

Motor Driver IC for 3-phase Brushless Motor

KA44143A Product Brief

The information described in this document is the exclusive intellectual property of Nuvoton Technology Corporation Japan and shall not be reproduced without permission from Nuvoton.

*Nuvoton is providing document only for reference purposes of KA44143A based system design.
Nuvoton assumes no responsibility for errors or omissions.
All data and specifications are subject to change without notice.*

For additional information or question, please contact Nuvoton Technology Corporation Japan.

www.nuvoton.co.jp

IMPORTANT NOTICE

Regarding the specifications of this product, it is considered that you have agreed to the quality level and disclaimer described below.

Support for industry standards and quality standards

Functional safety standards for automobiles ISO26262	No
AECQ-100	No
Market failure rate	50 Fit

Disclaimer

1. When the application system is designed using this IC, please design the system at your own risk. Please read, consider, and apply appropriate usage notes and description in this standard.
2. When designing your application system, please take into the consideration of break down and failure mode occurrence and possibility in semiconductor products. Measures on the systems such as, but not limited to, redundant design, mitigating the spread of fire, or preventing glitch, are recommended in order to prevent physical injury, fire, social damages, etc. in using the Nuvoton Technology Japan Corporation (hereinafter referred to as NTCJ) products.
3. When using this IC, for each actual application systems, verify the systems and the all functionality of this IC as intended in application systems and the safety including the long-term reliability at your own risk
4. Please use this IC in compliance with all applicable laws, regulations and safety-related requirements that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive. NTCJ shall not be held responsible for any damage incurred as a result of this IC being used not in compliance with the applicable laws, regulations and safety-related requirements.
5. This IC does not have any security functions using cryptographic algorithms, such as authentication, encryption, tampering detection.
6. Unless this IC is indicated by NTCJ to be used in applications as meeting the requirements of a particular industry standard (e.g., ISO 9001, IATF 16949, ISO 26262, etc.), this IC is neither designed nor intended for use in such environments for that applications. NTCJ shall not be held responsible for not meeting the requirements of a particular industry standard.
7. Using IC that have been indicated as compliant with industry functional safety standards does not warrant that the application meets the requirements of industry functional safety standards. NTCJ shall not be held responsible for the application compliance with requirements of the particular industry functional safety standard.
8. Unless this IC is indicated by NTCJ to be used in applications as meeting the requirements of a particular quality standard (e.g., AECQ-100, etc.), this IC is neither designed nor intended for use in such the environments for that applications. NTCJ shall not be held responsible for not meeting the requirements of a particular quality standard.
9. In case of damages, costs, losses, and/or liabilities incurred by NTCJ arising from customer's non-compliance with above from 1 to 8, customer will indemnify NTCJ against every damages, costs, losses and responsibility.

Motor Driver IC for 3-phase Brushless Motor

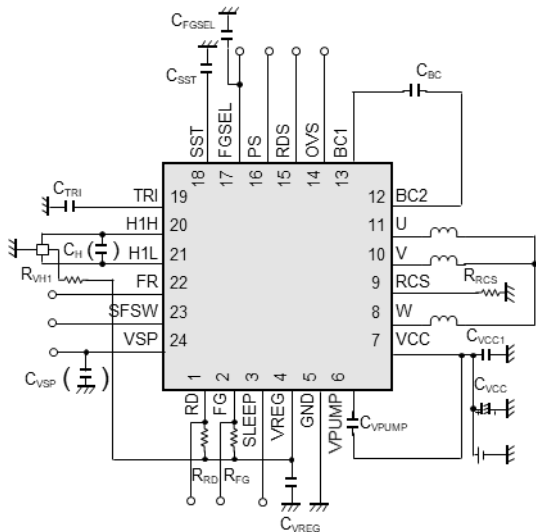
FEATURES

- KA44143A is a driver IC for 3-phase brushless motor optimized for fan motors. By employing the rotor position detector and sine wave PWM drive by 1-Hall-sensor, this IC achieves component reduction and miniaturization of motor set as well as motor drive at low noise, low vibration and low power consumption.
 - Supply voltage range: 4.5 V to 26.4 V
 - Built-in 5-V regulator
 - 3-phase full-wave sine-wave PWM drive by 1-Hall-sensor
 - Selectable Input Mode: Either linear voltage input or PWM input through VSP pin
 - Selectable the start frequency through SWSF pin
 - Conduction angle auto driver phase shift correction
 - Rotation direction selectable (Forward/Reverse)
 - FG pulse divide selectable
 - Sleep mode
 - Various protection functions:
 - Under Voltage Lock Out (UVLO), Over Voltage Lock Out (OVLO), Thermal protection, Over Load Protection, and Over Current Protection
 - Package
 - QFN 24L (4x4x0.8mm³, Lead Pitch 0.5mm)

APPLICATION

Refrigerator, Projector, Printer, Factory automation

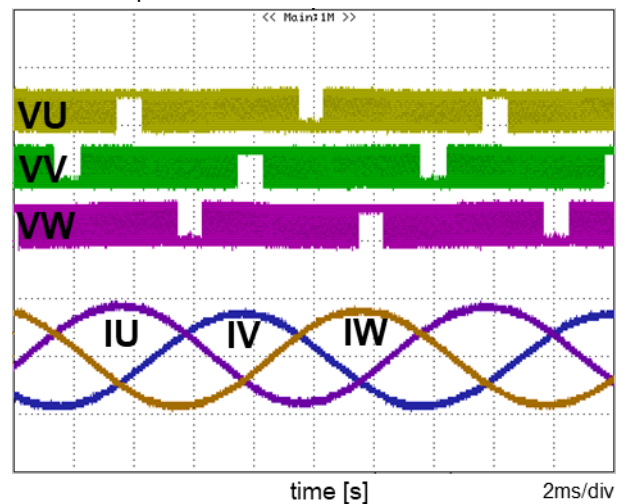
TYPICAL APPLICATION



Note: The application circuit is an example. The operation of the mass production set is not guaranteed. Sufficient evaluation and verification is required in the design of the mass production set. The Customer is fully responsible for the incorporation of the above illustrated application circuit in the design of the equipment.

MOTOR DRIVE WAVEFORM

KA44143A 3-phase full-wave sine-wave PWM drive



Condition: $V_{CC} = 12V$, $V_{FR} = 0V$, $V_{VSP} = \text{PWM mode}$ (60kHz, Duty60%)

Table of Contents

IMPORTANT NOTICE..... 2

FEATURES 3

APPLICATION 3

TYPICAL APPLICATION..... 3

1. ELECTRICAL CHARACTERISTICS 5

 1.1 ABSOLUTE MAXIMUM RATINGS 5

 1.2 POWER DISSIPATION RATING..... 6

 1.3 RECOMMENDED OPERATING CONDITIONS..... 7

 1.4 ELECTRICAL CHARACTERISTICS 8

2. PIN CONFIGURATION..... 12

 2.1 PIN ASSIGNMENT 12

 2.2 PIN FUNCTIONS..... 13

3. RECOMMENDED CIRCUIT..... 14

4. PACKAGE INFORMATION..... 15

5. USAGE PRECAUTIONS 16

6. REVISION HISTORY 19

1. ELECTRICAL CHARACTERISTICS

1.1 ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Rating	Unit	Notes
Supply voltage	V_{CC}	28	V	*1
Operating ambient temperature	T_{opr}	- 40 to +105	°C	*2
Storage temperature	T_{stg}	- 55 to +150	°C	*2
Input Voltage Range	V_{VREG}	- 0.3 to 6.0	V	*3
	$V_{SLEEP}, V_{H1H}, V_{H1L}, V_{FGSEL}, V_{VSP}, V_{SFSW}, V_{FR}, V_{RDS}, V_{PS}, V_{OVS}$	- 0.3 to 6.0	V	—
	V_{TRI}, V_{SST}	- 0.3 to 6.0	V	—
Output Voltage Range	V_{FG}, V_{RD}	- 0.3 to 6.0	V	—
	V_{VREG}	- 0.3 to 6.0	V	—
	V_{RCS}	- 0.3 to 6.0	V	*4
	V_{BC1}	28	V	*4
	V_{BC2}, V_{pump}	37	V	*4
Output Current Range	$I_{Upeak}, I_{Vpeak}, I_{Wpeak}$	± 2200	mA	*5, *6
	I_{FG}, I_{RD}	5	mA	—
	I_{VREG}	- 10	mA	—
ESD	HBM	2	kV	—

Note: This product may sustain permanent damage if subjected to conditions higher than the above stated absolute maximum rating. This rating is the maximum rating and device operating at this range is not guaranteed as it is higher than our stated recommended operating range. When subjected under the absolute maximum rating for a long time, the reliability of the product may be affected.

*1: The values under the condition not exceeding the above absolute maximum ratings and the power dissipation.

*2: Except for the power dissipation, operating ambient temperature, and storage temperature, all ratings are for $T_a = 25^\circ\text{C}$.

*3: Applying external voltage to this pin is possible only when this pin and VCC pin is connected. When applying external voltage to this pin, do not exceed the stated ratings even in transient state.

*4: Applying external voltage into these pins is prohibited. Do not exceed the stated ratings even in transient state.

*5: Applying external voltage into these pins is prohibited. Do not exceed the stated ratings even in transient state.

*6: For $V_{CC} \geq 5.6\text{ V}$, output current is $\pm 2200\text{ mA}$. For $V_{CC} < 5.6\text{ V}$, output current is $\pm 1500\text{ mA}$.

Please ensure that there is enough margin and the design does not exceed the allowable value of Power Dissipation(PD) and Area of Safe Operation(ASO).

1.2 POWER DISSIPATION RATING

Package	θ_{j-a}	θ_{j-c}	$P_D (T_a=25^\circ\text{C})$	$P_D (T_a=105^\circ\text{C})$
QFN 24L (4x4x0.8mm ³ , Lead Pitch 0.5mm)	56.1 °C/W	4.4 °C/W	2.22 W	0.8 W

Note: For the actual usage, follow the power supply voltage, load and ambient temperature conditions to ensure that there is enough margin and the thermal design does not exceed the allowable value.

* Glass-Epoxy Substrate (2 Layers) : 50 x 50 x 0.8t (mm), Heat dissipation fin: Die-pad, Soldered. (Heat dissipation via 2 layer board)

CAUTION



Although this IC has built-in ESD protection circuit, it may still sustain permanent damage if not handled properly. Therefore, proper ESD precautions are recommended to avoid electrostatic damage to the MOS gates.

1.3 RECOMMENDED OPERATING CONDITIONS

Parameter	Pin Name	Min.	Typ.	Max.	Unit	Notes
Supply voltage range	V _{CC}	4.5	—	26.4	V	—
Input voltage range	V _{SLEEP}	0	—	V _{VREG}	V	*1
	V _{H1H}	0	—	V _{VREG}	V	*1
	V _{H1L}	0	—	V _{VREG}	V	*1
	V _{PS}	0	—	V _{VREG}	V	*1
	V _{RDS}	0	—	V _{VREG}	V	*1
	V _{OVS}	0	—	V _{VREG}	V	*1
	V _{FGSEL}	0	—	V _{VREG}	V	*1
	V _{VSP}	0	—	V _{VREG}	V	*1
	V _{SFSW}	0	—	V _{VREG}	V	*1
	V _{FR}	0	—	V _{VREG}	V	*1
External constants	C _{VCC}	4.7μ	—	—	F	*2,*3
	C _{VCC1}	—	0.1μ	—	F	*2,*3
	C _{VREG}	—	0.1μ	—	F	*2,*4
	C _{SST}	22p	1800p	—	F	*2,*5
	C _{BC}	—	0.1μ	—	F	*2,*4
	C _{VPUMP}	—	0.1μ	—	F	*2,*4
	C _{TRI}	220p	390p	1300p	F	*2,*5
	R _{RCS}	0.15	0.22	—	Ω	*2,*5,*6
	R _{VH}	—	1k	—	Ω	*2,*5
	C _{FGSEL}	—	0.01μ	—	F	*2,*7
	C _{VSP}	—	0.1μ	—	F	*2,*8

Note:

*1: For setting range of input control voltage, refer to Electrical Characteristics (page 6 - 9) and Operation (page 12 - 34).

*2: Operation of mass production set is not guaranteed. Perform enough evaluation and verification on the design of mass production set.

*3: Please perform sufficient evaluation and verification to ensure that VCC pin voltage ripple is reduced.

*4: It is recommended to use the values indicated.

*5: Please choose the setting according to the usage. Please refer to the Electrical Characteristics (page 6 - 9) and Operation (page 12 - 34).

*6: Do not use resistor of value smaller than this. When using value smaller than the minimum value, latch-up function which is used to prevent thermal damage may operate due to external factors (PCB heat dissipation, metal impedance, etc...) or internal factors (threshold change, etc...).

*7: When using with FGSEL pin open, please connect capacitor to the FGSEL pin to prevent noise and carry out sufficient evaluation and verification

*8: When VSP pin is used for DC input, it is recommended to insert a capacitor to the VSP pin.

1.4 ELECTRICAL CHARACTERISTICS

at VCC = 12.0 V, VVREG = 5.0 V

Note: Ta = 25°C±2°C unless otherwise noted.

Parameter	Symbol	Condition	Limits			Unit	Notes
			Min.	Typ.	Max.		
CIRCUIT CURRENT							
V _{CC} current	I _{CC1}	—	3.0	5.6	9.0	mA	—
V _{CC} current at sleep mode	I _{CC3}	V _{SLEEP} = H	—	—	50	µA	—
REGULATOR BLOCK							
VREG voltage	V _{VREG}	—	4.7	5	5.3	V	—
Output impedance	Z _{VREG}	I _{VREG} = -10 mA	—	—	10	Ω	—
FG BLOCK							
FG output (low voltage)	V _{FGL}	I _{FG} = 1.0 mA	—	0.1	0.3	V	—
RD BLOCK							
RD output (low voltage)	V _{RDL}	I _{RD} = 1.0 mA	—	0.1	0.3	V	—
POWER BLOCK							
On resistance	R _{ONHL}	I = 400 mA	0.5	1.0	1.5	Ω	—
On resistance (V _{CC} =4.5V)	R _{ONHL}	V _{CC} = 4.5V I = 400 mA	—	1.25	2.05	Ω	—
Diode forward voltage	V _{DI}	I = 400 mA	0.6	0.8	1	V	—
MOTOR LOCK PROTECTION							
Lock detection time_LL	t _{LOCK1_LL}	RDS, SFSW = L,L	0.35	0.5	0.65	s	—
Lock release time_LL	t _{LOCK2_LL}	RDS, SFSW = L,L	3.5	5	6.5	s	—
Lock protection ratio_LL	PR _{RATIO_LL}	RDS, SFSW = L,L	9	10	11	—	—
Lock detection time_LH	t _{LOCK1_LH}	RDS, SFSW = L,H	0.7	1	1.3	s	—
Lock release time_LH	t _{LOCK2_LH}	RDS, SFSW = L,H	7	10	13	s	—
Lock protection ratio_LH	PR _{RATIO_LH}	RDS, SFSW = L,H	9	10	11	—	—
Lock detection time_HL	t _{LOCK1_HL}	RDS, SFSW = H,L	1.4	2	2.6	s	*1
Lock detection time_HH	t _{LOCK1_HH}	RDS, SFSW = H,H	0.35	0.5	0.65	s	*2
OVER CURRENT PROTECTION							
Over current detection level	V _{CL1}	—	0.225	0.250	0.275	V	—
SLEEP							
Low-level input voltage	V _{SLL}	—	—	—	0.5	V	—
High-level input voltage	V _{SLH}	—	2.5	—	—	V	—
Open-circuit voltage	V _{SLZ}	—	—	0	0.3	V	—
Input impedance	Z _{SL}	—	70	100	130	kΩ	—

at VCC = 12.0 V, VVREG = 5.0 V

Note: Ta = 25°C±2°C unless otherwise noted.

Parameter	Symbol	Condition	Limits			Unit	Notes
			Min.	Typ.	Max.		
Internal Oscillation Frequency							
Internal oscillation frequency	f _{OSC}	—	17.5	25	32.5	MHz	—
VSP							
Pin current	I _{VSP}	V _{VSP} =5.0V	—	15	45	μA	—
VSP DC Input Control							
Stop control VSP input	V _{VSPDCL}	—	0.9	1.0	1.1	V	—
Max. speed VSP input	V _{VSPDCH}	—	3.6	4.0	4.4	V	—
VSP PWM INPUT CONTROL							
Stop control VSP input	V _{VSPPWML}	V _{VREG} =V _{OSC} =5.0V	2	3	4	%	*3,*4
Max. speed VSP input	V _{VSPPWH}	V _{VREG} =V _{OSC} =5.0V	—	100	—	%	*3,*6
Low-level input voltage during PWM input	V _{VSPLL}	V _{VREG} =V _{OSC} =5.0V	—	—	1.0	V	*3
High-level input voltage during PWM input	V _{VSPHL}	V _{VREG} =V _{OSC} =5.0V	2.0	—	—	V	*3
PWM input frequency range	F _{PWM}	—	15	—	100	kHz	*3
TRIANGLE WAVE OSCILLATOR FOR PWM WAVEFORM (TRI PIN)							
Amplitude	V _{TRI}	—	1.36	1.53	1.70	V _{pp}	—
External capacitor charging current	I _{TRI1}	V _{TRI} =0.5V	−83.5	−64.5	−45.5	μA	—
External capacitor discharging current	I _{TRI2}	V _{TRI} =2.0V	45.5	64.5	83.5	μA	—
TRI pin input voltage during PWM control	V _{TRITH}	—	2.9	—	—	V	*3
TRIANGLE WAVE OSCILLATOR DURING SOFT START (SST PIN)							
Amplitude	V _{SST}	—	0.75	1.0	1.25	V _{pp}	—
External capacitor charging current	I _{SST1}	V _{SST} =0.6V	−6.0	−4.0	−2.0	μA	—
External capacitor discharging current	I _{SST2}	V _{SST} =1.6V	2.0	4.0	6.0	μA	—
SST pin input voltage when Soft Start not used	V _{SSTTH}	—	2.9	—	—	V	*5
HALL BLOCK							
Input dynamic range	V _{HALL}	—	0	—	VREG−2.0V	V	—
Pin current	I _{HALL}	—	−2	0	2	μA	—
Input offset voltage for H1H—H1L drop	V _{HOFS}	—	−6	0	6	mV	—
Min. input amplitude voltage	V _{HA}	—	25	—	—	mV	—
Hysteresis width	V _{HHYS}	—	7.5	10	13	mV	—

at VCC = 12.0 V, VVREG = 5.0 V

Note: Ta = 25°C±2°C unless otherwise noted.

Parameter	Symbol	Condition	Limits			Unit	Notes
			Min.	Typ.	Max.		
FR (3-STATE INPUT CIRCUIT)							
Low-level input voltage	V _{FRL}	—	—	—	0.8	V	—
Mid-level input voltage	V _{FRM}	—	1.3	—	2.0	V	—
High-level input voltage	V _{FRH}	—	2.5	—	—	V	—
Open-circuit voltage	V _{FRZ}	—	1.4	1.65	1.9	V	—
Pin current	I _{INFR}	V _{FR} = 0 V	- 40	- 20	—	μA	—
FGSEL (3-State Input circuit)							
Low-level input voltage	V _{FGSELL}	—	—	—	1.0	V	—
High-level input voltage	V _{FGSELH}	—	4.0	—	—	V	*7
Open-circuit voltage	V _{FGSELZ}	—	1.8	2.4	2.8	V	*8
Pin current	I _{INFG}	V _{FGSEL} = 0 V	- 40	- 20	—	μA	—
PS (2-State Input circuit)							
Low-level input voltage	V _{PSL}	—	—	—	1.0	V	—
High-level input voltage	V _{PSH}	—	4.0	—	—	V	*7
Open-circuit voltage	V _{PSZ}	—	—	0.0	0.5	V	—
Pin current	I _{INPS}	V _{PS} = 5.0 V	—	5	15	μA	—
RDS (2-State Input circuit)							
Low-level input voltage	V _{RDSL}	—	—	—	1.0	V	—
High-level input voltage	V _{RDSH}	—	4.0	—	—	V	*7
Open-circuit voltage	V _{RDSZ}	—	—	0.0	0.5	V	—
Pin current	I _{INRDS}	V _{RDS} = 5.0 V	—	5	15	μA	—
OVS (2-State Input circuit)							
Low-level input voltage	V _{OVSL}	—	—	—	1.0	V	—
High-level input voltage	V _{OVSH}	—	4.0	—	—	V	*7
Open-circuit voltage	V _{OVSZ}	—	—	0.0	0.5	V	—
Pin current	I _{INOVS}	V _{OV} = 5.0 V	—	5	15	μA	—
SFSW (2-State Input circuit)							
Low-level input voltage	V _{SFSWL}	—	—	—	1.0	V	—
High-level input voltage	V _{SFSWH}	—	4.0	—	—	V	*7
Open-circuit voltage	V _{SFSWZ}	—	—	0.0	0.5	V	—
Pin current	I _{INSFSW}	V _{SFSW} = 5.0 V	—	5	15	μA	—

at VCC = 12.0 V, VVREG = 5.0 V

Note: Ta = 25°C±2°C unless otherwise noted.

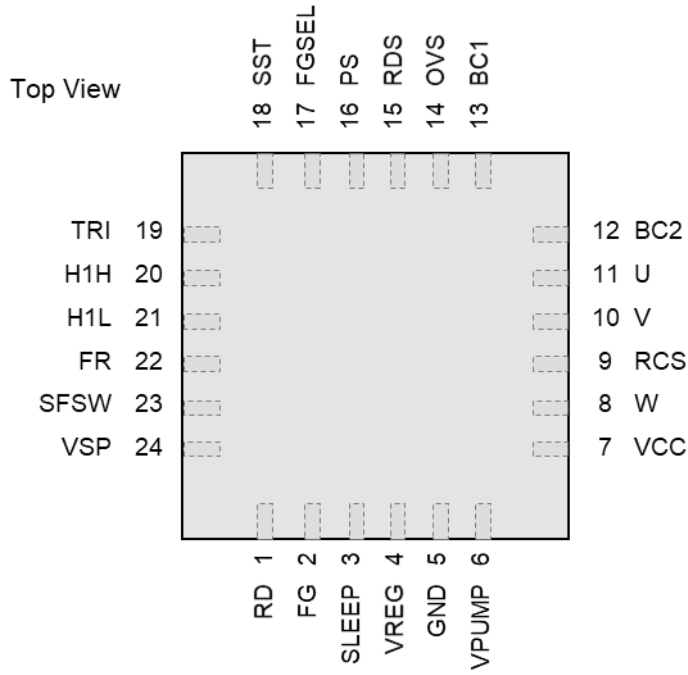
Parameter	Symbol	Condition	Limits			Unit	Notes
			Min.	Typ.	Max.		
Thermal Protection							
Protection operating temperature	TSD _{ON}	—	—	160	—	°C	*9*10
Hysteresis width	TSD _{HYS}	—	—	25	—	°C	*9*10
Output Block							
Output rising slew rate at source current	V _{TRSO}	—	—	300	—	V/μs	*9*10
Output falling slew rate at source current	V _{TFSO}	—	—	300	—	V/μs	*9*10
Output rising slew rate at sink current	V _{TRSI}	—	—	300	—	V/μs	*9*10
Output falling slew rate at sink current	V _{TFSI}	—	—	300	—	V/μs	*9*10
Triangle Wave Oscillator for PWM Waveform (TRI pin)							
Oscillation frequency range	f _{TRI}	—	15	—	100	kHz	*10
Standard oscillation frequency	F _{TRI}	C _{TRI} = 390 pF	—	55.4	—	kHz	*9*10
Triangle Wave Oscillator during Soft Start (SST pin)							
Standard oscillation frequency	F _{SST}	C _{SST} = 1800 pF	—	1.13	—	kHz	*9*10
Maximum Rotating Speed							
Minimum hall cycle	T _{HMIN}	—	—	173	—	μs	*9*10
Under Voltage Lock Out							
Protection operating voltage	V _{LVON}	—	—	3.55	—	V	*9*10
Protection release voltage	V _{LVOFF}	—	—	3.75	—	V	*9*10
Over Voltage Lock Out							
Protection operating voltage 1	V _{OVON1}	V _{OVS} = VREG	15.0	16.0	17.0	V	*10
Protection operating voltage 2	V _{OVON2}	V _{OVS} = 0V	26.4	27.2	28.0	V	*10

Note:

- *1: Motor Lock Protection is released immediately by UVLO signal input and SLEEP signal input.
- *2: Motor Lock Protection automatically resets immediately (after 70us elapses).
- *3: During PWM control setting, TRI pin must be connected to VREG pin.
- *4: It is recommended to input 0% Duty (Low input) when input STOP.
- *5: When Soft Start is not in used, SST pin must be connected to VREG pin.
- *6: Typical Design Value.
- *7: During High level setting, please ensure to connect to VREG pin.
- *8: Please connect a capacitor to FGSEL pin when it is open during use to prevent noise. To ensure the noise prevention, please perform sufficient evaluation and verification.
- *9: Typical Design Value.
- *10: These are values checked by design but not production tested.

2. PIN CONFIGURATION

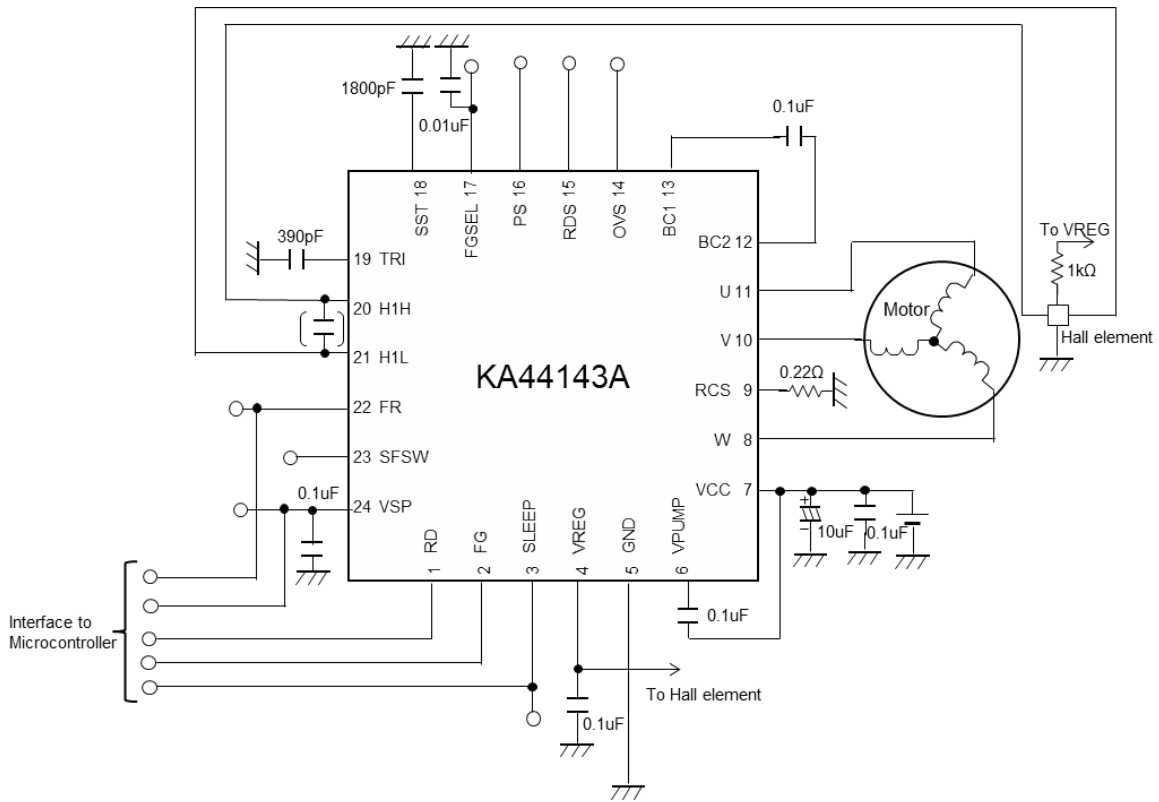
2.1 PIN ASSIGNMENT



2.2 PIN FUNCTIONS

Pin No.	Pin name	Type	Description
1	RD	Output	Over load protection
2	FG	Output	FG external output
3	SLEEP	Input	Sleep setting
4	VREG	Output	Internal reference voltage
5	GND	Ground	Ground
6	VPUMP	Output	Charge pump circuit output
7	VCC	Power	Supply voltage for motor
8	W	Output	W-phase output
9	RCS	Output	Motor current detector
10	V	Output	V-phase output
11	U	Output	U-phase output
12	BC2	Output	Capacitor connection pin 2 for charge pump
13	BC1	Output	Capacitor connection pin 1 for charge pump
14	OVS	Input	Over voltage detection selectable threshold. High for 16V detection, Low for 27.2V detection
15	RDS	Input	Selectable Release of Motor lock protection. High to use the release of lock protection. Low to disable the release of lock protection.
16	PS	Input	Selectable phase shift mode. High to enable constant phase shift mode. Low to enable Auto Phase FB shift mode.
17	FGSEL	Input	FG pulse count select
18	SST	Input / Output	Capacitor connection pin for Soft Start triangle wave oscillator frequency setting
19	TRI	Input / Output	Capacitor connection pin for PWM triangle wave oscillator frequency setting
20	H1H	Input	Hall amplifier input (+)
21	H1L	Input	Hall amplifier input (-)
22	FR	Input	Rotation direction select (Forward/Reverse)
23	SFSW	Input	Selectable the start frequency
24	VSP	Input	Voltage input for setting rotating speed

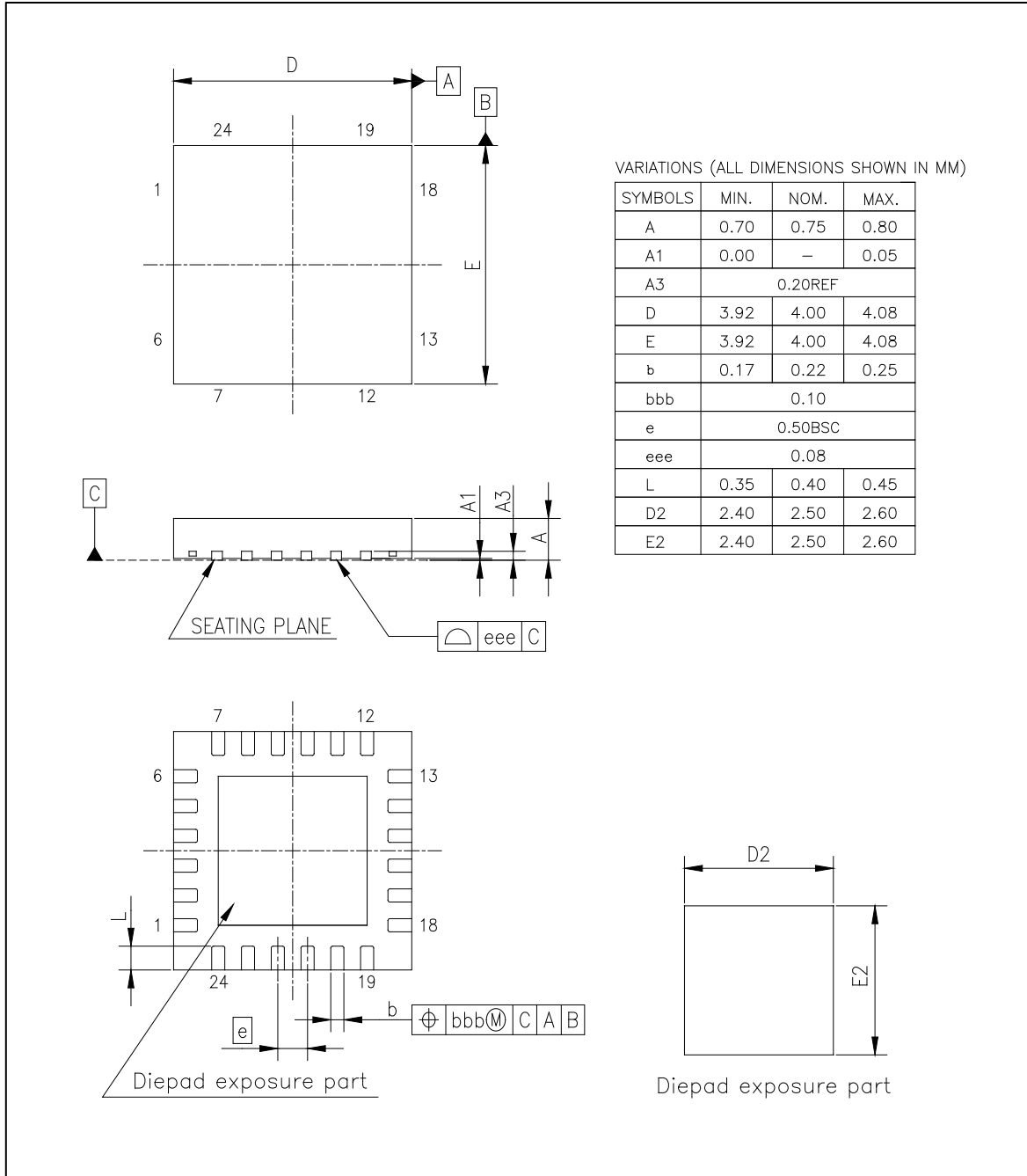
3. RECOMMENDED CIRCUIT



Note: The recommended circuit is an example. The operation of the mass production set is not guaranteed. Sufficient evaluation and verification is required in the design of the mass production set. Customer is fully responsible for the incorporation of the above illustrated application circuit in the production.

4. PACKAGE INFORMATION

QFN 24L 4x4mm², Thickness 0.8mm, Lead Pitch 0.5mm,
Lead Length 0.4mm, EP Size 2.5x2.5mm

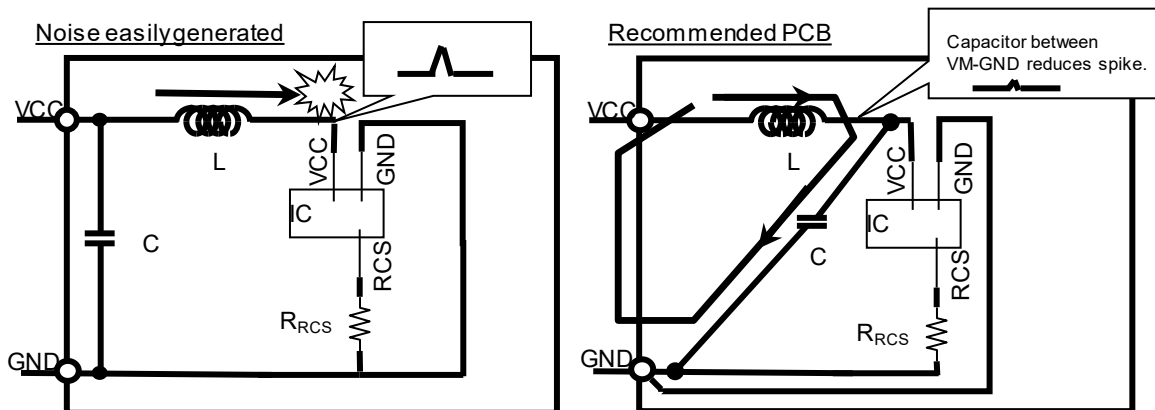


5. USAGE PRECAUTIONS

Below are the precautions to take note when using this IC.

1. Pay attention to the direction of the IC. When mounting it in the wrong direction onto the PCB (printed-circuit-board), it might be damaged.
2. Pay attention in the PCB (printed-circuit-board) pattern layout in order to prevent damage due to short circuit between pins. In addition, refer to the Pin Description for the pin configuration.
3. Perform visual inspection on the PCB before applying power, otherwise damage might happen due to problems such as solder-bridge between the pins of the IC. Also, perform full technical verification on the assembly quality, because the same damage possibly can happen due to conductive substances, such as solder ball, that adhere to the IC during transportation.
4. Take notice in the use of this IC that it might be damaged when an abnormal state occurs such as output pin-VCC short (Power supply fault), output pin-GND short (Ground fault), or output-to-output-pin short (load short). Safety measures such as installation of fuses are recommended because the extent of the above-mentioned damage will depend on the current capability of the power supply.
5. This IC may be changed in order to improve the performance without notice, please make sure the latest specification is used before your final design.
6. Apply power supply with low impedance to VCC and connect bypass capacitor near to the IC.
7. When designing PCB pattern for RCS pin (Pin 9), place a resistor for current detection (RRCS) close to the IC. The setting value for over current protection may fluctuate due to the impedance of wiring pattern between RCS pin and the RCS resistor.
8. When VCC is input, VCC voltage will start to rise to the designated voltage. However, at the same time, motor driver starts driving and when this results in decreases the VCC voltage, it may disrupt the normal start-up. Therefore, please conduct sufficient evaluation and verification to ensure the power supply current.
9. The minimum input amplitude of hall signal comparator should be designed in consideration of tolerances and temperature characteristics of the hall element, so that it will not result in failure to the motor operation.
10. In the 1-HALL-sensor system motor driver adopted in this IC, energization pattern of a cycle is generated based on previous 1-cycle of a HALL input signal. Therefore, when the acceleration of a motor is very high, the motor may be unable to accelerate normally because of the big difference in cycle between the generated energization pattern and the motor rotation.
 When using a motor with very high speed acceleration, ensure to conduct sufficient technical evaluation and examination on the sudden acceleration from low rotation. When the above acceleration problems arises, the problem may be improved by putting the speed to zero first and then input the required speed. Please conduct sufficient evaluation before use.
 (When HALL input signal of below 10Hz is inputted to this IC, putting the speed to zero and then input the required speed again will restart the rotation.)
11. Do not change the control signal of SLEEP pin (pin 3) from Low to High while motor is running at high speed. The IC can be damaged due to the effect of induced voltage and conduction angle. Conduct sufficient technical evaluation to verify.
12. Brake current during short brake is determined by the motor running speed and motor characteristics. Before the short brake, please review and evaluate by reducing the motor current and lower the motor speed. Please perform sufficient evaluation to ensure that the IC is not damaged.
13. In case the motor running speed changes from high to low rapidly, supply voltage can be increased due to the flow back of motor current. Conduct sufficient evaluation and examination to ensure there is no issue.
14. When designing PCB pattern, place a resistor for current detection (RCS) close to the IC. The setting value for over current protection may fluctuate due to the impedance of wiring pattern between RCS pin and the RCS resistor.
15. FG pin (Pin 1) and RD pin (Pin 2) are open-drain outputs. Connect a pull-up resistor to the designated power supplies and use this IC within the allowable voltage and current ranges.
16. For the below pins, please ensure to connect to VREG pin under High level condition. TRI pin (Under PWM control), SST pin (When Soft Start not used), FGSEL pin, PS pin, RDS pin, OVS pin and SFSW pin.
 In addition, these terminals, changing the applied voltage during the operation of this product, we do not assume.
 When changing the voltage applied to the terminal settings, please temporarily turn off the power.
17. When connecting TRI pin to VREG pin using PWM input mode, please make sure to input High level or Low level to the VSP pin. Other voltage levels between High and Low level may result in unexpected operation.
18. Due to the initial position of the rotor, the starting torque differs slightly during start-up. For motor type that requires large inertia force to turn, please ensure that sufficient starting current is available for the motor. Please perform sufficient testing and evaluations to ensure this.

19. If the soft-start timing is too long, it will result in the motor not having enough starting torque and lock protection detection will be triggered if soft start timing is more than 0.5s (typ). This will cause the motor to be unable to start. Please evaluate and check this condition thoroughly when using this function.
20. Sufficiently check the characteristics before use. When there is changes in the external circuits, please check both static and transient characteristics and ensure that there is enough margin
21. When input power to VCC(Pin7), it is recommended that VCC voltage rises slower than $1.5V/\mu s$ and when turn off, VCC voltage drops slower than $-1.5V/\mu s$.
When performing power up and shutdown at high-speed, please ensure sufficient evaluation is performed to verify that there is no problem.
22. Capacitor between VCC and GND
This IC employs the PWM driving method and hence, output transistor switches under high current condition and this easily generates noise. Therefore the IC may be damaged or malfunction due to noise.
Hence, it is necessary to ensure that the power supply is stable so as to avoid circuit damaged or malfunction due to noise.
Where possible, place a capacitor between VCC and GND near to the IC so that IC will not malfunction due to PWM noise and gets damaged.
23. Points to note for Motor PCB pattern
As this IC is used under high current, it is necessary to take note of common impedance in the pattern.
Please take care of the following in the pattern design of the motor PCB.
 - As high current flows from VCC connector to the IC VCC pin (Pin7) and through the metal lines, if the metal line is a 'L' shape pattern, noise may be easily generated resulting in malfunction and damage during switching (Bottom left figure).
From the figure on the right, if a capacitor is placed with respect to the connector near VCC, a noise discharge route is created and this reduces the VCC voltage directly to the IC pin. Where possible, please follow the figure on the right.
In addition, metal line impedance depends on the pattern length and therefore, please keep the metal line between VCC connector and IC VCC pin as short and as thick as possible in the design.
 - The line between current detection resistor (RRCS) to RCS pin (Pin9) is very important. Therefore, where possible, it is recommended to use an isolated line to connect from the start of the detection resistor to the RCS pin.
Accurate current value may not be detected due to metal impedance if RRCS is placed far from the IC.
Therefore, if it is not possible to place near to the IC, please ensure that the motor current waveform and RRCS current waveform is accurate.
 - Please ensure that the line between the GND connector and RCS resistor is isolated from the IC GND pin (Pin5).
If a common line is used, it may result in malfunction or IC ground connection voltage unstable due to line impedance.
In addition, to reduce line impedance effect, please ensure that GND line is as short and as thick as possible in the design.



19. This IC has five protecting functions. Pay attention to the descriptions below.

Function	Operate/Release	Conditions	Remarks
Under voltage lock out (UVLO)	<ul style="list-style-type: none"> Operate VCC ≤ 3.55V Release VCC ≥ 3.75 V 	(Short brake) Upper-phase: OFF Lower-phase: ON	Large current may be generated due to a short brake during motor rotation. Conduct sufficient verification to prevent damages.
Over voltage lock out (OVLO)	<ul style="list-style-type: none"> Operate/Release VCC input voltage1: 16.0V (typ.) VCC input voltage2: 27.2V (typ.) 	(Short brake) Upper-phase: OFF Lower-phase: ON	Large current may be generated due to a short brake during motor rotation. Conduct sufficient verification to prevent damages.
Over Current Protection (CL)	<ul style="list-style-type: none"> Operate: RCSS voltage ≥ 0.25V (typ.) Release: RCSS voltage ≤ 0.25V (typ.) 	(Short brake) Upper-phase: OFF Lower-phase: ON	R _{RCS} is a current detection resistor. Concerning level of detection, false detection may occur due to the effect of PCB layout or noise. In addition, when specifying the resistance value of R _{RCS} , take the followings into consideration: Level of detection, tolerance in resistance value of R _{RCS} , temperature, ratings, etc.
Motor Lock Protection	<ul style="list-style-type: none"> Operate: Hall signal input cycle ≥ 0.5 s (RDS=L, SFSW=L) (RDS=H, SFSW=H) ≥ 1.0 s (RDS=L, SFSW=H) ≥ 2.0 s (RDS=H, SFSW=L) (Based on the rising or falling edge of H1H-H1L) Release: • With RDS and SFSW is set to following voltage, any of the below 7 conditions will result in the protection to release. • RDS = L or open and SFSW = L or H • RDS = H and SFSW = H <ol style="list-style-type: none"> SLEEP is input with 'H' UVLO operates (VCC<3.55V) Automatic reset after the following time; 5 s (RDS=L, SFSW=L) 10 s (RDS=L, SFSW=H) 70 μs (RDS=H, SFSW=H) Hall signal being input (Rising or falling edge of H1H-H1L) VSP(PWM)<3.0%(typ), or VSP(DC)<1.0V(typ) is inputted FR signal switch is inputted SBRK signal is inputted <ul style="list-style-type: none"> Control restrictions to protection functions When RDS is set to 'H' and SFSW is set to 'L', the above ③~⑦ will be disabled. 	(Short brake) Upper-phase: OFF Lower-phase: ON	Brake current may be generated due to protection circuit operating during the motor rotation. Conduct sufficient verification to prevent damages.
Thermal Protection	<ul style="list-style-type: none"> Operate: IC junction temperature > 160°C Release: IC junction temperature < 135°C 	All phases: OFF	Since all phases are OFF when protecting function operates, reverse current may be generated due to the repetition ON-OFF switching of the protection function during motor rotation. Pay attention to the voltage rise.

6. REVISION HISTORY

Date	Revision	Description
2021.2.8	1.00	1. initially issued.
2021.2.24	1.03	1. initially issued as Datasheet
2022.1.27	1.05	1. Added important notice on page2 2. Operating ambient temperature max “ 95°C”-> “ 105°C” on page.5 3. POWER DISSIPATION RATING PD(Ta=70°C) 1.42W -> PD(Ta=105°C) 0.8W on page.6 4. Remove important notice page from previous version page 15

Important Notice

Nuvoton Products are neither intended nor warranted for usage in systems or equipment, any malfunction or failure of which may cause loss of human life, bodily injury or severe property damage. Such applications are deemed, “Insecure Usage”.

Insecure usage includes, but is not limited to: equipment for surgical implementation, atomic energy control instruments, airplane or spaceship instruments, the control or operation of dynamic, brake or safety systems designed for vehicular use, traffic signal instruments, all types of safety devices, and other applications intended to support or sustain life.

All Insecure Usage shall be made at customer’s risk, and in the event that third parties lay claims to Nuvoton as a result of customer’s Insecure Usage, customer shall indemnify the damages and liabilities thus incurred by Nuvoton.

Please note that all data and specifications are subject to change without notice.
All the trademarks of products and companies mentioned in this datasheet belong to their respective owners.