AP1040
32V 2ch H-Bridge Motor Driver IC

1. General Description

The AP1040 is a 2ch H-Bridge motor driver that supports a maximum output current of 2.0A and from 8 to 32V operation voltage. The control mode of the AP1040 can be switched between parallel input mode and complemental input mode by the SEL pin. The built-in PWM duty control circuit enables speed adjustment of the motor by the VREF voltage for both forward and reverse rotations. The AP1040 has a through current prevention, a low voltage detection, a thermal protection and an overcurrent protection circuits for the output stage as protection circuits. The detection time of the overcurrent protection circuit can be adjusted by the resistance value connected to the TBLANK pin.
The AP1040 adopts a space saving 24-pin QFN package with good heat dissipation. It is ideal for a high current DC brush motor driver IC.

2. Features

- Motor Drive Voltage : 8V~32V (Single Power Supply)
- Control Power Supply : Not Necessary
- Maximum Output Current (DC) : 1.2A @Ta=25°C
- Maximum Output Current (Peak) : 2.0A @Ta=25°C, t<10ms
- ON Resistance of H-Bridge : 0.7Ω (High+Low) @Ta=25°C
- Input Interface : Parallel Input or Complemental Input
- PWM Pulse : Maximum 200kHz
- Protection Function : Over Heat Detection, Overcurrent Detection, Low Voltage Detection and Through Current Protection Functions
- Output Pin for Error Detection Flags
- Overcurrent Detection Time Adjustment Pin
- PWM Duty Control by VREF Pin
- Operation Temperature Range : -30°C~85°C
- Package : 24-pin QFN 4mm × 4mm

3. Table of Contents

4. Block Diagram

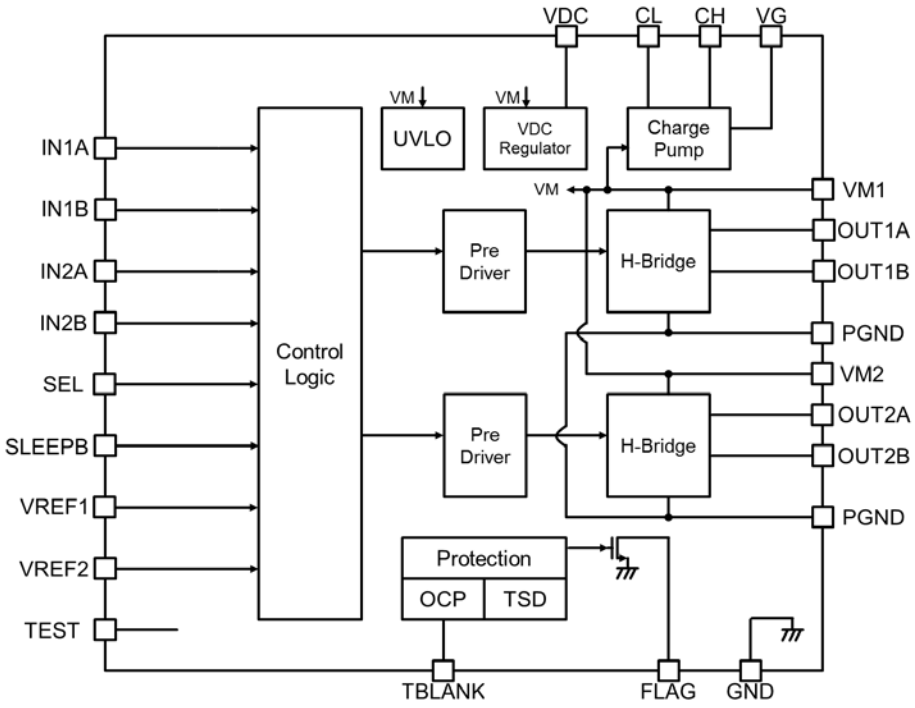


Figure 1. Block Diagram

5. Pin Configulations and Functions

5.1. Pin Layout

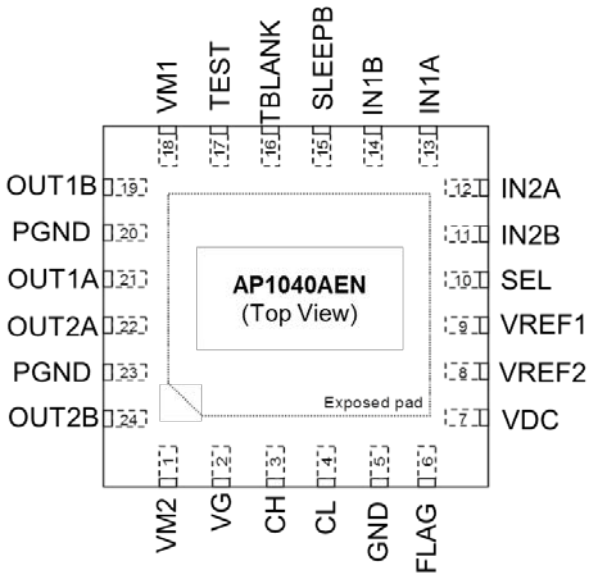


Figure 2. Pin Layout

5.2. Pin Functions

No.	Pin Name	I/O	Function	Note
1	VM2	P	Motor Driver Power Supply	(Note 2)
2	VG	O	Connect Pin for Stabilizing Capacitor	
3	CH	I/O	Connect Pin for Charge Pump Capacitor	
4	CL	I/O	Connect Pin for Charge Pump Capacitor	
5	GND	P	Ground	(Note 3)
6	FLAG	O	Flag Signal Output	
7	VDC	O	Connect Pin for Stabilizing Capacitor	Do not connect this pin to external circuits. (Note 4)
8	VREF2	I	Analog Signal Input for PWM-Duty Control	
9	VREF1	I	Analog Signal Input for PWM-Duty Control	
10	SEL	I	Input Logic Switching	100kΩ Internal Pull Down
11	IN2B	I	Motor Driver Signal Input	100kΩ Internal Pull Down
12	IN2A	I	Motor Driver Signal Input	100kΩ Internal Pull Down
13	IN1A	I	Motor Driver Signal Input	100kΩ Internal Pull Down
14	IN1B	I	Motor Driver Signal Input	100kΩ Internal Pull Down
15	SLEEPB	I	Power Save Signal Input	100kΩ Internal Pull Down
16	TBLANK	I/O	Connect Pin for Overcurrent Detection Time Adjustment Resistor	
17	TEST	-	TEST Pin	(Note 5)
18	VM1	P	Motor Driver Power Supply	(Note 2)
19	OUT1B	O	Motor Driver Output	
20, 23	PGND	P	Power Ground	(Note 3)
21	OUT1A	O	Motor Driver Output	
22	OUT2A	O	Motor Driver Output	
24	OUT2B	O	Motor Driver Output	
-	Exposed Pad	P	Heat Dissipation Pad	(Note 3)

Note 1. I: Input, O: Output, P: Power
Note 2. The VM1 pin and the VM2 pin must be connected on the PCB.
Note 3. The GND pin, the PGND pin and the exposed pad must be connected on the PCB.
Note 4. The only following two items are allowed to be connected to the VDC pin.
- Pull-up Resistor for the FLAG pin: from 50 kΩ to 1 MΩ
- Voltage Source for the VREF pin: Total Resistance from 50 kΩ to 1 MΩ

Note 5. Connect the TEST pin to GND.

6. Absolute Maximum Ratings

Parameter	Symbol	Min.	Max.	Unit	Condition
Motor Drive Power Supply Voltage (VM1, VM2)	VM	-0.3	35	V	
VDC Pin Voltage	V_{VDC}	-0.3	5.5	V	
Input Pin Voltage (IN1A, IN1B, IN2A, IN2B, SEL, SLEEPB, VREF1, VREF2, TBLANK, FLAG)	V_{term1}	-0.3	5.5	V	
Output Pun Voltage (OUT1A, OUT1B, OUT2A, OUT2B)	V_{term2}	-0.3	VM	V	
VG, CH Pin Voltage	V_{term3}	VM-0.3	VM+5.5	V	
VCL Pin Voltage	VCL	-0.3	VDC	V	
Motor Driver Maximum Current (2ch simultaneous driving)	I_{load1}	-	1.2	A/ch	Ta=25°C (Note 7)
		-	0.79	A/ch	Ta=85°C (Note 7)
Motor Driver Maximum Current (1ch driving)	I_{load2}	-	1.5	A	Ta=25°C (Note 7)
		-	1.1	A	Ta=85°C (Note 7)
Motor Driver Maximum Output Peak Current 1	I_{load3}	-	2.0	A	within 10ms during 200ms (Note 7)
Motor Driver Maximum Output Peak Current 2	I_{load4}	-	10.0	A	within 30us during 30ms (Note 7) (Note 8)
Power Dissipation	PD	-	3.1	W	Ta=25°C (Note 9)
		-	1.6	W	Ta=85°C (Note 9)
Maximum Operation Junction Temperature	Tj	-	150	°C	
Storage Temperature	Tstg	-40	150	°C	

Note 6. All voltages are with respect to ground (GND, PGND, Exposed Pad=0V).
Note 7. The maximum output current will be limited depending on the temperature (Ta) and the heat dissipation characteristic of the PCB.
Note 8. The power consumption of the IC by Joule heating should be 3 mJ/1 pulse or less.
Note 9. The thermal resistance of the package is shown below. (JEDEC51 standard 4 layered PCB)
Derating is necessary according to Figure 3 if the temperature (Ta) exceeds 25°C. θja=40°C/W

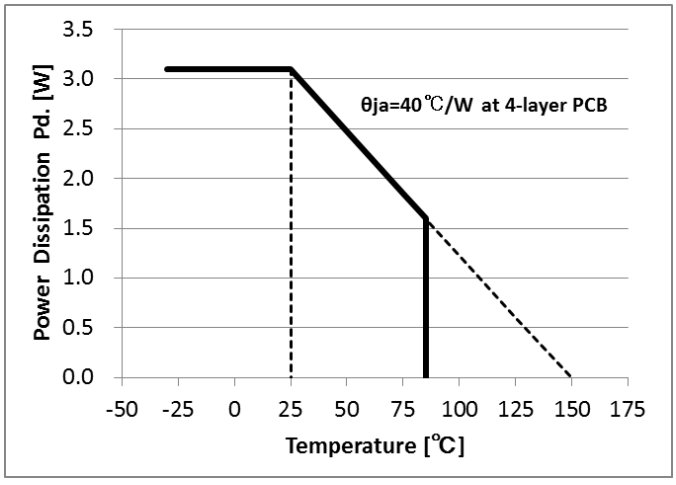


Figure 3. Maximum Power Dissipation

WARNING: Operation at or beyond these limits may result in permanent damage to the device.
Normal operation is not guaranteed at these extremes.

7. Recommended Operation Conditions

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Motor Drive Power Supply Voltage	VM	8.0	24.0	32.0	V	
VREF1, 2 Pins Input Voltage	V_{VREF}	0.2	-	5.0	V	
Input Frequency Range	FIN	-	-	200	kHz	
Operation Temperature Range	Ta	-30	-	85	°C	

Note 10. All voltages are with respect to GND.

8. Electric Characteristics

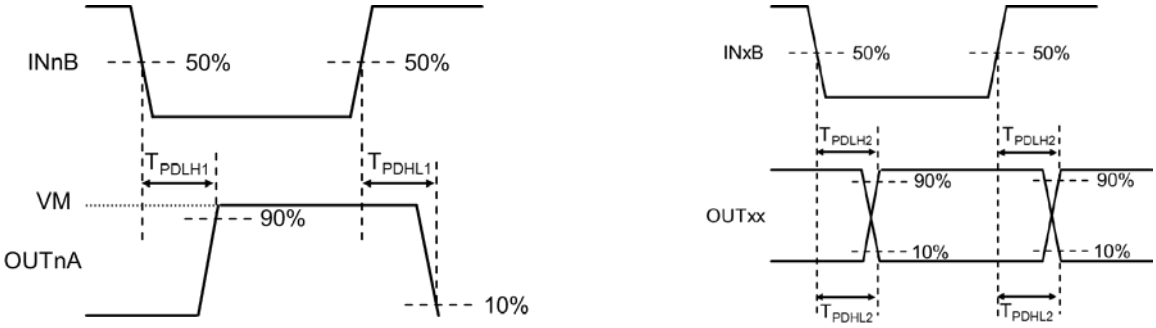
(Ta =25°C; VM=8V~32V; unless otherwise specified)

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Quiescent Current						
Power-off Quiescent Current	I_{VMPOFF}	SLEEPB = "L"	-	10	30	μA
Standby Quiescent Current	I_{VMSTBY}	SLEEPB = "H", SEL=INnA=InnB= "L"	-	2.0	4.5	mA
Operation Quiescent Current	I_{VM1}	SLEEPB= "H", SEL=InnA= "H" InnB=PWM (200kHz)	-	6.0	11.0	mA
Motor Driver						
Driver On-resistance (High + Low)	R_{ON}	Iload=1.2A, Ta=25°C	-	0.7	0.94	Ω
Body Diode Forward Direction Voltage	V_F	I_F=0.1A	-	0.8	1.0	V
Output Propagation Delay ("L"→"H")	T_{PDLH1}	tr=tf=10ns OUTA-OUTB=1kΩ Connection (Figure 4) Condition (a) (Note 12)	-	0.4	1.0	μs
Output Propagation Delay ("H"→"L")	T_{PDHL1}		-	0.15	1.0	μs
Output Propagation Delay ("L"→"H")	T_{PDLH2}	tr=tf=10ns OUTA-OUTB=1kΩ Connection (Figure 4) Condition (b)	-	0.22	1.0	μs
Output Propagation Delay ("H"→"L")	T_{PDHL2}		-	0.15	1.0	μs
Minimum Output Pulse Width	t_{PWO}	Input Signal Width t_{PWM}: 1μs (Figure 5)	0.6	1.0	1.4	μs
PWM-Duty Control Circuit						
PWM Frequency	f_{PWM}		20	44	80	kHz
PWM-Duty Accuracy (Note 11)	Duty1	Duty=30% to 100%	-5	-	5	%
	Duty2	Duty=20% to 30%	-10	-	10	%
	Duty3	Duty=10% to 19%	-15		15	%
	Duty4	Duty=6% to 9%	-25	-	25	%

(Ta =25°C; VM=8V~32V; unless otherwise specified)

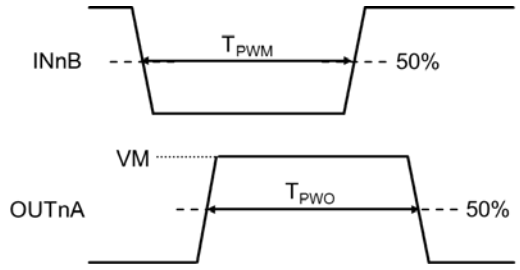
Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Control Logic						
VDC Pin Voltage	V_{DC}		4.1	4.5	4.9	V
Input High Level Voltage	V_{IH}		2.0	-	-	V
Input Low Level Voltage	V_{IL}		-	-	0.8	V
Input Hysteresis	V_{HYS}	(Note 13)	0.2	0.4	-	V
Input High Level Current	I_{IH}	V_{IH}=5.5V	-1.0	-	1.0	μA
Input Low Level Current	I_{IL}	V_{IL}=0V	-1.0	-	1.0	μA
Pull-down Resistance	R_{PD}		50	100	150	kΩ
Protection Functions						
VM Under Voltage Lockout	VM_{UVLO}		5.7	6.35	7.0	V
VM Under Voltage Hysteresis	VM_{HYS}		0.4	0.5	0.6	V
Overheat Detection Temperature	T_{TSD}	(Note 13)	150	175	200	°C
High-Side Driver Overcurrent Detection Level	I_{COPH}		2.5	4.5	7.0	A
Low-Side Driver Overcurrent Detection Level	I_{COPL}		2.5	4.5	7.0	A
Overcurrent Detection Time	T_{OCP}	R_{TBLANK}=22kΩ	1.4	2.0	2.6	μs
FLAG Pin Voltage	V_{FLAG}	Iload=0.2mA	-	-	0.4	V

Note 11. PWM-duty accuracy is the accuracy when the input voltage of the VREF pin is set to a resistively divided voltage of the VDC pin.
Note 12. All voltages are with respect to GND (GND = 0V).
Note 13. Not tested in production.



a) SEL= “L”, InnA = “H”, InnB = PWM　　b) SEL= “H”, InnA = “H”, InnB = PWM

Figure 4. Timing Chart of Output Propagation Delay Time



SEL= “H”, InnA= “H”, InnB = PWM

Figure 5. Timing Chart of Minimum Output Pulse Width

9. Functional Descriptions

9.1. Control Logic

■ Truth Value Table in Operation Status

Table 1. Output State of the Input Signal (InnA, InnB, SEL, SLEEPB)

MODE	Input Signal				Output		Operation
	SLEEPB	SEL	InnA	InnB	OUTnA	OUTnB	
1	H	L	L	L	Hi-Z	Hi-Z	Standby (Spin-out)
2			L	H	L	H	Reverse
3			H	L	H	L	Forward
4			H	H	L	L	Break (Stop)
5		H	L	X	L	L	Break (Stop)
6			H	L	H	L	Forward
7			H	H	L	H	Reverse
8	L	X	X	X	Hi-Z	Hi-Z	Power-off

Note 14. X: Don't Care

■ SLEEPB Pin Function

The AP1040 becomes power-off state by inputting "L" level signal to the SLEEPB pin.
When the AP1040 is powered off, most of internal circuits (regulator, charge pump, control circuit, protection circuit and etc.) are disabled and the AP1040 output is Hi-Z.
By inputting "H" level signal to the SLEEPB pin, the AP1040 is powered on, the control circuit and protection functions are reset and the AP1040 enters operation mode. It is recommended to input "L" level signal to the SEL, INAn and INBn pins for 3 ms (max) until the internal circuit stabilizes after releasing the power-off state.
In order to prevent a malfunction just after turning on the power supply, it is recommended to input "L" level signal to the SLEEPB pin up on power-up.
Before the internal circuit stabilizes, note that the start timing of motor driving will be undefined if input conditions of the SEL pin, INA/INB pin, etc. are set as the motor driving condition or if the power is turned on while the input level of the SLEEPB pin is "H".

Table 2. SLEEPB Pin Setting

SLEEPB Pin	Status
L	Power Off (Output: Hi-Z, Internal Circuit Stop)
H	Normal Mode

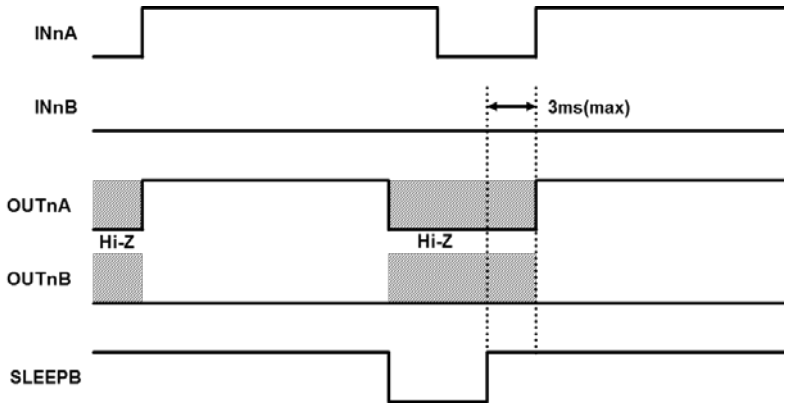


Figure 6. Power-off Release Timing Chart Example

■ SEL Pin Function

Parallel or Complemental input mode can be selected by the SEL pin. Parallel input mode suits for forward or invert standard motor driving operation. Complemental input mode suits for forward or invert motor driving operation while fixing the INA level and inputting PWM signal to the INB.
In both modes, the output voltage can be controlled by inputting PWM signal (max.= 200kHz) to the INA pins and INB pins. The minimum pulse period of the PWM signal is 1μs.
When controlling the motor current using the PWM signal to INA or INB, please note that the motor current according to the PWM signal may not be obtained unless the VREF terminal is set to 3.6 V or more.

Note that the motor current corresponding to PWM current may not be obtained unless the VREF pin voltage is set to 3.6V or more when controlling the motor current using the PWM signal for INA or INB input.

Table 3. SEL Pin Setting

SEL Pin	Status
L	Parallel Input Mode
H	Complemental Input Mode

■ Each Mode Operation

<Standby (Spin-out)>
OUT pins (motor output) become high impedance. All the internal circuits are in operation. It is recommended to set the SLEEPB pin to “L” → “H” level in this standby (spin-out) state.

<Forward>
OUTA pins output “H” level and OUTB pins output “L” level. When connecting a motor between OUTA and OUTB, a current flows from the OUTA pin to the OUTB pin.

<Reverse>
OUTA pins output “L” level and OUTB pins output “H” level. When connecting a motor between OUTA and OUTB, a current flows from the OUTB pin to the OUTA pin.

<Break (Stop)>
OUTA pins and OUTB pins output “L” level signal. Use this mode to stop a rotating motor.

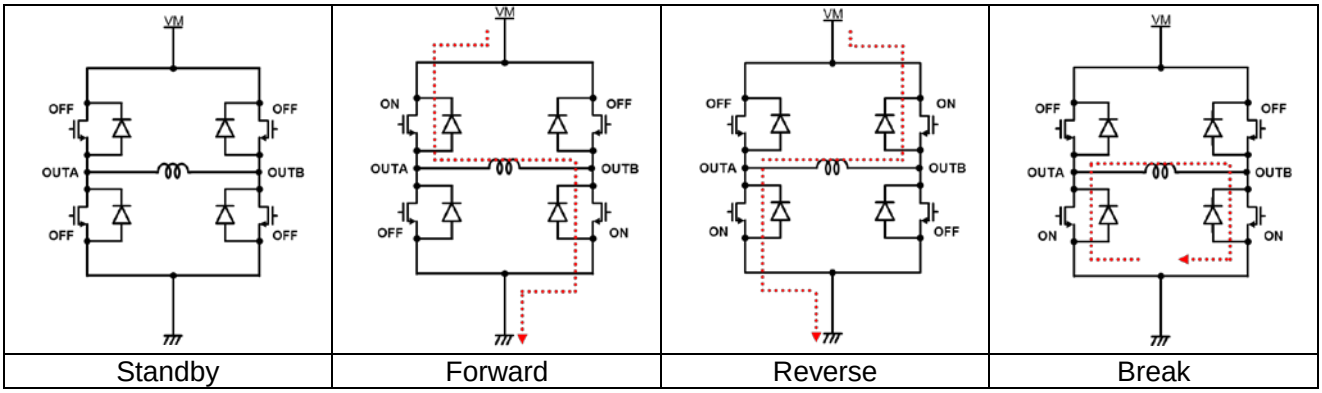


Figure 7. Output Status in Basic Operation Modes Outputs

9.2. PWM Duty Control

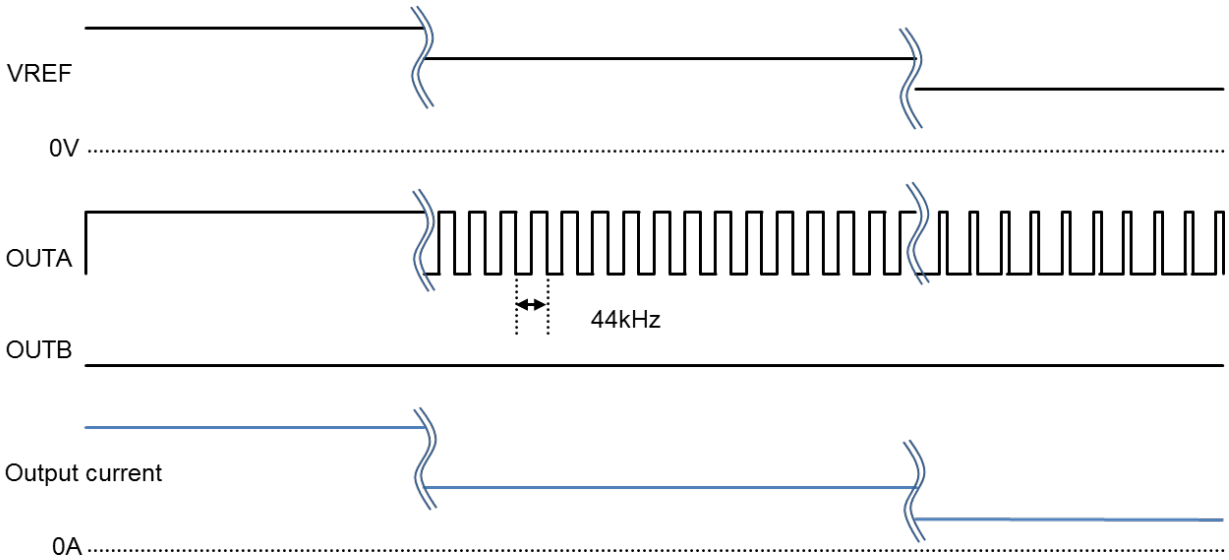
It is possible to control the PWM duty of the OUT pins by the voltage (DC) input to the VREF pin. With this function, the output current can be adjusted according to the VREF pin voltage. On-duty can be calculated by the following formula.

$$\text{PWM Duty} = \{\text{VREF}\times(1-0.025) / (\text{VDC}\times 0.8)\}+0.025 \quad [\%]$$

For example, PWM duty will be 50% if VREF = 1.75 V. When VREF is 3.6 V or more, the PWM duty will be 100%.

The switching frequency of PWM duty is determined internally and fixed to 44 kHz.
The AP1040 operates in Break mode while the PWM duty mode is off.

In order to maintain the accuracy of the PWM-duty control by the VREF pin, INA and INB should be fixed.



* This figure shows SEL=L or H , INA=H, and INB=L

Figure 8. Timing Chart of PWM-Duty Control

9.3. Protection Functions

■ Shoot-through Current Prevention

The AP1040 has shoot-through current prevention circuit that generates an OFF period (dead time) forcibly to prevent a shoot-through current of the output stage when the output signal is switched from “H” to “L” level or from “L” to “H” level. The dead time is 200 ns.

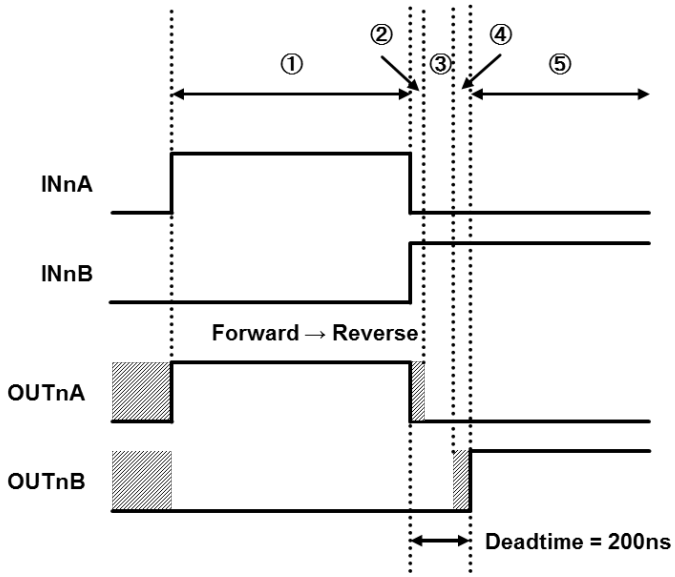


Figure 9. Timing Chart of Shoot-through Current Protection Circuit

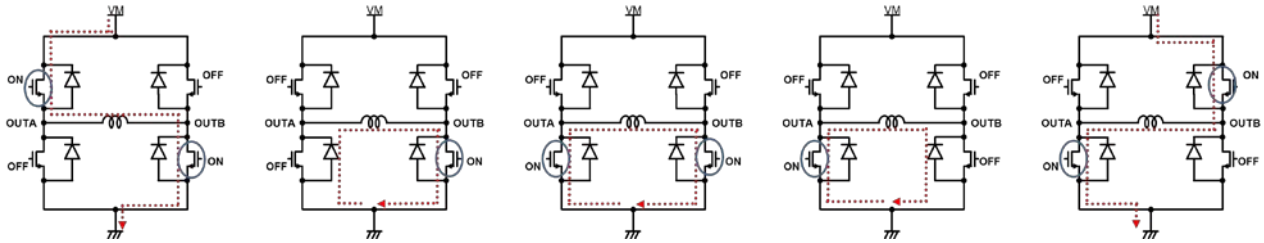


Figure 10. Forward ↔ Reverse Switching Output Pin Status

■ Under Voltage Detection Circuit (UVLO)

The AP1040 integrates a low voltage detection circuit in order to prevent malfunction of the IC when motor drive power supply voltage (VM) is low. If the VM voltage is lower than 6.35 V, the AP1040 sets the output stage to Hi-Z state. At this time, most internal circuits such as internal regulators and charge pumps are disabled, and the control logic and protection function are reset (initialized).

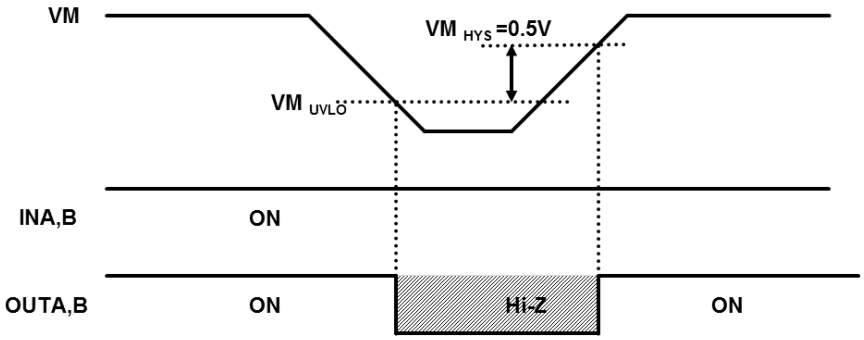
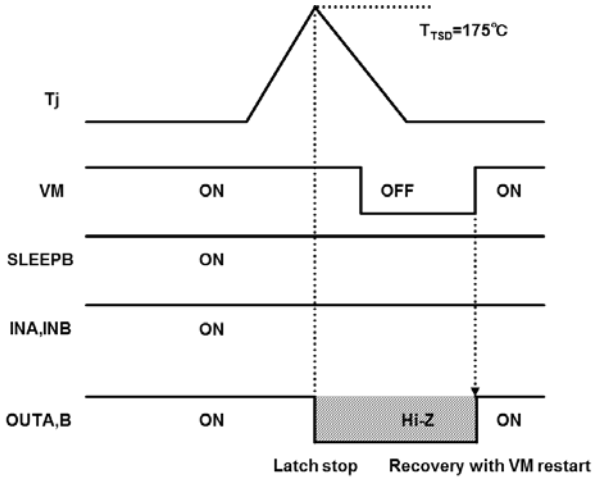


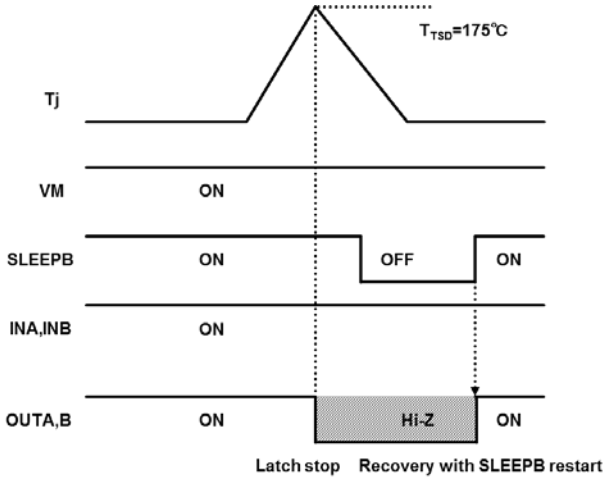
Figure 11. Timing Chart of Under Voltage Detection Circuit

■ Thermal Shutdown Circuit (TSD)

When the internal temperature (Tj) of the IC reaches 175 °C, the thermal shutdown circuit turns off the output stage (OUT pins = Hi-Z). Since this function , latches off, it is necessary to turn on the motor drive power supply voltage (VM) again or restart the SLEEPB pin (“L” → “H”) for recovery.



Recovery with VM restart



Recovery with SLEEPB restart

Figure 12. Timing Chart of Thermal Shutdown Circuit

■ Overcurrent Protection Circuit (OCP)

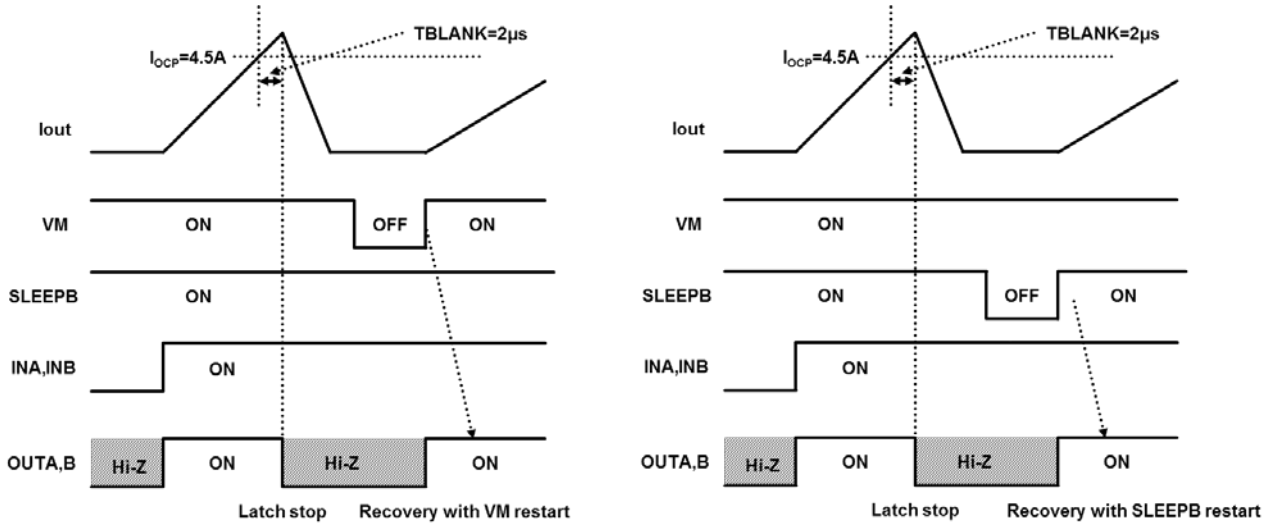
An overcurrent protection circuit is built in the output stage of the AP1040. When the current exceeding the overcurrent detection current (I_{OCP}), that is set inside the IC, continues to flow for the time set by TBLANK (2 μs/@R_{TBLANK} = 22 kΩ), the output stage is turned off (OUT pin = Hi- Z).
Since this function, latches off, it is necessary to turn on the motor drive power supply voltage (VM) again or restart the SLEEPB pin (“L” → “H”) for recovery.

The AP1040 can adjust the overcurrent detection time by a resistor connecting to the TBLANK pin. The detection time can be adjusted from 1.5 to 11 μs. This detection time is obtained by the following formula.

$$T_{BLANK} = \{(R_{TBLANK}\ [k\Omega] \times 89) + 39\} \times 10^{-9}\ \ [s]$$

R_{TBLANK} = Should be in the range from 16.5 to 123kΩ

For example, if R_{TBLANK}=22kΩ, T_{BLANK} will be 2μs.



Recovery with VM restart Recovery with SLEEPB restart

Figure 13. Overcurrent Protection Circuit Timing

Note 15. Note that there is a possibility that overcurrent protection may be repeated as latch → release → latch if latch is released while the AP1040 is still in the abnormal state after overcurrent protection operation. It may cause heat generation or deterioration of the IC.
Note 16 When using the motor drive power supply voltage (VM) at a voltage higher than 28 V, set the detection time of overcurrent protection to 1.5 μs to 6.8 μs.

■ Error Detection Signal

The AP1040 has an open drain FLAG pin to output an abnormality detection signal. When using the FLAG pin, it must be pulled up to the VDC or to the external power supply (3.0 V to 5.5 V) by 100 kΩ. The FLAG pin becomes “H” when the thermal protection or overcurrent protection circuit works. It keeps outputting “L” level (< 0.5 Vmax) in normal condition. The FLAG pin can be open when it is not used.

10. Recommended External Circuit

■ Typical Connection Diagram

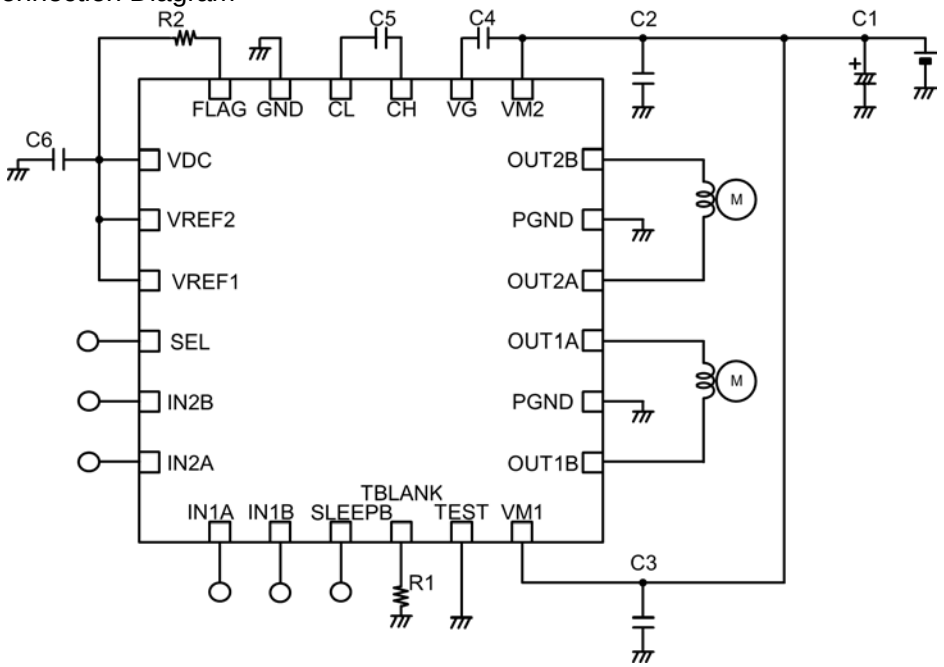


Figure 14. Typical Connection Diagram

Note 17 When using the PWM-duty control with the VREF pin, an arbitrary voltage that is resistively divided from VDC should be input to the VREF or input a voltage directly to the VREF pin rather than connecting VREF1 or VREF2 directly to the VDC pin.

■ Recommended External Parts

Table 4. Recommended External Parts

Items	Symbol	Min.	Typ.	Max.	Unit	Note
Motor Driver Power Supply Connection Capacity	C1	5.0	-	100	μF	
	C2	0.1	1.0	-	μF	
	C3	0.1	1.0	-	μF	
Charge Pump Capacity	C4	0.01	0.1	0.2	μF	
	C5	0.01	0.1	0.2	μF	
VDC Pin Connection Capacity	C6	0.1	0.22	-	μF	
Overcurrent Detection Time Adjustment Resistance	R1	16.5	22	123	kΩ	
FLAG Pin Pull Up Resistance	R2	50	100	1000	kΩ	

Note 18. Above values are recommended examples. It should be tested on your system board for the appropriate value.

Note 19. Capacitances from C1 to C3 should be adjusted according to load current profile, load capacitance and wiring resistance of your system board.

■ Recommended Layout Diagram

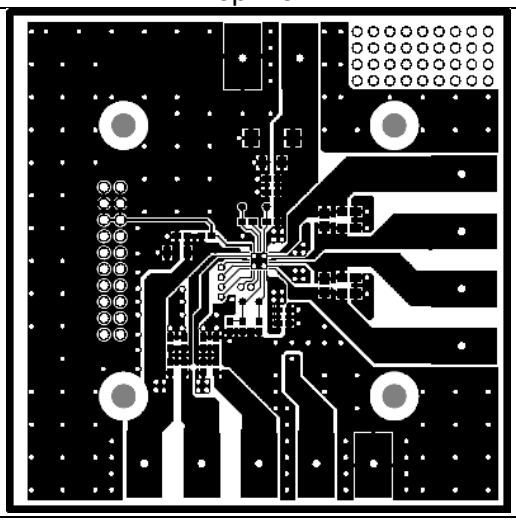
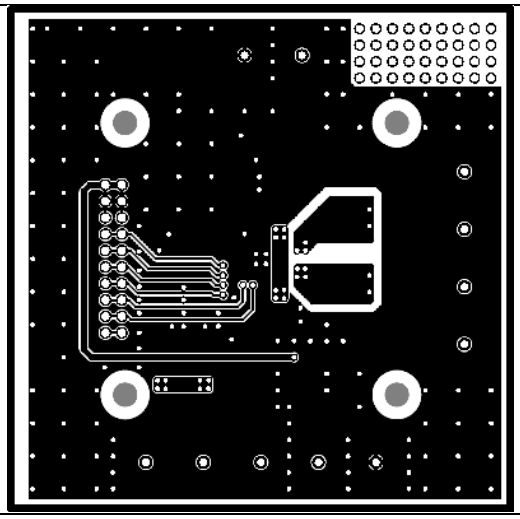
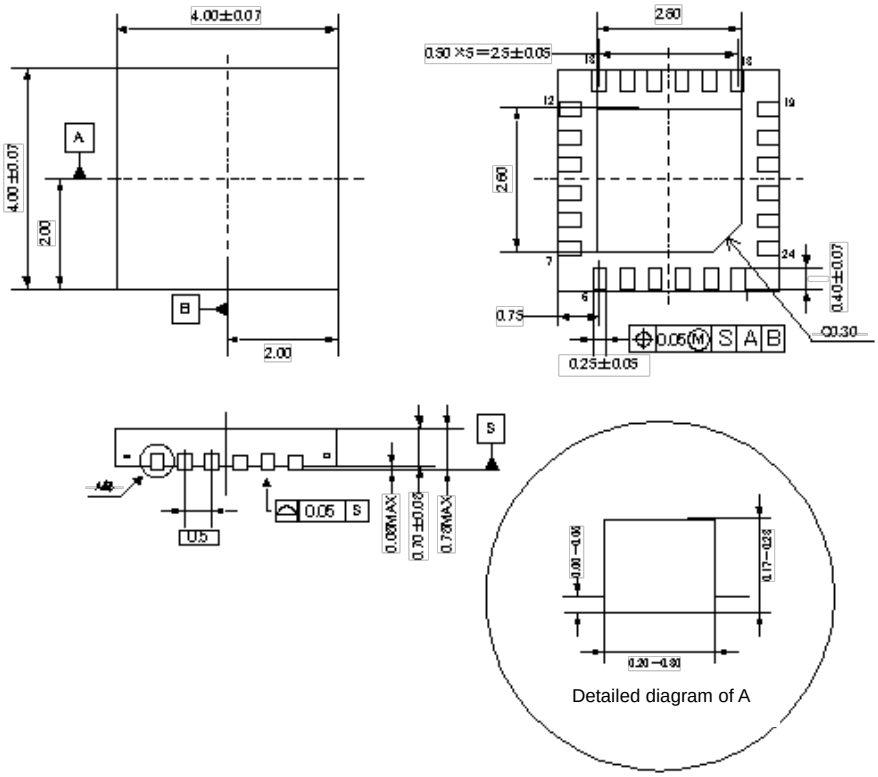
Top View	Bottom View
	

Figure 15. Layout Pattern Example

Note 20. GND area should be consolidated in wiring on the printed circuit board.
Note 21. The exposed pad (heat sink) on the bottom surface of the package must be connected to PCB ground since it shares ground with the IC.
Note 22. Vias are effective for dissipating heat to each layer of PCB board.

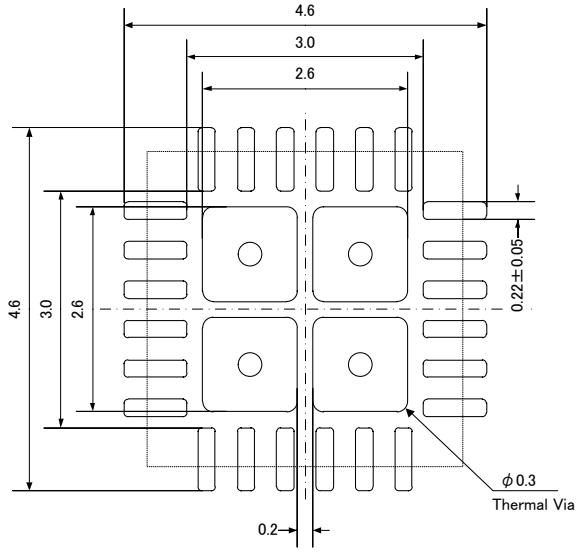
11. Package

11.1. Outline Dimensions

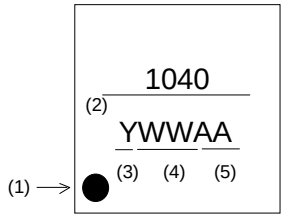


Unit: mm

11.2. Land Pattern



11.3. Marking



(1) 1pin Indication
(2) Market No.
(3) Year code (last 1 digit)
(4) Week code
(5) Management code

12. Ordering Guide

AP1040AEN Ta=-30°C ~ +85°C 24-pin QFN

13. Revision History

Date (Y/M/D)	Revision	Reason	Page	Contents
18/04/12	00	First Edition		
18/06/06	01	Second Edition	5	Motor Driver Maximum Current (Iload1) 1.1A→1.2A

IMPORTANT NOTICE

0. Asahi Kasei Microdevices Corporation (“AKM”) reserves the right to make changes to the information contained in this document without notice. When you consider any use or application of AKM product stipulated in this document (“Product”), please make inquiries the sales office of AKM or authorized distributors as to current status of the Products.
1. All information included in this document are provided only to illustrate the operation and application examples of AKM Products. AKM neither makes warranties or representations with respect to the accuracy or completeness of the information contained in this document nor grants any license to any intellectual property rights or any other rights of AKM or any third party with respect to the information in this document. You are fully responsible for use of such information contained in this document in your product design or applications. AKM ASSUMES NO LIABILITY FOR ANY LOSSES INCURRED BY YOU OR THIRD PARTIES ARISING FROM THE USE OF SUCH INFORMATION IN YOUR PRODUCT DESIGN OR APPLICATIONS.
2. The Product is neither intended nor warranted for use in equipment or systems that require extraordinarily high levels of quality and/or reliability and/or a malfunction or failure of which may cause loss of human life, bodily injury, serious property damage or serious public impact, including but not limited to, equipment used in nuclear facilities, equipment used in the aerospace industry, medical equipment, equipment used for automobiles, trains, ships and other transportation, traffic signaling equipment, equipment used to control combustions or explosions, safety devices, elevators and escalators, devices related to electric power, and equipment used in finance-related fields. Do not use Product for the above use unless specifically agreed by AKM in writing.
3. Though AKM works continually to improve the Product’s quality and reliability, you are responsible for complying with safety standards and for providing adequate designs and safeguards for your hardware, software and systems which minimize risk and avoid situations in which a malfunction or failure of the Product could cause loss of human life, bodily injury or damage to property, including data loss or corruption.
4. Do not use or otherwise make available the Product or related technology or any information contained in this document for any military purposes, including without limitation, for the design, development, use, stockpiling or manufacturing of nuclear, chemical, or biological weapons or missile technology products (mass destruction weapons). When exporting the Products or related technology or any information contained in this document, you should comply with the applicable export control laws and regulations and follow the procedures required by such laws and regulations. The Products and related technology may not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations.
5. Please contact AKM sales representative for details as to environmental matters such as the RoHS compatibility of the Product. Please use the Product in compliance with all applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive. AKM assumes no liability for damages or losses occurring as a result of noncompliance with applicable laws and regulations.
6. Resale of the Product with provisions different from the statement and/or technical features set forth in this document shall immediately void any warranty granted by AKM for the Product and shall not create or extend in any manner whatsoever, any liability of AKM.
7. This document may not be reproduced or duplicated, in any form, in whole or in part, without prior written consent of AKM.