Brushed DC Motor Driver Circuit

MX1515

Overview

This product provides an integrated brushed DC motor driver solution for battery-powered toys and low-voltage or battery-powered motion control applications. The circuit internally integrates a two-channel H-bridge driver circuit designed with N-channel and P-channel power MOSFETs, suitable for driving the steering wheels and rear-wheel drive of electric toy cars. The circuit has a wide operating voltage range (from 2V to 9.6V). The steering wheel drive has a maximum continuous output current of up to 1.5A and a maximum peak output current of 2.5A. The rear wheel drive has a maximum continuous output current of up to 1.5A and a maximum peak output current of 2.5A.

This driver circuit includes an over-temperature protection circuit. When the load current through the driver circuit is far greater than the circuit's maximum continuous current, limited by the package's heat-dissipation capability, the junction temperature of the internal chip will rise rapidly. Once it exceeds the set value (typical value 150℃), the internal circuit will immediately shut off the output power transistor, cutting off the load current, to prevent safety hazards such as the plastic package smoking or catching fire caused by continued temperature rise. The built-in temperature hysteresis circuit ensures that after the circuit returns to a safe temperature, control of the circuit is allowed again.

Features

- Low standby current (less than 0.1uA);
- Low quiescent operating current;
- Integrated H-bridge driver circuit;
- Built-in shoot-through (non-overlap) prevention circuit;
- Power MOSFETs with low on-state resistance;
- Built-in over-temperature protection circuit with hysteresis effect (TSD);
- ESD withstand level: 3KV (HBM).

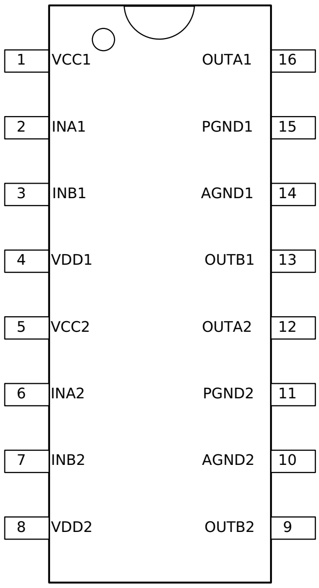
Typical Applications

- Toy motor driver powered by 2-6 AA/AAA dry cells;
- Toy motor driver powered by 2-6 Ni-MH / Ni-Cd rechargeable batteries;
- Motor driver powered by 1-2 lithium cells

Ordering Information

Product Model	Package	Operating Temperature
MX1515	DIP16	-20℃ ~ 85℃

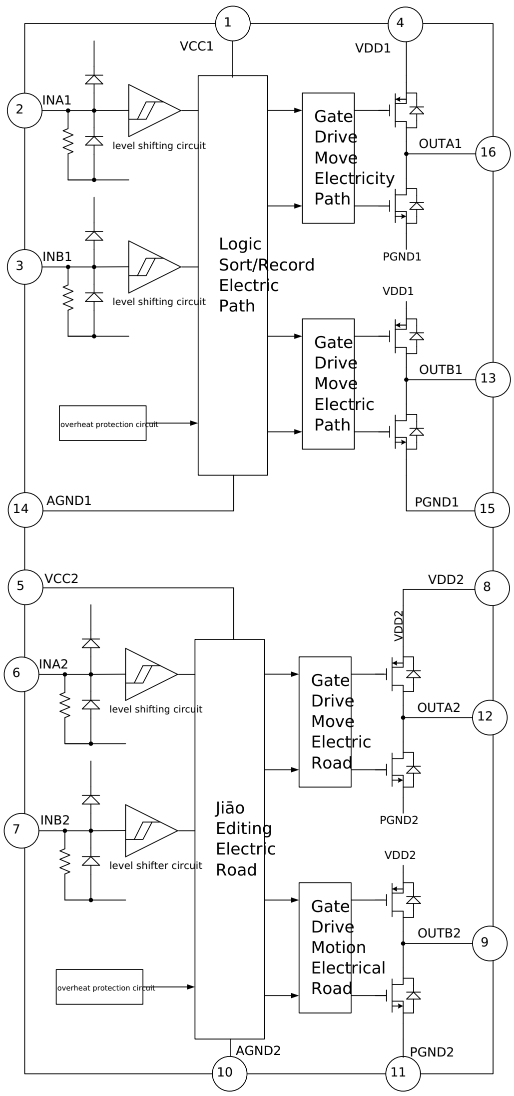
Pin arrangement



Pin definitions

Pin number	Pin name	Input/Output	Pin function description
1	VCC1	-	1 channel logic control power supply end
2	INA1	I	1 channel forward logic input
3	INB1	I	1 channel reverse logic input
4	VDD1	-	1 channel power supply end
5	VCC2	-	2 channel logic control power supply end
6	INA2	I	2 channel forward logic input
7	INB2	I	2 channel logic input
8	VDD2	-	2 channel power supply end
9	OUTB2	O	2 channel reverse output
10	AGND2	-	2 channel logic control circuit ground end
11	PGND2	-	2 channel output power transistor ground
12	OUTA2	O	2 channel forward output
13	OUTB1	O	1 channel reverse output
14	AGND1	-	1 channel logic control circuit ground terminal
15	PGND1	-	1 channel output power transistor ground terminal
16	OUTA1	O	1 channel forward output

Functional block diagram

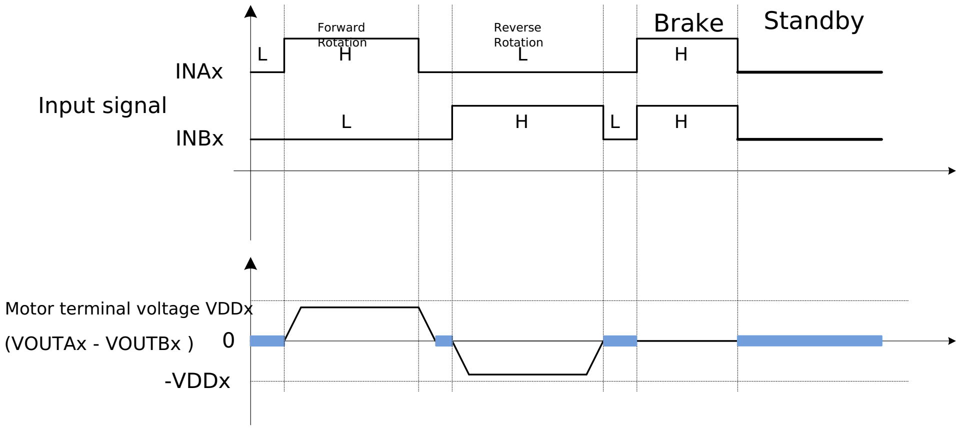


Logic Truth Table

INAx	INBx	OUTAx	OUTBx	Function
L	L	Z	Z	Standby
H	L	H	L	Forward Rotation
L	H	L	H	Reverse Rotation
H	H	L	L	Brake

Note: x represents 1 or 2.

Typical Waveform Diagram



Note: x represents 1 or 2.

Absolute Maximum Ratings (TA=25℃)

Parameter		Symbol	Value	Unit
Maximum Logic Control Supply Voltage		VCCx(MAX)	7	V
Maximum Power Supply Voltage		VDDx(MAX)	10	
Maximum Export Output Voltage		VOUT(MAX)	VDDx	
Maximum External Input Voltage		VIN(MAX)	VCCx	
Maximum Peak Output Current	1 Channel	IOUT(PEAK)	2.5	A
	2 Channel		2.5	
Maximum Power Dissipation		PD	2	W
Thermal Resistance to Environment	DIP16 Package	θJAD	70	℃/W
Operating temperature range		Topr	-20~+85	℃
juncture temperature		TJ	150	℃
Storage temperature		Tstg	-55~+150	℃
Soldering temperature		TLED	260℃, 10 s	
ESD(Note 3)			3000	V

Note: (1) X represents 1 or 2.

(2) The maximum power dissipation under different ambient temperatures is PD=(150℃-TA)/θJA, where TA is the ambient temperature of circuit operation and θJA is the thermal resistance of the package. 150℃ represents the maximum junction temperature of the circuit.

(3) Method to calculate circuit power: P = I^2 R

Where P is circuit power, I is continuous output current, R is the on-state resistance of the circuit. Circuit power P must be less than the maximum power PD.

(4) Human model, 100pF capacitor discharges through 1.5KΩ resistor.

Recommended operating conditions (TA=25℃)

Parameter		Symbol	Minimum	Typical value (VDD=6.5V)	Maximum value	Unit
Logic and control supply voltage		VCCx	1.8	--	5	V
Power supply voltage		VDDx	2	--	9.6	V
continuous output current	1 channel	IOUT1		1.5		A
	2 channels	IOUT2		1.5		

Note: (1) x represents 1 or 2.

(2) The logic supply VCC and the power supply VDD are completely independent inside and can be powered separately. When the logic supply VCC loses power, the circuit will enter standby mode.

(3) The test condition for continuous output current is when the circuit is mounted on a PCB.

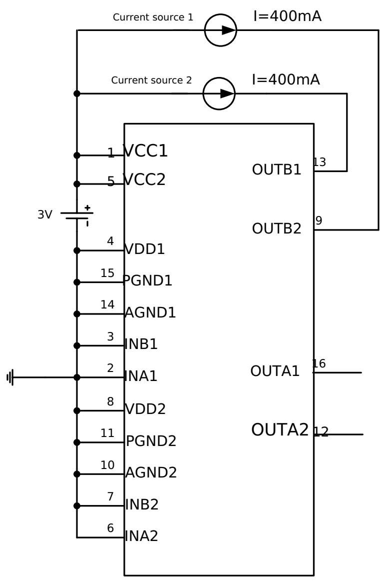
Electrical Characteristics Table

(TA=25℃, VCCx=3V, VDDx =6V Unless otherwise specified)

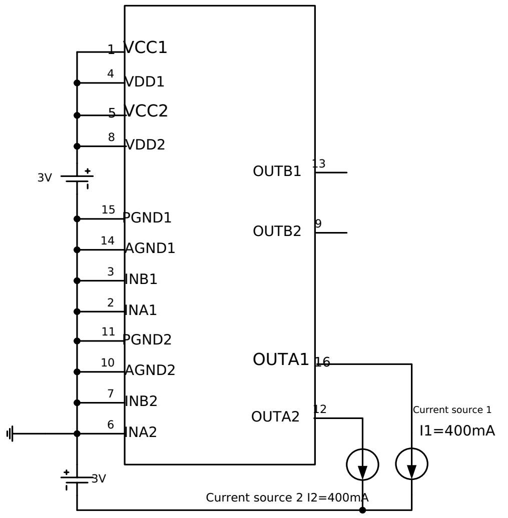
Parameters	Symbols	Conditions	Min.	Typ.	Max.	Unit
Power Parameters						
VCCx Standby Current	IVCCST	INAx=INBx= L;VCCx=7V; VDDx=10V; Output Open	--	0	10	uA
VDDx Standby Current	IVDDST		--	0	10	
VCCx Static Power Current	IVCCx	INAx=H OR INBx=H; Output Open	--	182	--	uA
VDDx Static Power Current	IVDDx	INAx=H OR INBx=H; Output Open	--	83	--	
Input Logic Level						
Input High Level	VINH		2	--	--	V
Input Low Level	VINL		--	--	0.8	
Input Voltage Hysteresis	VHYS			0.6		
Input High-Level Current	IINH	VINH=2.5V,VCCx=3V		191		uA
Input Pull-Down Resistor	RIN	VINH=3V,VCCx=3V		12		kΩ
Power MOSFET On-Resistance						
1 Channel On-Resistance	RON1	IO=±200mA VDD1=6V TA=25℃		0.47		Ω
		IO=±1.5A VDD1=6.5V TA=25℃		0.58		
2 Channel On-Resistance	RON2	IO=±200mA VDD1=6V TA=25℃		0.47		
		IO=±1.5A VDD1=6.5V TA=25℃		0.58		
Protection Function Parameters						
Thermal Shutdown Temperature Point	TSD		--	150	--	℃
Thermal Shutdown Temperature Hysteresis	TSDH		--	20	--	
Power MOSFET body diode conduction characteristics - Channel 1						
PMOS body diode	VPD	I=400mA, VCC1=3V, VDD1=INA1=INB1=0V		0.76		V
NMOS body diode	VND	I=-400mA, VCC1=VDD1=3V, INA1=INB1=0V		0.75		
Power MOSFET body diode conduction characteristics - Channel 2						
PMOS body diode	VPD	I=400mA, VCC1=3V, VDD1=INA1=INB1=0V		0.76		V
NMOS body diode	VND	I=-400mA, VCC1=VDD1=3V, INA1=INB1=0V		0.75		
Motor drive time parameter - Channel 1						
Output rise time	tr	INB1=H, INA1 input pulse signal		300		ns
Output fall time	tf	Duty cycle of 50%		10		
Output delay time	trf	Signal frequency 20KHz		40		
Output delay time	tfr	Load motor resistance 1.3Ω, motor idling		240		
Motor drive time parameter - Channel 2						
Output rise time	tr	INB1=H, INA1 input pulse signal		300		ns
Output fall time	tf	Duty cycle of 50%		10		
Output delay time	trf	Signal frequency 20KHz		40		
Output delay time	tfr	Load motor resistance 1.3Ω, motor idling		240		

Note: x represents 1 or 2.

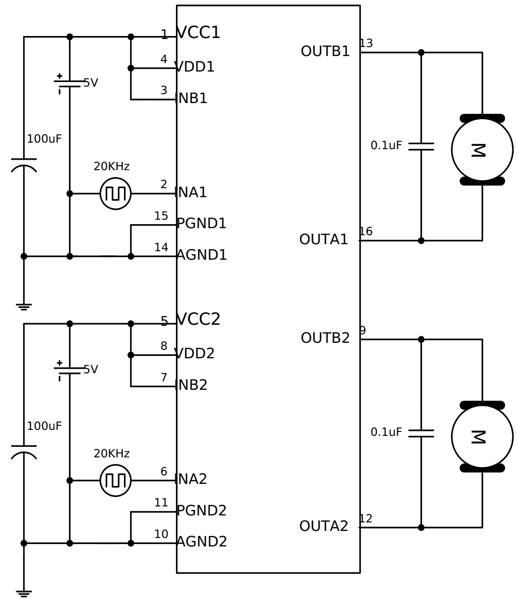
Test schematic diagram



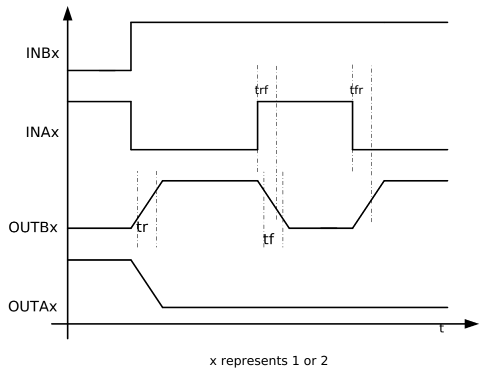
PMOS body diode conduction voltage test schematic



NMOS body diode conduction voltage test schematic



Time parameter test schematic



Time parameter definition

Typical application circuit diagram

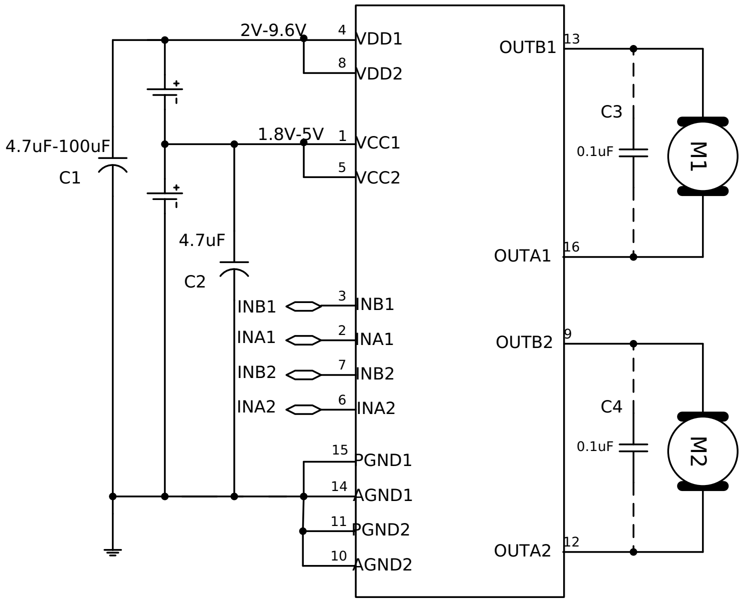


Figure 1 MX1515 Typical Application Schematic

Special Precautions:

The decoupling capacitor (C1) of the power supplies VDD1 and VDD2 to ground in Figure 1 should be adjusted according to the specific application; the higher the VDD1 and VDD2 voltages, the higher the output peak current, and the larger the C1 value. However, C1 should be at least 4.7μF. Under high voltage and high current conditions, C1 is recommended to be 100μF.

Logic supply VCC1 and VCC2 to ground capacitor C2 must be at least 4.7μF. In practical applications, you do not need to place a separate capacitor near the chip; it can be shared with other control chips (RX2, MCU), etc. If VCC1 and VCC2 to ground have no capacitor, the circuit may enter a lockout state when overloaded and overheats. After entering lockout, you must change the input signal state once to restore normal operation. As long as the ground capacitance for VCC1 and VCC2 exceeds 4.7μF, the circuit will not experience a lockout.

The 0.1μF capacitors (C3, C4) between OUTAx and OUTBx (x=1,2) in the driver circuit of Figure 1 represent capacitors connected at both ends of the motor and do not require to be added separately.

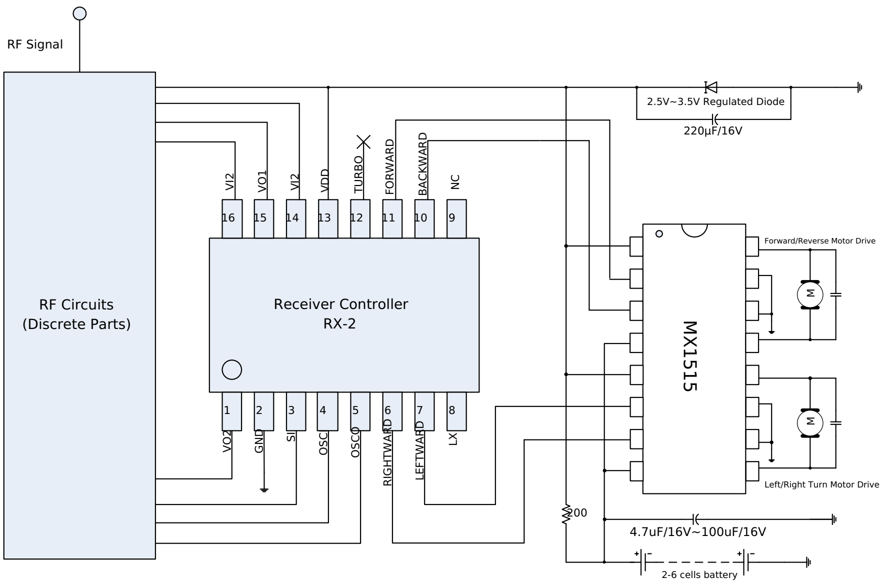


Figure 2 2-6 cell battery-powered toy remote control car motor drive schematic

As shown in Figure 2, the motor drive circuit using MX1515 has the same drive current for Channel 1 and Channel 2, and can drive the front/rear wheel motors and front steering motor according to actual needs.

The decoupling capacitors from VDD1 and VDD2 to ground in Figure 2 should be selected based on actual usage. The higher the VDD1 and VDD2 voltages and the motor current, the larger the capacitor value required. The capacitor must be greater than 4.7uF.

Application notes

1. Basic operating modes

a) Standby mode

In standby mode, INAx = INBx = L. All internal circuitry, including the driver power transistor, is in a cut-off state. The circuit consumes a very low current. At this time, the motor output terminals OUTAx and OUTBx are both in high-impedance states.

b) Forward rotation mode

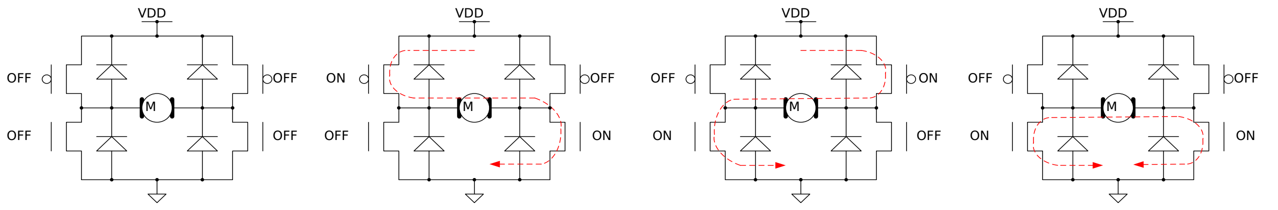
Definition of forward rotation mode: INAx = H, INBx = L. The motor drive terminal OUTAx outputs a high level, OUTBx outputs a low level. The motor drive current flows from OUTAx into the motor and from OUTBx to ground, defining forward rotation.

c) Reverse rotation mode

Definition of reverse rotation mode: INAx = L, INBx = H. The motor drive terminal OUTBx outputs a high level, OUTAx outputs a low level. The motor drive current flows from OUTBx into the motor and from OUTAx to ground, defining reverse rotation.

d) Braking mode

Braking mode is defined as: INAx = H, INBx = H. The motor drive terminals OUTAx and OUTBx both output low levels, and the energy stored in the motor is rapidly released through the NMOS on the OUTAx side or the NMOS on the OUTBx side, causing the motor to stop spinning in a short time. Note that in braking mode the circuit will consume static power.

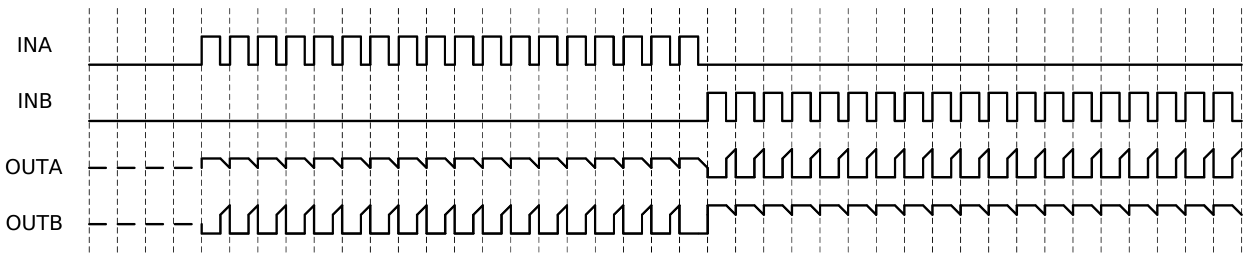


a)Standby mode b)Forward rotation mode c)Reverse mode d)Brake mode

e)PWM Mode A

When the input signal INAx is a PWM signal, INBx=0 or INAx=0, INBx is a PWM signal, the motor speed will be controlled by the duty cycle of the PWM signal. In this mode, the motor drive circuit switches between conduction and standby modes; in standby mode, all the switching devices are off, and the energy stored inside the motor can only be slowly released through the body diode of the power MOSFET.

Note: due to the high-impedance state in operation, the motor speed cannot be precisely controlled by the duty cycle of the PWM signal. If the PWM signal frequency is too high, the motor may fail to start.



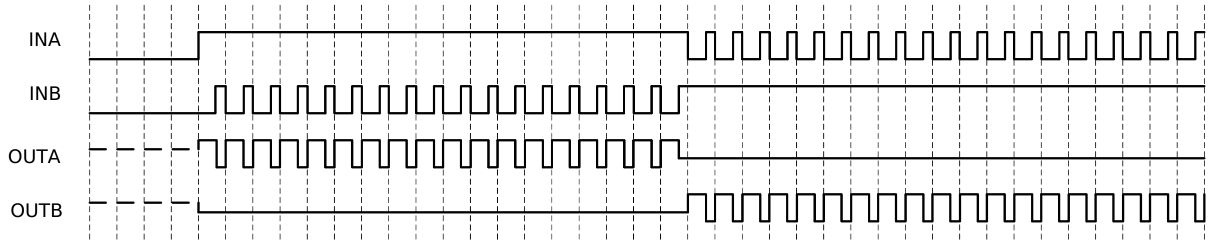
PWM Mode A signal waveform diagram

f)PWM Mode B

When the input signal INAx is a PWM signal, INBx=1 or INAx=1, INBx is a PWM signal, the motor speed will be controlled by the duty cycle of the PWM signal. In this mode, the motor drive circuit output switches between conduction and braking modes; in braking mode, the energy stored in the motor is rapidly released through the low-side NMOS transistor.

Note: because braking state exists during operation, the motor energy can be released quickly and the motor speed can be precisely controlled by the PWM signal duty cycle. However, be aware that if the PWM signal frequency is too low, the motor may fail to rotate smoothly due to entering braking mode.

To reduce motor noise, it is recommended that the PWM signal frequency be greater than 10KHz and less than 50KHz.



PWM Mode B signal waveform diagram

2. Anti-Common-Mode Conduction Circuit

In a full-bridge drive circuit, the state where the high-side PMOS power transistor and the low-side NMOS power transistor in a half-bridge are turned on simultaneously is called common-mode conduction. Common-mode conduction will cause a transient large current from power to ground, which leads to additional power loss and, in extreme cases, can burn the circuit. The built-in dead-time can prevent common-mode conduction. The typical dead-time is 300 ns.

3. Overheat protection circuit

When the junction temperature of the driving circuit exceeds the preset temperature (typical value 150°C), the TSD circuit starts to operate, and the control circuit forcibly turns off all output power devices, causing the driving circuit output to enter a high-impedance state. The TSD circuit is designed with thermal hysteresis; only when the junction temperature falls to the preset temperature (typical value 130°C) does the circuit return to normal operation.

4. Maximum continuous power dissipation of the driving circuit

This series of motor driver circuits all include overheat protection, so when the power consumption of the drive circuit is too high, the circuit will enter thermal shutdown mode, and the motor will not operate normally in the shutdown state. The formula for maximum continuous power dissipation of the driver circuit is:

$$PM = (150°C - TA) / θJA$$

Where 150°C is the preset temperature point for thermal shutdown, TA is the ambient temperature of the circuit (°C), and θJA is the junction-to-ambient thermal resistance (°C/W). Note: The maximum continuous power of the driving circuit depends on ambient temperature, package form, and heat dissipation design, and is not directly related to the on-resistance of the circuit.

5. Drive circuit power consumption

The on-resistance of the power MOSFET inside the motor drive circuit is the main factor affecting the drive circuit's power consumption. The formula for drive circuit power consumption is

$$PD = IL^2 \times RON$$

Where IL is the output current of the motor drive circuit, and RON is the on-resistance of the power MOSFET.

Note: The on-resistance of the power MOSFET increases with temperature. When calculating the maximum continuous output current and power, the temperature dependence of the on-resistance must be considered.

6. Maximum continuous output current of the driving circuit

The maximum continuous output current of the driving circuit can be calculated from its maximum continuous power dissipation and the drive circuit's power consumption. The formula is:

$$I_L = \sqrt{(150 - T_A)/(\theta_{JA} * R_{ONT})}$$

Where RONT is the on-resistance of the power MOSFET after accounting for temperature characteristics.

Note: The maximum continuous output current of the drive circuit is related to the ambient temperature, package form, heat dissipation design, and the on-resistance of the power MOSFET, etc.

factors.

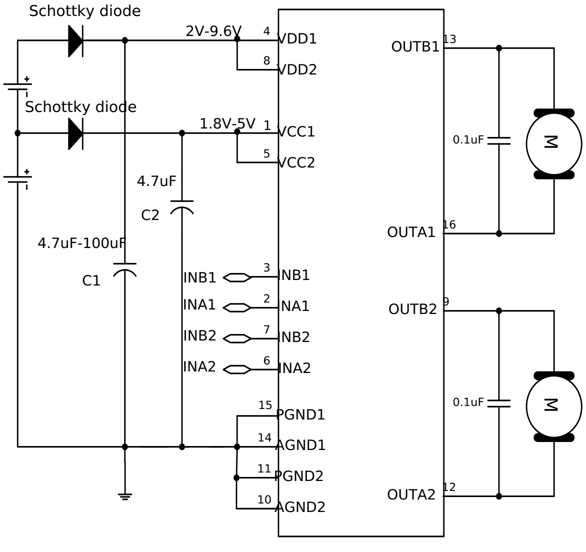
7. Motor internal resistance selection

The above analysis shows that the maximum continuous power of the motor driver circuit is limited. If the motor being driven has a very small internal resistance and the stall current exceeds what the driver circuit can sustain as a maximum continuous output current, the motor driver circuit can easily enter thermal shutdown. When a toy car runs or repeatedly moves forward/backward, it may vibrate. When selecting motor driver circuits, the motor's internal resistance must be considered. Note: x represents 1 or 2.

Special Notes

1. Power and Ground Reversed Connection

Reversing the circuit's power supply and ground connection will cause damage to the circuit. In severe cases, it may cause the plastic package to smoke. Consider connecting two power Schottky diodes in series at the circuit's power terminal to the positive terminal of the battery. This can prevent circuit damage caused by connecting the battery backwards. The maximum continuous current capability of the power Schottky diodes must be greater than the motor's locked-rotor continuous current; otherwise, the Schottky diodes may be damaged due to overheating. The power Schottky diodes' reverse breakdown voltage must be greater than the highest supply voltage. If the reverse breakdown voltage is too low, when the battery is connected in reverse, the Schottky diodes will be driven into breakdown and could burn out.



2. Power supply VDD1, VDD2 decoupling capacitor to ground (C1)

The driving circuit requires the addition of a decoupling capacitor to ground for the power supplies VDD1 and VDD2 (C1). It has two main purposes: 1) absorb energy released from the motor to the power supply, stabilize the supply voltage, and prevent over-voltage breakdown of the circuit; 2) at motor start or during fast forward/reverse switching, the motor needs a large instantaneous current to start quickly. Because the battery response speed and the connection leads are long, it often cannot output a large transient current immediately; at this time, it depends on an energy storage capacitor near the motor driver circuit to release the transient large current.

Based on the energy storage characteristics of capacitors, the larger the capacitance, the smaller the voltage fluctuation within the same time. Therefore, under high voltage and high current conditions, it is recommended that C1 be 100uF. The exact capacitance should be chosen according to the specific application, but C1 should be at least 4.7uF.

3. Electrostatic protection

The circuit's input/output ports use CMOS devices and are sensitive to ESD. Although an electrostatic discharge protection circuit is designed, anti-static measures should be taken during transport, packaging, processing, and storage, with emphasis on anti-static considerations during processing.

4. Output-to-ground short circuit, output端 short circuit

4. When in normal operation, a short circuit between the high-level output and ground or a short circuit between OUTAx and OUTBx will cause very large current internally, generating large power dissipation, triggering the internal overheat shutdown circuit to protect the circuit from immediate burn. However, since the overheat protection only detects temperature and not transient current through the circuit, output-to-ground short-circuit current is very large and can easily damage the circuit. Avoid output-to-ground shorts in use. Include current-limiting measures during testing to prevent similar damage.

5. Output-to-power supply short circuit

In normal operation, when the circuit's low-level output is shorted to the power supply, the circuit will be damaged.

6. Motor stall

In normal operation, if the load motor driven by the driver stalls and the stall current exceeds the driver's maximum continuous current, the driver will enter overheating protection mode to prevent damage. However, if the stall current greatly exceeds the maximum peak current, the circuit is more likely to be damaged.

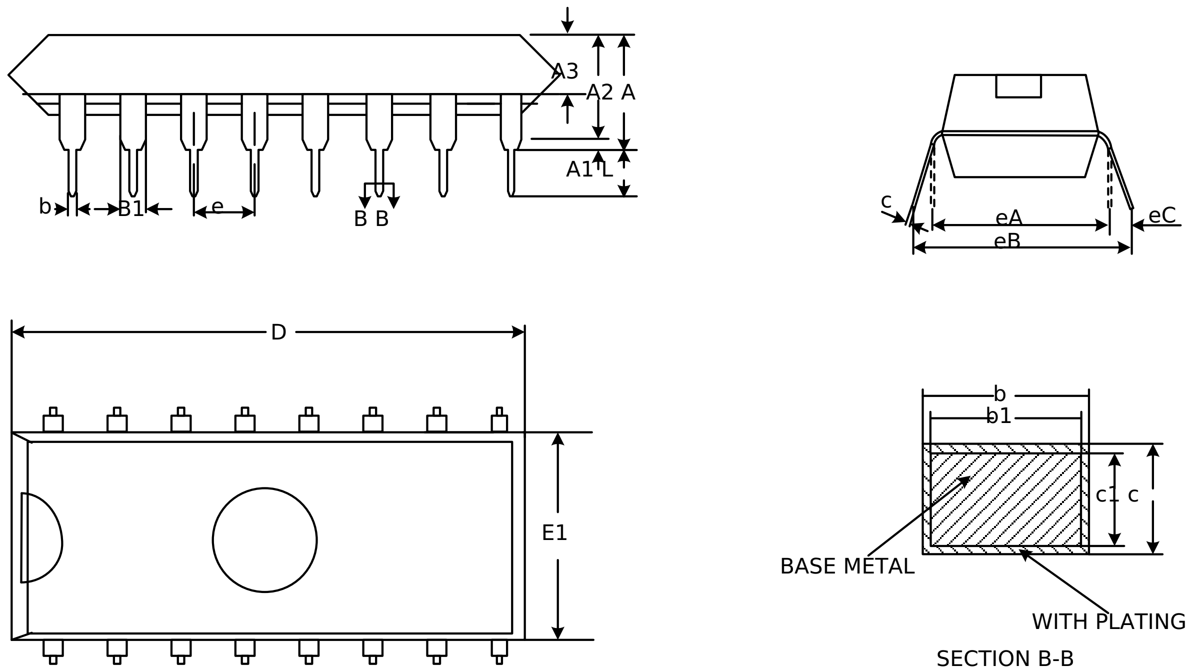
7. Peak current greatly exceeds rated value

When approaching or exceeding the maximum operating voltage and the peak current greatly exceeds the absolute maximum peak current, the chip can burn out.

Note: x represents 1 or 2.

Package Outline Dimensions Diagram

DIP16:



SECTION B-B

SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	3.60	3.80	4.00
A1	0.51	_	_
A2	3.10	3.30	3.50
A3	1.42	1.52	1.62
b	0.44	_	0.53
b1	0.43	0.46	0.48
B1	1.52BSC		
c	0.25	_	0.31
c1	0.24	0.25	0.26
D	18.90	19.10	19.30
E1	6.15	6.35	6.55
e	2.54BSC		
eA	7.62BSC		
eB	7.62	_	9.50
eC	0	_	0.94
L	3.00	_	_

Version History

V1.0 Initial Version

V1.1 Corrected some wording errors, changed the operating voltage in features from 2-10V to 2-9.6V. 10V is the limit; changing to 9.6V is more reasonable. VDD to ground decoupling capacitor changed from 10μF-100μF to 4.7μF-100μF.