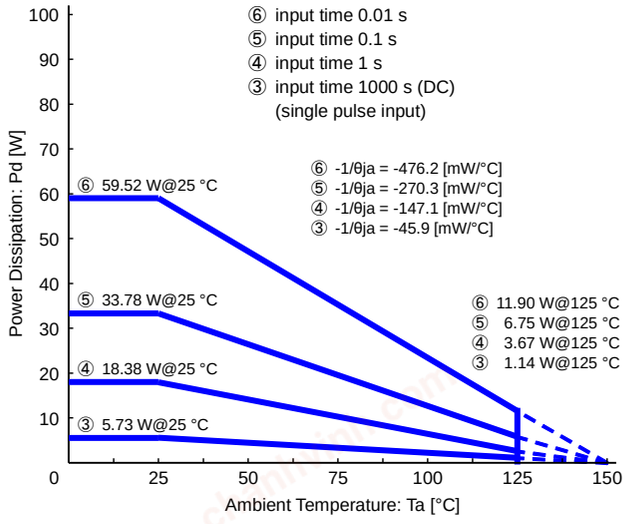
4. Thermal Derating Curve

Thermal derating curve indicates power that can be consumed by the IC with reference to ambient temperature. Power that can be consumed by IC begins to attenuate at certain ambient temperature (25 °C), and becomes 0 W at the maximum junction temperature (150 °C). The inclination is reduced by the reciprocal of thermal resistance θja.



When Ta = 25 °C or more, the temperature decreases at a slope of 1/θja
①114.3 mm x 76.2 mm x 1.57 mmt FR-4 1-layer board
②114.3 mm x 76.2 mm x 1.6 mmt FR-4 4-layers board
(Backside copper foil area 74.2 mm x 74.2 mm)

Figure 75. Derating Curve by Mounted Board



When Ta = 25 °C or more, the temperature decreases at a slope of 1/θja
114.3 mm x 76.2 mm x 1.6 mmt FR-4 4-layers board
(Backside copper foil area 74.2 mm x 74.2 mm)

Figure 76. Derating Curve by Transient Thermal Resistance (Reference Value)

5. Thermal Design

The power consumption significantly changes depending on the supply voltage and motor drive output current etc.
Also, the power dissipation (Pd) will change depending on the mounting board status and surrounding etc.
Be sure to consider the thermal resistance data and transient thermal resistance data with actual operating conditions.
In addition, be sure to perform thermal design with enough derating margin.

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ASO; Area of Safe Operation (SOA; Safety Operating Area)

1. ASO

The power area that we can use the IC without characteristic deterioration and destruction of power transistor which constitute a motor drive of the IC is called ASO or SOA (safety operating area). Be sure to check ASO when output transistor is destroyed even if absolute maximum ratings of power voltage, motor current and power dissipation is satisfied.

2. ASO of Power MOS

Because motor drive of the IC is composed of power DMOS FET, ASO is defined by three absolute maximum ratings (motor drive voltage, motor drive current and power dissipation). There must be the operation point of the power transistor under any circumstance in this area. Additionally, actual ASO have limit area by ON-Resistance characteristics of motor drive output.

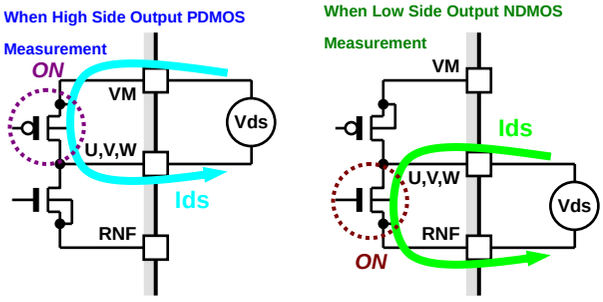


Figure 77. ASO Measure Schematic Diagram

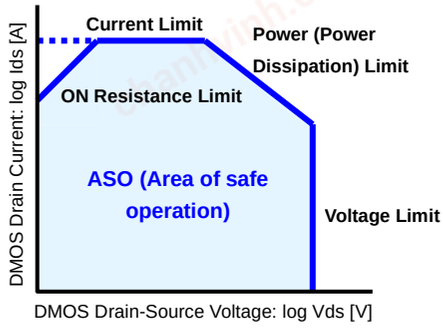


Figure 78. ASO Conceptual Diagram

3. ASO Derating

Since the power limit of ASO is dependent on the ambient temperature, it is necessary to confirm busy condition of the application, and to do derating (reduction). Derating rate is 0.8 %/°C if ambient temperature (25 °C) or more. Furthermore, when current input time changes, transient thermal resistance changes and power limit of ASO is derating. When the ambient temperature is higher, or input time is longer, ASO will be smaller.

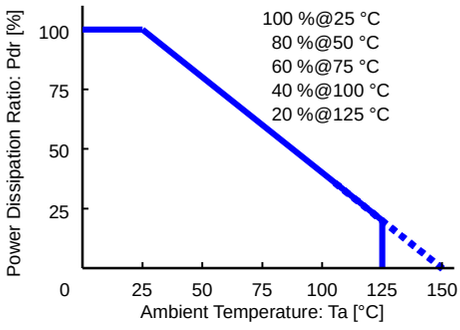


Figure 79. ASO Derating Curve

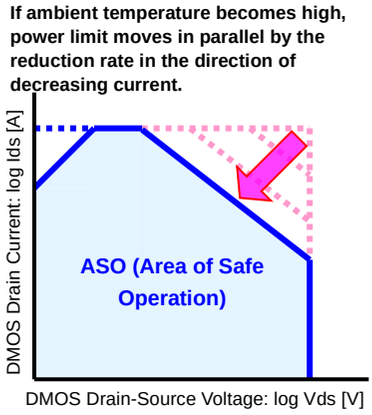


Figure 80. ASO Conceptual Diagram (The Relationship of Ambient Temperature)

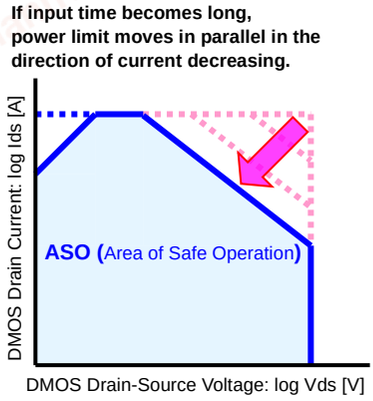


Figure 81. ASO Conceptual Diagram (The Relationship of Input Time)

(1) ASO Derating Margin

It is necessary to not only derate by input time and ambient temperature but also derate (derating margin) by secure reliability. Even if operating point is in ASO area, it is not good to operate at near limit in this area from the viewpoint of reliability. Be sure to secure enough derating margin, in consideration of ASO data with actual operating conditions.

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ASO; Area of Safe Operation (SOA; Safety Operating Area) - continued

4. ASO Measurement Data (Reference Data)
   Test board: IC socket board (160.0 mm x 160.0 mm x 1.6 mmt FR-4 Single)

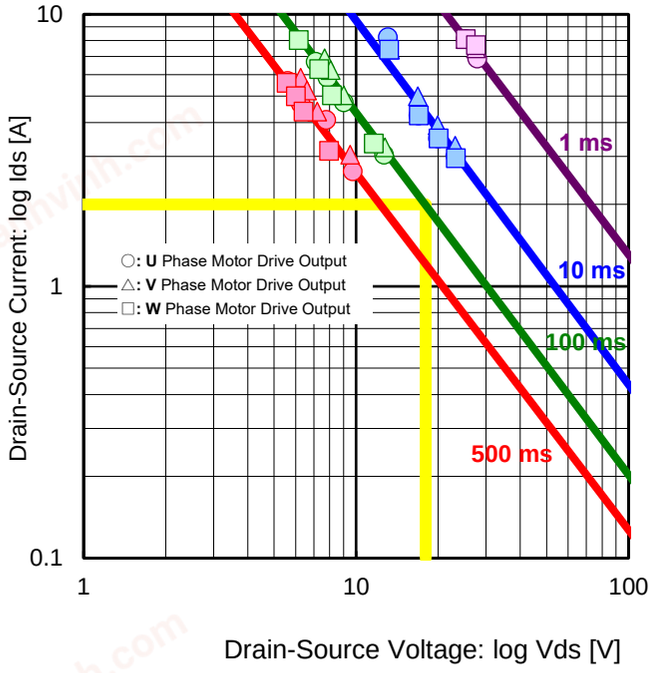


Figure 82. Drain-Source Current vs Drain-Source Voltage
Motor Drive Output High Side DMOS ASO
Ta = 25 °C (Input Time Comparison)

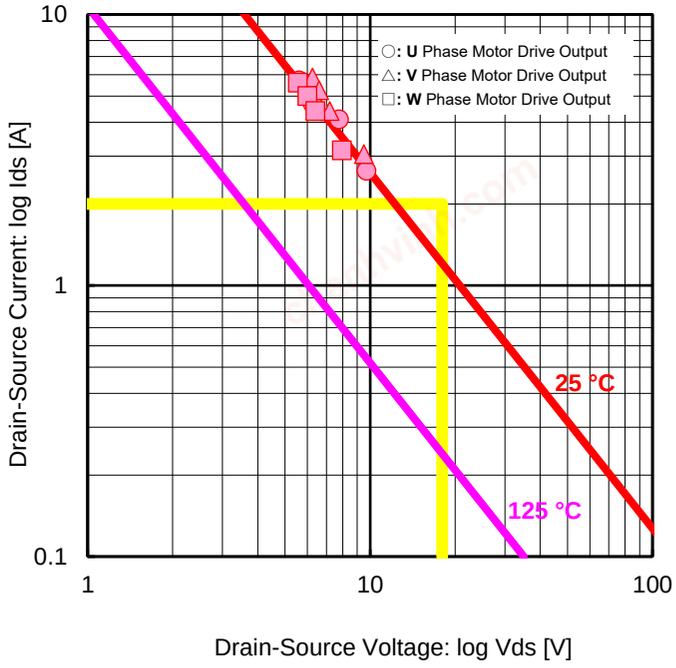


Figure 83. Drain-Source Current vs Drain-Source Voltage
Motor Drive Output High Side DMOS ASO
Pw = 500 ms (Temperature Derating)

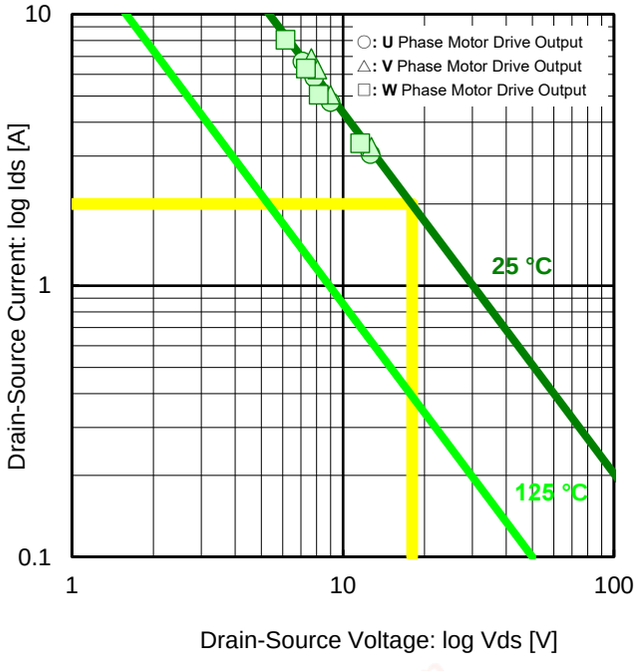


Figure 84. Drain-Source Current vs Drain-Source Voltage
Motor Drive Output High Side DMOS ASO
Pw = 100 ms (Temperature Derating)

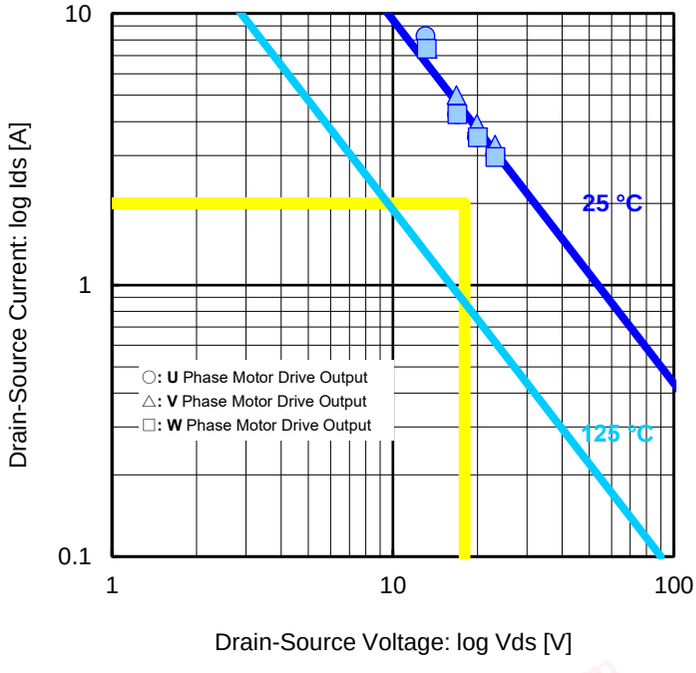


Figure 85. Drain-Source Current vs Drain-Source Voltage
Motor Drive Output High Side DMOS ASO
Pw = 10 ms (Temperature Derating)

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4. ASO Measurement Data (Reference Data) - continued
Test board: IC socket board (160.0 mm x 160.0 mm x 1.6 mmt FR-4 Single)

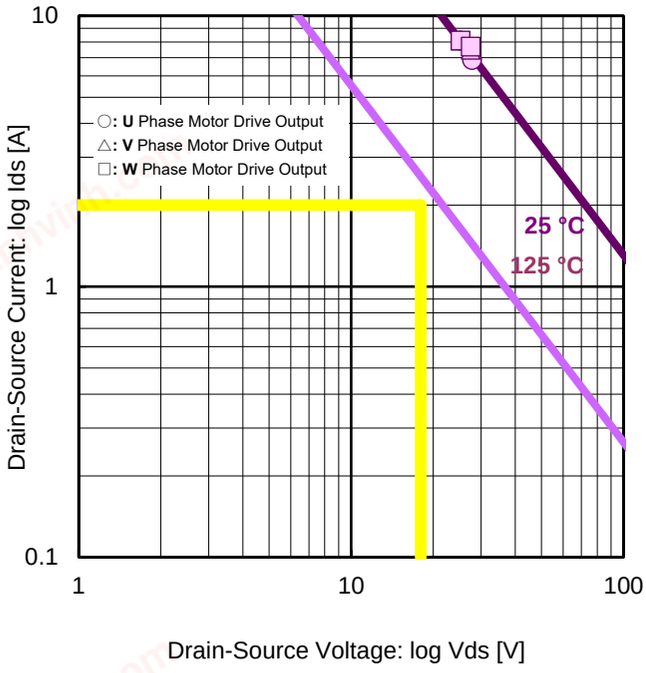


Figure 86. Drain-Source Current vs Drain-Source Voltage
Motor Drive Output High Side DMOS ASO
Pw = 1 ms (Temperature Derating)

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4. ASO Measurement Data (Reference Data) - continued
Test board: IC socket board (160.0 mm x 160.0 mm x 1.6 mmt FR-4 Single)

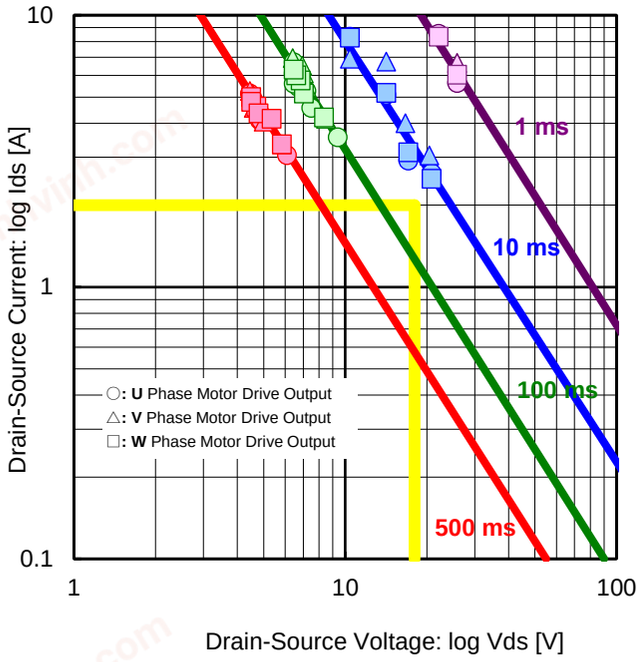


Figure 87. Drain-Source Current vs Drain-Source Voltage
Motor Drive Output Low Side DMOS ASO
Ta = 25 °C (Input Time Comparison)

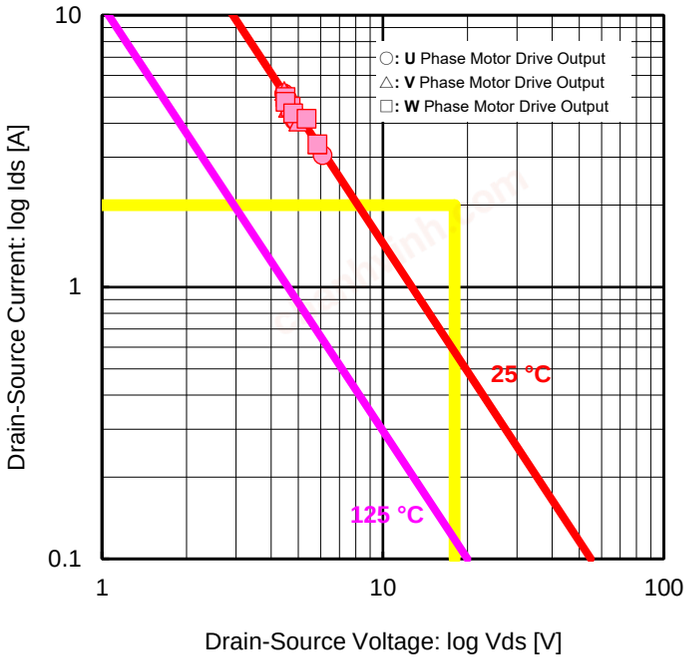


Figure 88. Drain-Source Current vs Drain-Source Voltage
Motor Drive Output Low Side DMOS ASO
Pw = 500 ms (Temperature Derating)

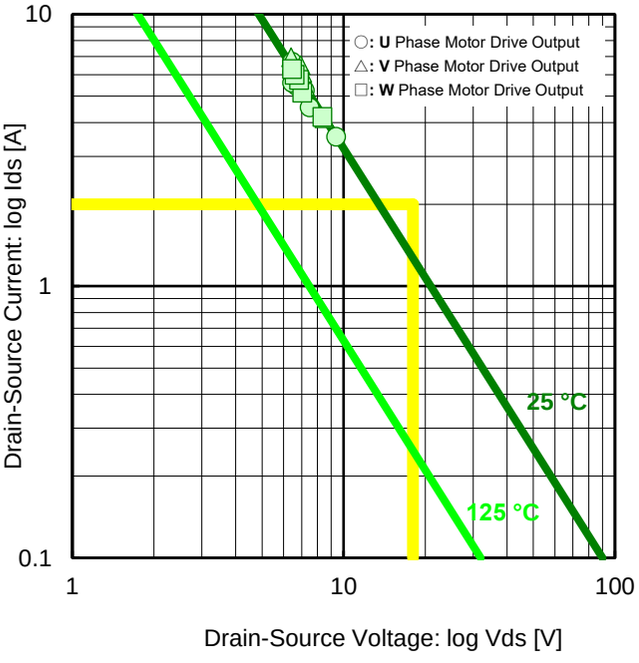


Figure 89. Drain-Source Current vs Drain-Source Voltage
Motor Drive Output Low Side DMOS ASO
Pw = 100 ms (Temperature Derating)

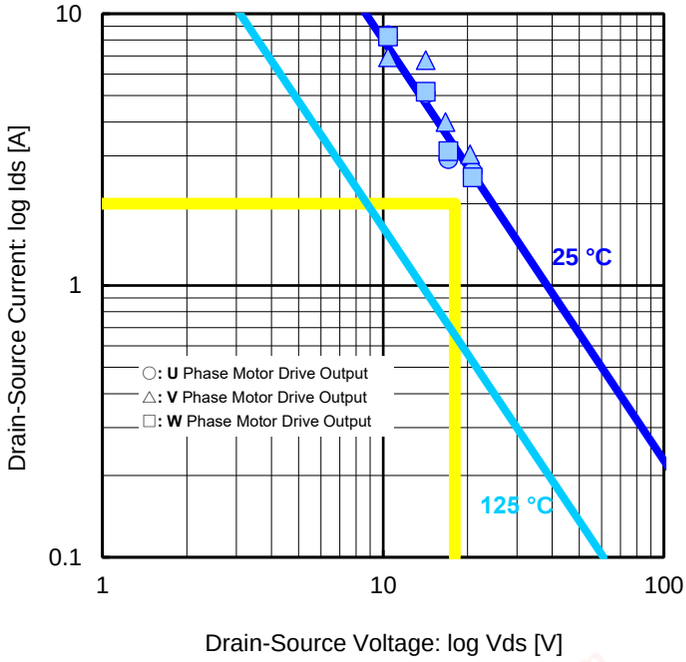


Figure 90. Drain-Source Current vs Drain-Source Voltage
Motor Drive Output Low Side DMOS ASO
Pw = 10 ms (Temperature Derating)

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4. ASO Measurement Data (Reference Data) - continued
Test board: IC socket board (160.0 mm x 160.0 mm x 1.6 mmt FR-4 Single)

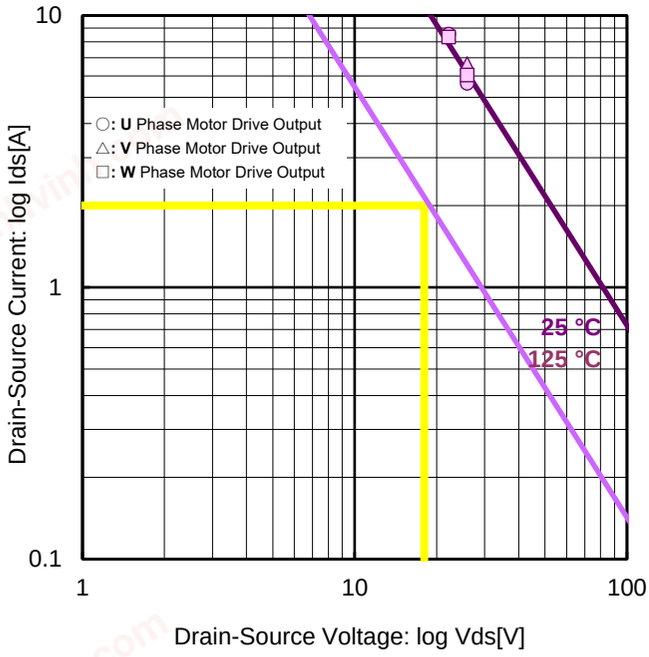


Figure 91. Drain-Source Current vs Drain-Source Voltage
Motor Drive Output Low Side DMOS ASO
Pw = 1 ms (Temperature Derating)

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Safety Measure

1. Measures against Destruction of Reverse Power Supply Connection

Reverse connection of the power supply cause IC destruction or deterioration because the current flows through a path different from the normal path. If there is a possibility of reverse connection, it is necessary to insert a reverse connection destruction protection diode between the power supply and the power supply pin.

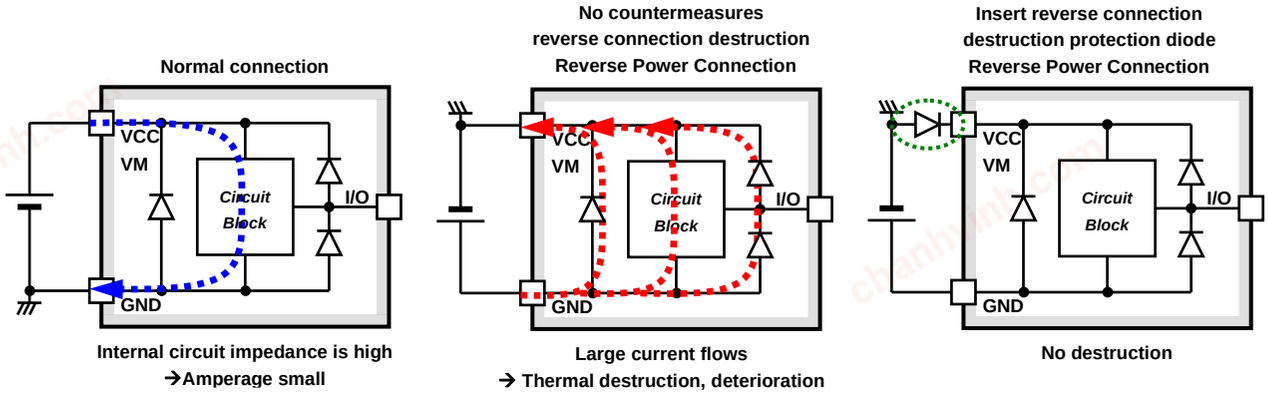


Figure 92. Flow of Current when Power is Connected Reversely

The example of reverse connection prevention circuit to supress power loss of application is shown below.

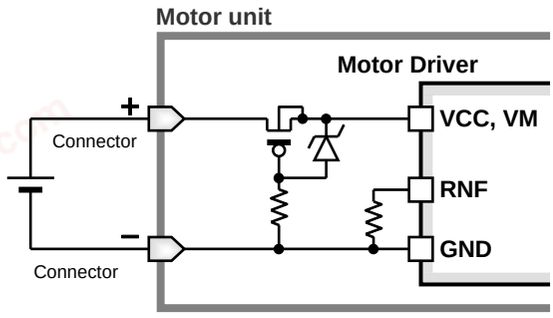


Figure 93. Example of Reverse Connection Prevention Circuit that can Supress Power Loss 1

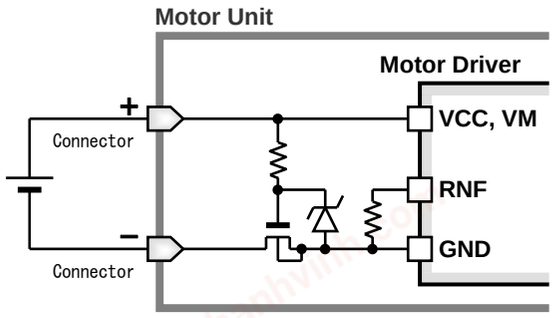


Figure 94. Example of Reverse Connection Prevention Circuit that can Supress Power Loss 2

2. Measure against VCC Voltage Rise by Back Electromotive Force

Back electromotive force (Back EMF) generates regenerative current to power supply. However, when reverse connection protection diode is connected, or the power supply does not have sufficient current absorption capacity, the power supply pin voltage and the motor drive output pin voltage rise during regenerative braking.

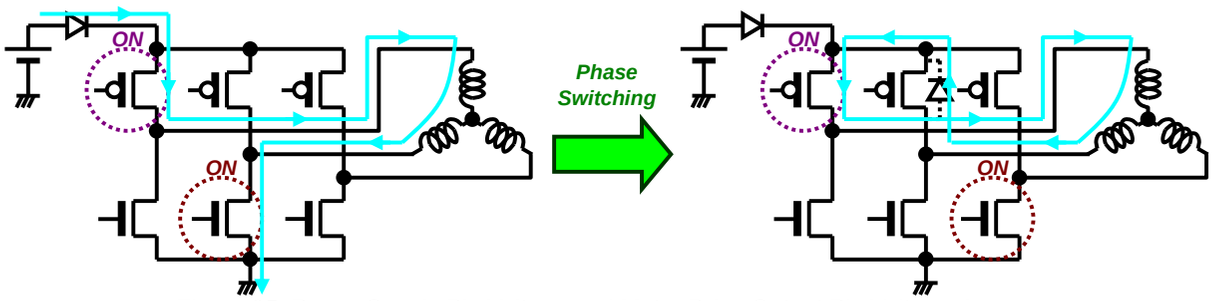


Figure 95. Power Supply Pin Voltage and Motor Drive Output Pin Voltage rise by Back Electromotive Force

When the voltage rise by back electromotive force may exceed to absolute maximum ratings, place Capacitor or Zener diode between VCC and GND. If necessary, add both.

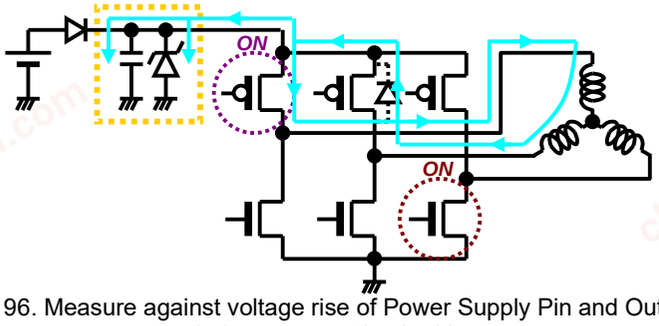


Figure 96. Measure against voltage rise of Power Supply Pin and Output Pin during regenerative braking

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Safety Measure - continued

3. Power Supply Stabilization Measure by Voltage Fluctuation of Power Line
   Be sure to insert inductor such as resistor or ferrite bead between power supply and power pin and form a filter when power supply pin may be beyond absolute maximum ratings or may detect UVLO function by voltage fluctuation of power line. Then, be sure to use bypass capacitor together, lower impedance of power supply route and supply stable voltage to driver.

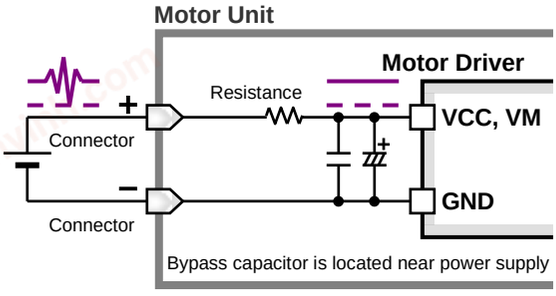


Figure 97. Power Supply Stabilization Measure (RC Filter)

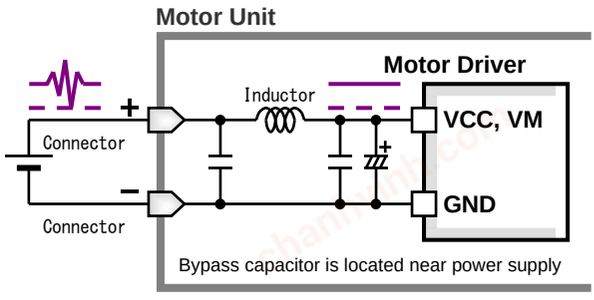


Figure 98. Power Supply Stabilization Measure (LC Filter)

4. Open Drain Pin Protection Measure
   You can set the circuit in the motor unit to prevent the connector from exceeding the absolute maximum rating and being destructed when the connector is directly connected to power supply by mistake etc.

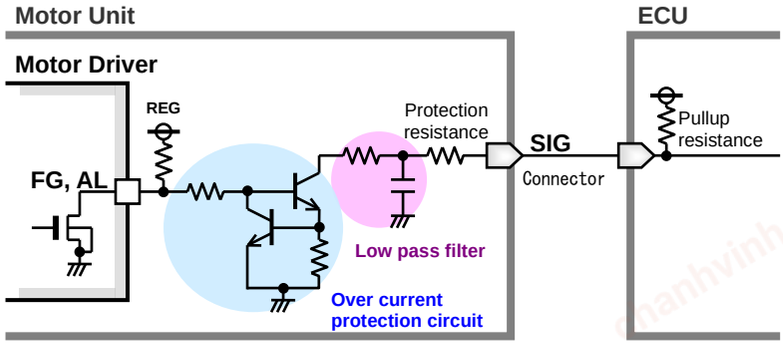


Figure 99. Example of Open Drain Pin Protection Measure

5. GND Line PWM Switching Prohibited
   The control method to change the motor speed by PWM switching the ground line is forbidden, because the GND pin potential cannot be kept to a minimum.

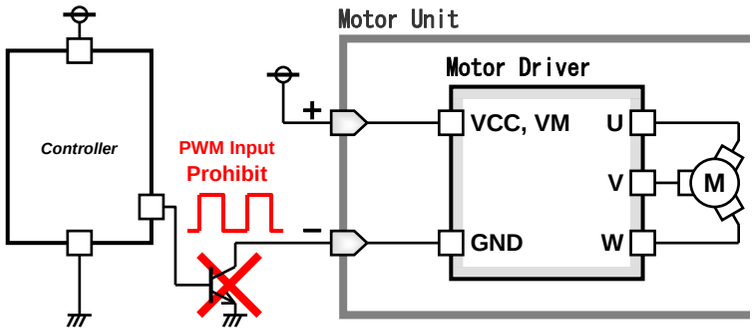


Figure 100. GND Line PWM Switching Prohibited

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Operational Notes

1. **Reverse Connection of Power Supply**
   Connecting the power supply in reverse polarity can damage the IC. Take precautions against reverse polarity when connecting the power supply, such as mounting an external diode between the power supply and the IC's power supply pins.

2. **Power Supply Lines**
   Design the PCB layout pattern to provide low impedance supply lines. Furthermore, connect a capacitor to ground at all power supply pins. Consider the effect of temperature and aging on the capacitance value when using electrolytic capacitors.

3. **Ground Voltage**
   Ensure that no pins are at a voltage below that of the ground pin at any time, even during transient condition. However, pins that drive inductive loads (e.g. motor driver outputs, DC-DC converter outputs) may inevitably go below ground due to back EMF or electromotive force. In such cases, the user should make sure that such voltages going below ground will not cause the IC and the system to malfunction by examining carefully all relevant factors and conditions such as motor characteristics, supply voltage, operating frequency and PCB wiring to name a few.

4. **Ground Wiring Pattern**
   When using both small-signal and large-current ground traces, the two ground traces should be routed separately but connected to a single ground at the reference point of the application board to avoid fluctuations in the small-signal ground caused by large currents. Also ensure that the ground traces of external components do not cause variations on the ground voltage. The ground lines must be as short and thick as possible to reduce line impedance.

5. **Recommended Operating Conditions**
   The function and operation of the IC are guaranteed within the range specified by the recommended operating conditions. The characteristic values are guaranteed only under the conditions of each item specified by the electrical characteristics.

6. **Inrush Current**
   When power is first supplied to the IC, it is possible that the internal logic may be unstable and inrush current may flow instantaneously due to the internal powering sequence and delays, especially if the IC has more than one power supply. Therefore, give special consideration to power coupling capacitance, power wiring, width of ground wiring, and routing of connections.

7. **Testing on Application Boards**
   When testing the IC on an application board, connecting a capacitor directly to a low-impedance output pin may subject the IC to stress. Always discharge capacitors completely after each process or step. The IC's power supply should always be turned off completely before connecting or removing it from the test setup during the inspection process. To prevent damage from static discharge, ground the IC during assembly and use similar precautions during transport and storage.

8. **Inter-pin Short and Mounting Errors**
   Ensure that the direction and position are correct when mounting the IC on the PCB. Incorrect mounting may result in damaging the IC. Avoid nearby pins being shorted to each other especially to ground, power supply and output pin. Inter-pin shorts could be due to many reasons such as metal particles, water droplets (in very humid environment) and unintentional solder bridge deposited in between pins during assembly to name a few.

9. **Unused Input Pins**
   Input pins of an IC are often connected to the gate of a MOS transistor. The gate has extremely high impedance and extremely low capacitance. If left unconnected, the electric field from the outside can easily charge it. The small charge acquired in this way is enough to produce a significant effect on the conduction through the transistor and cause unexpected operation of the IC. So unless otherwise specified, unused input pins should be connected to the power supply or ground line.

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Operational Notes – continued

10. Regarding the Input Pin of the IC

This monolithic IC contains P+ isolation and P substrate layers between adjacent elements in order to keep them isolated. P-N junctions are formed at the intersection of the P layers with the N layers of other elements, creating a parasitic diode or transistor. For example (refer to figure below):

When GND > Pin A and GND > Pin B, the P-N junction operates as a parasitic diode.
When GND > Pin B, the P-N junction operates as a parasitic transistor.

Parasitic diodes inevitably occur in the structure of the IC. The operation of parasitic diodes can result in mutual interference among circuits, operational faults, or physical damage. Therefore, conditions that cause these diodes to operate, such as applying a voltage lower than the GND voltage to an input pin (and thus to the P substrate) should be avoided.

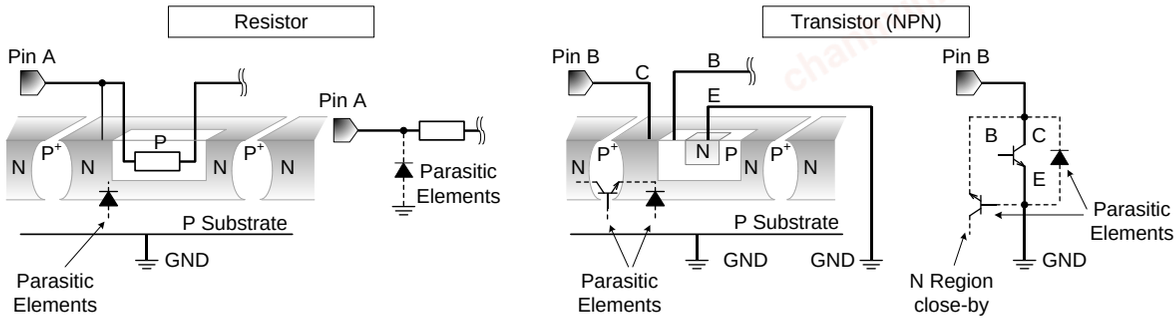


Figure 101. Example of Monolithic IC Structure

11. Ceramic Capacitor

When using a ceramic capacitor, determine a capacitance value considering the change of capacitance with temperature and the decrease in nominal capacitance due to DC bias and others.

12. Thermal Shutdown Circuit (TSD)

This IC has a built-in thermal shutdown circuit that prevents heat damage to the IC. Normal operation should always be within the IC's maximum junction temperature rating. If however the rating is exceeded for a continued period, the junction temperature (Tj) will rise which will activate the TSD circuit that will turn OFF power output pins. When the Tj falls below the TSD threshold, the circuits are automatically restored to normal operation.
Note that the TSD circuit operates in a situation that exceeds the absolute maximum ratings and therefore, under no circumstances, should the TSD circuit be used in a set design or for any purpose other than protecting the IC from heat damage.

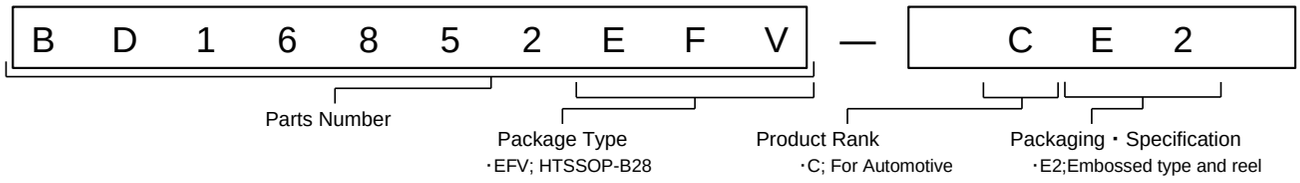
13. Over Current Protection Circuit (OCP)

This IC incorporates an integrated overcurrent protection circuit that is activated when the load is shorted. This protection circuit is effective in preventing damage due to sudden and unexpected incidents. However, the IC should not be used in applications characterized by continuous operation or transitioning of the protection circuit.

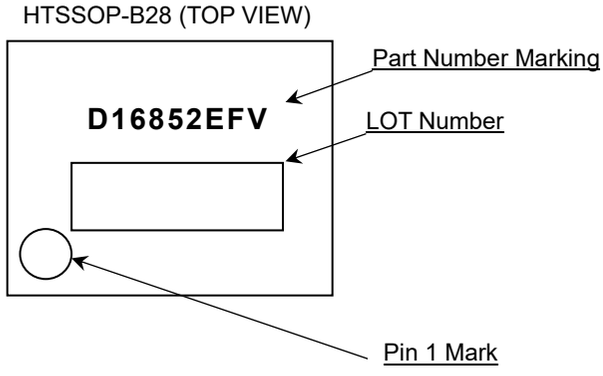
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Ordering Information



Marking Diagram

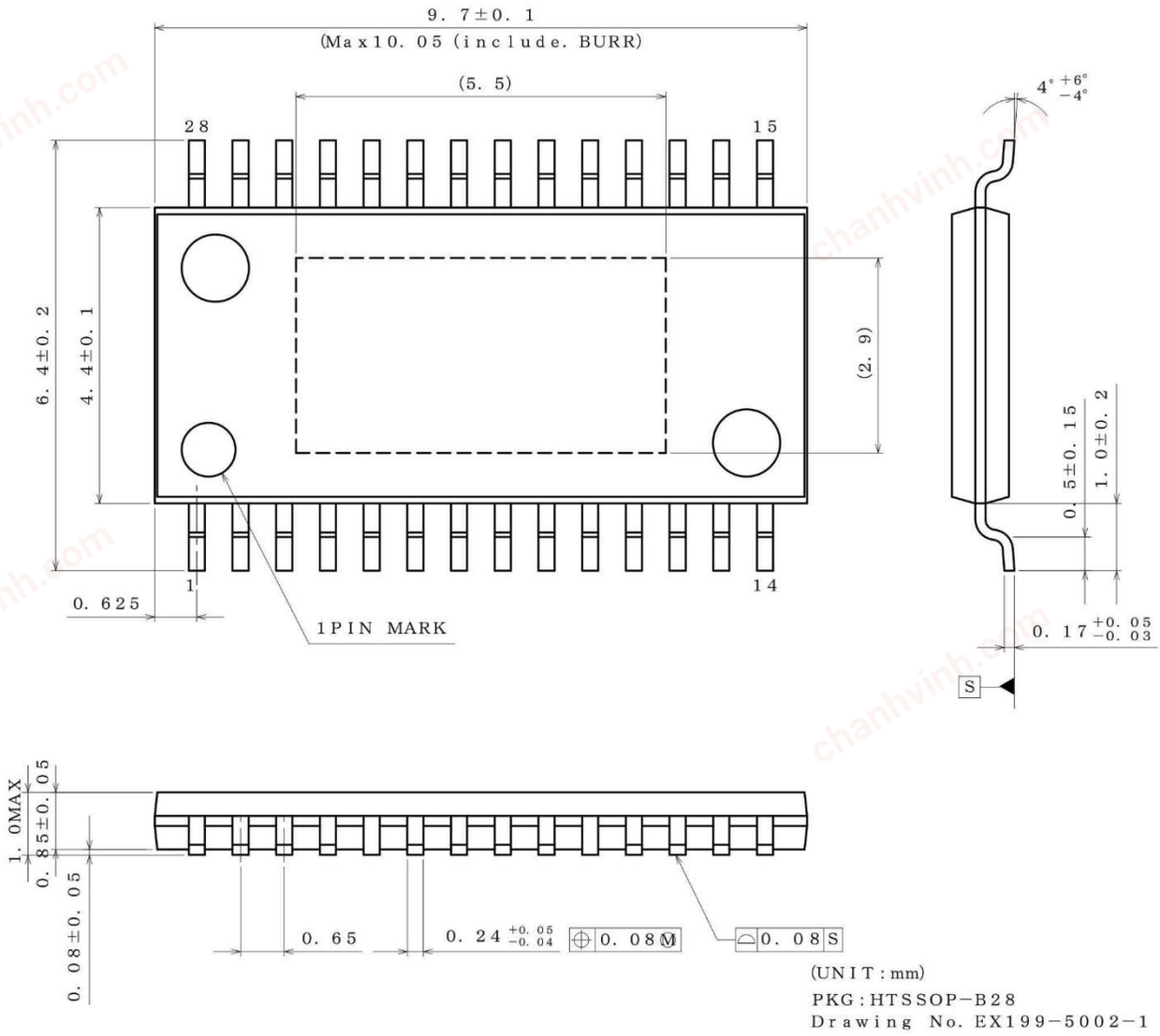


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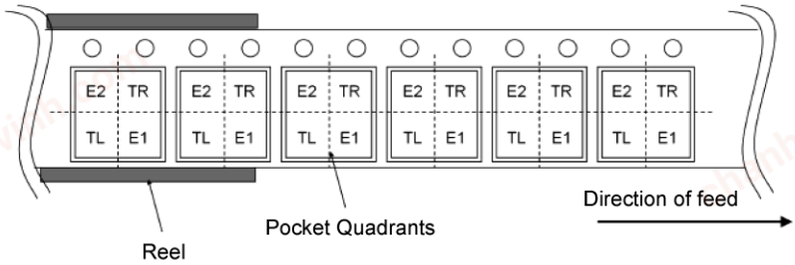
Physical Dimension and Packing Information

Package Name	HTSSOP-B28



< Tape and Reel Information >

Tape	Embossed carrier tape
Quantity	2500pcs
Direction of feed	E2 The direction is the pin 1 of product is at the upper left when you hold reel on the left hand and you pull out the tape on the right hand



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Revision History

Date	Revision	Changes
27.Sep.2021	001	New Release

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Notice

Precaution on using ROHM Products

1. If you intend to use our Products in devices requiring extremely high reliability (such as medical equipment (Note 1), aircraft/spacecraft, nuclear power controllers, etc.) and whose malfunction or failure may cause loss of human life, bodily injury or serious damage to property ("Specific Applications"), please consult with the ROHM sales representative in advance. Unless otherwise agreed in writing by ROHM in advance, ROHM shall not be in any way responsible or liable for any damages, expenses or losses incurred by you or third parties arising from the use of any ROHM's Products for Specific Applications.

(Note1) Medical Equipment Classification of the Specific Applications

JAPAN	USA	EU	CHINA
CLASSⅢ	CLASSⅢ	CLASSⅡb	CLASSⅢ
CLASSⅣ		CLASSⅢ	

2. ROHM designs and manufactures its Products subject to strict quality control system. However, semiconductor products can fail or malfunction at a certain rate. Please be sure to implement, at your own responsibilities, adequate safety measures including but not limited to fail-safe design against the physical injury, damage to any property, which a failure or malfunction of our Products may cause. The following are examples of safety measures:
   [a] Installation of protection circuits or other protective devices to improve system safety
   [b] Installation of redundant circuits to reduce the impact of single or multiple circuit failure

3. Our Products are not designed under any special or extraordinary environments or conditions, as exemplified below. Accordingly, ROHM shall not be in any way responsible or liable for any damages, expenses or losses arising from the use of any ROHM's Products under any special or extraordinary environments or conditions. If you intend to use our Products under any special or extraordinary environments or conditions (as exemplified below), your independent verification and confirmation of product performance, reliability, etc, prior to use, must be necessary:
   [a] Use of our Products in any types of liquid, including water, oils, chemicals, and organic solvents
   [b] Use of our Products outdoors or in places where the Products are exposed to direct sunlight or dust
   [c] Use of our Products in places where the Products are exposed to sea wind or corrosive gases, including Cl_2, H_2S, NH_3, SO_2, and NO_2
   [d] Use of our Products in places where the Products are exposed to static electricity or electromagnetic waves
   [e] Use of our Products in proximity to heat-producing components, plastic cords, or other flammable items
   [f] Sealing or coating our Products with resin or other coating materials
   [g] Use of our Products without cleaning residue of flux (Exclude cases where no-clean type fluxes is used. However, recommend sufficiently about the residue.); or Washing our Products by using water or water-soluble cleaning agents for cleaning residue after soldering
   [h] Use of the Products in places subject to dew condensation

4. The Products are not subject to radiation-proof design.

5. Please verify and confirm characteristics of the final or mounted products in using the Products.

6. In particular, if a transient load (a large amount of load applied in a short period of time, such as pulse, is applied, confirmation of performance characteristics after on-board mounting is strongly recommended. Avoid applying power exceeding normal rated power; exceeding the power rating under steady-state loading condition may negatively affect product performance and reliability.

7. De-rate Power Dissipation depending on ambient temperature. When used in sealed area, confirm that it is the use in the range that does not exceed the maximum junction temperature.

8. Confirm that operation temperature is within the specified range described in the product specification.

9. ROHM shall not be in any way responsible or liable for failure induced under deviant condition from what is defined in this document.

Precaution for Mounting / Circuit board design

1. When a highly active halogenous (chlorine, bromine, etc.) flux is used, the residue of flux may negatively affect product performance and reliability.

2. In principle, the reflow soldering method must be used on a surface-mount products, the flow soldering method must be used on a through hole mount products. If the flow soldering method is preferred on a surface-mount products, please consult with the ROHM representative in advance.

For details, please refer to ROHM Mounting specification

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Precautions Regarding Application Examples and External Circuits

1. If change is made to the constant of an external circuit, please allow a sufficient margin considering variations of the characteristics of the Products and external components, including transient characteristics, as well as static characteristics.

2. You agree that application notes, reference designs, and associated data and information contained in this document are presented only as guidance for Products use. Therefore, in case you use such information, you are solely responsible for it and you must exercise your own independent verification and judgment in the use of such information contained in this document. ROHM shall not be in any way responsible or liable for any damages, expenses or losses incurred by you or third parties arising from the use of such information.

Precaution for Electrostatic

This Product is electrostatic sensitive product, which may be damaged due to electrostatic discharge. Please take proper caution in your manufacturing process and storage so that voltage exceeding the Products maximum rating will not be applied to Products. Please take special care under dry condition (e.g. Grounding of human body / equipment / solder iron, isolation from charged objects, setting of Ionizer, friction prevention and temperature / humidity control).

Precaution for Storage / Transportation

1. Product performance and soldered connections may deteriorate if the Products are stored in the places where:
   - [a] the Products are exposed to sea winds or corrosive gases, including Cl_2, H_2S, NH_3, SO_2, and NO_2
   - [b] the temperature or humidity exceeds those recommended by ROHM
   - [c] the Products are exposed to direct sunshine or condensation
   - [d] the Products are exposed to high Electrostatic

2. Even under ROHM recommended storage condition, solderability of products out of recommended storage time period may be degraded. It is strongly recommended to confirm solderability before using Products of which storage time is exceeding the recommended storage time period.

3. Store / transport cartons in the correct direction, which is indicated on a carton with a symbol. Otherwise bent leads may occur due to excessive stress applied when dropping of a carton.

4. Use Products within the specified time after opening a humidity barrier bag. Baking is required before using Products of which storage time is exceeding the recommended storage time period.

Precaution for Product Label

A two-dimensional barcode printed on ROHM Products label is for ROHM's internal use only.

Precaution for Disposition

When disposing Products please dispose them properly using an authorized industry waste company.

Precaution for Foreign Exchange and Foreign Trade act

Since concerned goods might be fallen under listed items of export control prescribed by Foreign exchange and Foreign trade act, please consult with ROHM in case of export.

Precaution Regarding Intellectual Property Rights

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