ACM6753 Three-Phase 180° sinusoidal, Sensor-less or Single Hall BLDC Motor Driver

1. Features

- Input Voltage Range: 5V to 18V
- Total Driver H+L Rds(on)=200mΩ, 3.2A capability
- 180° sinusoidal drive for low audible noise
- Sensor-less Operation or Single Hall Control, No External Sense Resistor Required
- Built-in 5V and 3.3V LDO
- FG Speed Output
- Brake Control
  - BRAKE pin Control
  - I²C Interface: Brake Command
- Flexible Speed Configuration Interface
  - Dedicated SPEED Pin: Accepts Either Analog or PWM Input
  - I²C Interface: Speed Command
- Protection
  - Over Current Protection
  - Lock Detection
  - UVLO/OVLO Protection
  - Over Temperature Protection
  - Voltage Surge Protection
- Supply current with Standby current 55uA, wake up by I²C command or SPEED Pin
- Supply current with Sleep current 20uA, wake up by SPEED Pin

2. Applications

- Fan driver
- Pump driver

3. General Description

The ACM6753 device is a three-phase sensor-less motor driver with integrated power MOSFETs, which can provide drive current up to 3.2A peak. The device is specially designed for cost-sensitive , low noise, low-external-component-count applications.

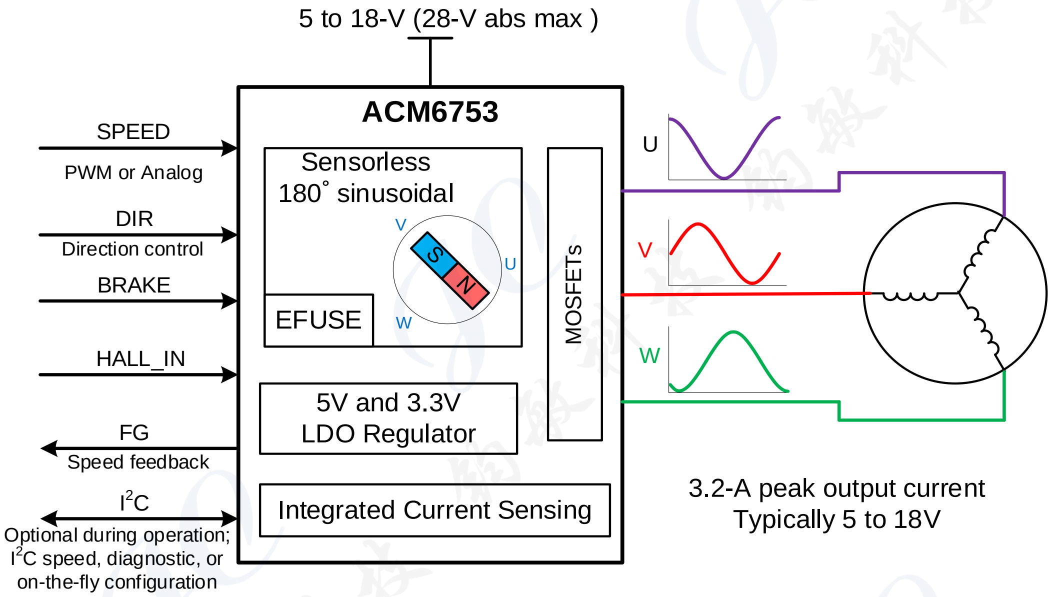
The ACM6753 device uses a sensor-less control scheme or single Hall Control to provide continuous sinusoidal drive, which significantly reduces the pure tone acoustics that typically occur as a result of commutation.

The algorithm configuration can be programmed via EFUSE, which allows the device to operate stand-alone once it has been configured. The device receives a speed command through a PWM input, analog voltage or I²C command.

There are a large number of protection features integrated in to ACM6753, intended to protect the device, motor and system against fault events.

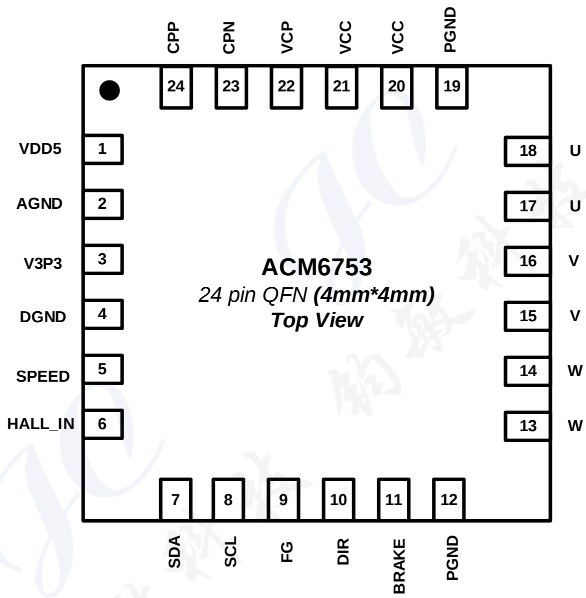
4. Device Information

Part number	Package	Body size
ACM6753	QFN (24)	4 mm × 4 mm



Simplified Schematic

5. Pin Configuration and Function Descriptions



Pin No.	Name	Type	Description
1	VDD5	Power	Internal 5V Regulator Output. Convert from supply voltage VCC. This is a 5V constant voltage output for internal analog circuit
2	AGND	Ground	Analog ground
3	V3P3	Power	Internal 3.3V Regulator Output. Convert from internal 5V voltage. This is a 3.3V constant voltage output for internal digital circuit
4	DGND	Ground	Digital ground
5	SPEED	Input	Speed control signal for PWM or analog input speed command, works under 3.3V domain.
6	HALL_IN	Input	Hall Sensor input,works under 3.3V domain.
7	SDA	Input/Output	I²C data signal,works under 3.3V domain.
8	SCL	Input	I²C clock signal,works under 3.3V domain.
9	FG	Output	Motor speed indicator output. Open-drain output requires and external pull-up resistor to 3.3V

10	DIR	Input	Direction of motor spinning. When low, phase driving sequence is OUT A -> OUT C->OUT B When high, phase driving sequence is OUT A->OUT B->OUT C Set to High by an external pull-up resistor to 3.3V or by external micro-controller's GPIO (such kinds GPIO has internal pull-up resistor). Set to Low by connect to GND directly or by external micro-controller's GPIO.
11	BRAKE	Input	High->Brake the motor Low->Normal Set to High by an external pull-up resistor to 3.3V or by external micro-controller's GPIO (such kinds GPIO has internal pull-up resistor). Set to Low by connect to GND directly or by external micro-controller's GPIO.
12, 19	PGND	Ground	Power stage ground
13, 14	W	Output	Motor W phase
15, 16	V	Output	Motor V phase
17, 18	U	Output	Motor U phase
20, 21	VCC	Power	Device power supply
22	VCP	Power	Charge pump output. Connect a X5R or X7R, 1μF, 16-V ceramic capacitor between the VCP and VCC pins
23	CPN	Power	Charge pump switching node. Connect a X5R or X7R, 0.1μF, ceramic capacitor between the CPP and CPN pins. Recommends a capacitor voltage rating at least twice the normal operating voltage of the device.
24	CPP	Power	
Thermal Pad	-	GND	Must be connected to ground

6. *Device Family Comparison*

Device Name	VDD	Control Type	Sensor	Output Current
ACM6573	5V ~ 18V	180° sinusoidal	Sensor-less or Single Hall Control	3.2A

7. *Specifications*

7.1 Absolute Maximum Ratings

Operating with ambient temperature range (unless otherwise noted)(1)

		MIN	MAX	UNIT
Input voltage(2)	VCC	-0.3	20	V
	SPEED	-0.3	VDD5+0.3	
	PGND, AGND, DGND	-0.3	0.3	
	SCL, SDA	-0.3	4	
	BRAKE	-0.3	4	
	HALL_IN	-0.3	4	
	DIR	-0.3	4	
Output voltage	U, V, W	-1	20	V
	VDD5	-0.3	7	
	V3P3	-0.3	4	
	FG	-0.3	4	
	VCP	-0.3	$V_{(VCC)}$+5	
	CPP	-0.3	$V_{(VCC)}$+5	
	CPN	-0.3	25	
Maximum junction temperature range, T_{J_MAX}		-40	150	℃
T_{stg}	Storage temperature	-55	150	℃

(1) Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under Recommended Operating Conditions. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

(2) All voltage values are with respect to the network ground terminal (GND) unless otherwise noted.

7.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins(1)	+/- 2500	V
		Charged-device model (CDM),per JEDEC specification JESD22-C101, all pins(2)	+/- 1500	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

7.3 Recommended Operating Conditions

Over operating free-air temperature range (unless otherwise noted)

		MIN	NOM	MAX	UNIT
Supply Voltage	VCC	5	12	18	V
Voltage	U, V, W	-0.7		18	V
	SCL, SDA, FG, DIR, BRAKE, HALL_IN	-0.1	3.3	3.6	V
	SPEED,	-0.3	3.3 or 5	VDD5+0.3	
	PGND, AGND, DGND	-0.1		0.1	V
T_A	Ambient Operating Temperature	-40		125	℃

7.4 Thermal Information

THERMAL METRIC		QFN 24 PINS	UNIT
$R_{\Theta JA}$	Junction-to-ambient thermal resistance, 2-side PCB, 1-in.^{2} copper	45	℃/W
$R_{\Theta JC(top)}$	Junction-to-top case thermal resistance, measure at the center on the top of the package	20	℃/W

7.5 Electrical Characteristics

Over operating free-air temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
SUPPLY CURRENT						
I_{VCC}	Hi-Z Mode	T_A=25°C; SPEED = 0 V; $V_{(VCC)}$=12V;		8.5		mA
	Standby Mode (No program to EFUSE)	T_A=25°C; SPEED = 0 V; $V_{(VCC)}$=12V;		55	65	µA
	Sleep Mode (EFUSE been programmed)	T_A=25°C; SPEED = 0 V; $V_{(VCC)}$=12V;		20	30	µA
OVLO						
OVLO_R	V_{CC} Under Voltage Protection Threshold	Rise Threshold, T_A = 25°C		22		V
OVLO_F		Fall Threshold, T_A = 25°C		21.5		V
UVLO						
UVLO_R	V_{CC} Under Voltage Protection Threshold	Rise Threshold, T_A = 25°C		4.8		V
UVLO_F		Fall Threshold, T_A = 25°C		4.5		V
LDO OUTPUT						
VDD5	T_A = -40°C~125°C		4.8	5	5.2	V
V3P3	T_A = -40°C~125°C		3	3.3	3.6	V
INTEGRATED MOSFET						
$R_{DS(ON)}$	Series resistance (High side + Low side)	T_A=25°C; $V_{(VCC)}$=12V; $V_{(VCP)}$=17V		0.2		Ω
		T_A=85°C; $V_{(VCC)}$=12V; $V_{(VCP)}$=17V		0.26		Ω
SPEED – ANALOG MODE						
V_{ANA_FS}	Analog full-speed voltage			$V_{(V3P3)}$× 0.9		V
V_{ANA_ZS}	Analog zero-speed voltage			100		mV
T_{SAM}	Analog speed sample period			320		µS
V_{ANA_RES}	Analog voltage resolution			5.8		mV
SPEED – PWM DIGITAL MODE						
V_{DIG_IH}	PWM input high voltage		2			V
V_{DIG_IL}	PWM input low voltage				0.6	V
f_{PWM}	PWM input frequency		0.1		100	kHz
STANDBY MODE (No program to EFUSE)						
V_{EN_SB}	Analog voltage-to-enter standby mode	SPEED_CTRL_MODE=0 (analog mode)	30			mV
V_{EX_SB}	Analog voltage-to-exit standby mode	SPEED_CTRL_MODE=0 (analog mode)		120		mV
$t_{EX\_SB\_ANA}$	Time-to-exit from standby mode	SPEED_CTRL_MODE=0 (analog mode), SPEED > V_{EX_SB}		1		ms
$t_{EN\_SB\_ANA}$	Time-to-enter standby mode	SPEED_CTRL_MODE=0 (analog mode), SPEED < V_{EN_SB}		5		ms
$t_{EX\_SB\_PWM}$	Time-to-exit from standby mode	SPEED_CTRL_MODE=1 (PWM mode), SPEED > V_{DIG_IH}		1		ms
$t_{EN\_SB\_PWM}$	Time-to-enter standby mode	SPEED_CTRL_MODE=1 (PWM mode), SPEED < V_{DIG_IL}		5		ms
SLEEP MODE (EFUSE been programmed)						
V_{EN_SL}	Analog voltage-to-enter sleep	SPEED_CTRL_MODE=0 (analog	30			mV

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
	mode	mode)				
V_{EX_SL}	Analog voltage-to-exit sleep mode		2.2	3.3		V
$t_{EX\_SL\_ANA}$	Time-to-exit from sleep mode	SPEED_CTRL_MODE=0 (analog mode), SPEED > V_{EX_SB}		5		ms
$t_{EN\_SL\_ANA}$	Time-to-enter sleep mode	SPEED_CTRL_MODE=0 (analog mode), SPEED < V_{EN_SB}		5		ms
$t_{EX\_SL\_PWM}$	Time-to-exit from sleep mode	SPEED_CTRL_MODE=1 (PWM mode), SPEED > V_{DIG_IH}		5		ms
$t_{EN\_SL\_PWM}$	Time-to-enter sleep mode	SPEED_CTRL_MODE=1 (PWM mode), SPEED < V_{DIG_IL}		5		ms
DIGITAL I/O (DIR, BRAKE, FG)						
V_{DIR_H}	Input high		2.2			V
V_{DIR_L}	Input low				0.6	V
V_{BRAKE_H}	Input high		2.2			V
V_{BRAKE_L}	Input low				0.6	V
I_{FG_SINK}	Output sink current	V_{OUT} = 0.3V	5			mA
I²C SERIAL INTERFACE						
V_{I2C_H}	Input high		2.2			V
V_{I2C_L}	Input low				0.6	V
LOCK DETECTION RELEASE TIME						
T_{LOCK_OFF}	Lock release time			5		s
T_{LOCK_ENTER}	Lock enter time			0.3		s
OVERCURRENT PROTECTION						
I_{OC_LIMIT}	Over-current protection threshold	T_A = 25°C; PHASE	3.5	4	4.5	A
LOCK DETECTION CURRENT THRESHOLD						
I_{LOCK_LIMIT}	Lock detection current limit threshold	LOCK_CURRENT_THR = 000		0.4		A
		LOCK_CURRENT_THR = 001		0.8		
		LOCK_CURRENT_THR = 010		1.2		
		LOCK_CURRENT_THR = 011		1.6		
		LOCK_CURRENT_THR = 100		2		
		LOCK_CURRENT_THR = 101		2.4		
		LOCK_CURRENT_THR = 110		2.8		
		LOCK_CURRENT_THR = 111		3.2		
THERMAL SHUTDOWN						
T_{SDN}	Shutdown temperature threshold	Shutdown temperature		150		°C
T_{SDN_HYS}		Hysteresis		10		°C

8. Typical Characteristics

9. Detailed Description

9.1 Overview

The ACM6753 is a three-phase sensor-less motor driver with integrated power MOSFETs, which provide drive current capability up to 3.2A peak current (2.5A continuous). The device is specifically designed for low noise, low external component count, ≤ 18V Motor drive applications. The device is configurable through a simple I²C interface to accommodate different motor parameters and spin-up profiles for different customer applications.

A 180° sensor-less control scheme provides continuous sinusoidal output voltages to the motor phases to enable ultra-quiet motor operation by keeping the electrically induced torque ripple small.

The ACM6753 features extensive protection and fault detect mechanisms to ensure reliable operation. Voltage surge protection prevents the input VCC capacitor from overcharging, which is typical during motor deceleration. The device provides phase to phase over-current protection without the need for an external current sense resistor. Rotor lock detect is available through several methods. These methods can be configured with register settings to ensure reliable operation. The device provides additional protection for under-voltage lockout (UVLO), over-voltage lockout (OVLO) and thermal shutdown.

The commutation control algorithm continuously measures the motor phase current and periodically measures the VCC supply voltage. The device uses this information for BEMF estimation, and the information is also provided through the I^2C register interface for debug and diagnostic use in the system, if desired.

ACM6753 interface is flexible. In addition to the I^2C interface, the system can use the discrete FG pin, DIR pin, BRAKE pin and SPEED pin. SPEED is the speed command input pin. It controls the output voltage amplitude. DIR is the direction control input pin. BRAKE is the brake control input pin. FG is the speed indicator output, which shows the frequency of the motor commutation.

EFUSE is integrated in ACM6753 as memory for the motor parameter and operation settings. EFUSE data transfers to the register after power on and exit from sleep mode.

The ACM6753 device can also operate in register mode. If the system includes a micro-controller communicating through the I^2C interface, the device can dynamically update the motor parameter and operation settings by writing to the registers. In this configuration, the EFUSE data is bypassed by the register settings.

9.2 Function Block Diagram

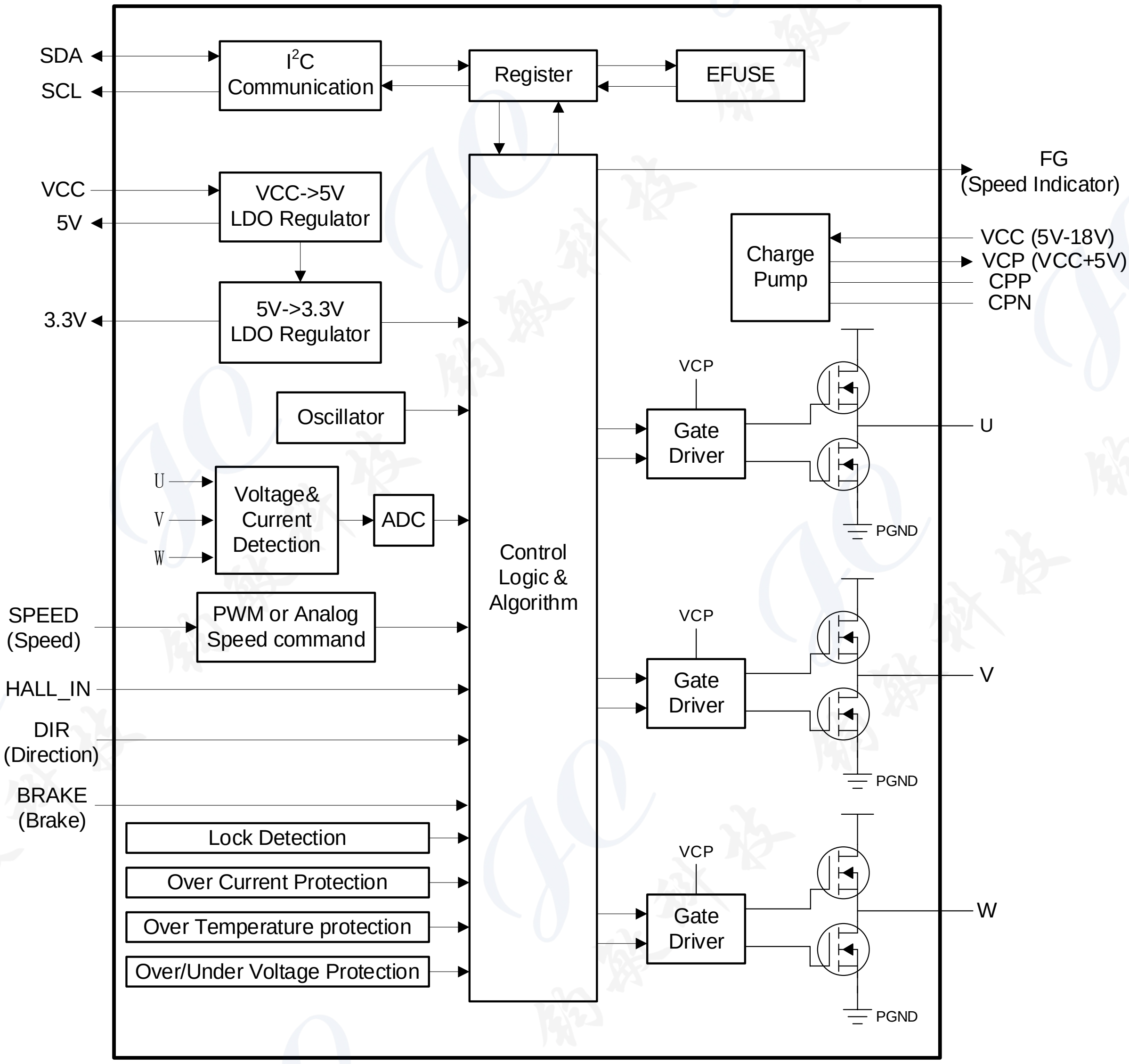


Figure 1 Function Block Diagram

9.3 Feature Description

9.3.1 Regulators

The ACM6753 includes a 5V LDO and a 3.3V LDO. The 5V LDO is powered by VCC and the 3.3V LDO is powered by 5V LDO. Both 5V LDO and 3.3V LDO are for internal circuits only. But can also been used for pull-up voltage for the FG, DIR, SDA, SCL, HALL_IN and BRAKE interface.

Both VDD5 and V3P3 capacitor must be connected to GND.

9.3.2 Protection Circuits

9.3.2.1 Thermal Shutdown

The ACM6753 has a built-in thermal shutdown function, which shuts down the device when junction temperature is more than 150°C and recovers operating conditions when junction temperature falls to 140°C.
The Over temperature status bit (address 0x03 bit 1) is set during thermal shutdown.

9.3.2.2 Under-voltage Protection

The ACM6753 has built-in UVLO function block. The hysteresis of UVLO threshold is 0.3V. The device is locked out when VCC is down to 4.5V and woke up at 4.8V. The UVLO fault bit (Register address 0x03 bit 3) is set during under-voltage shutdown.

9.3.2.3 Over-voltage Protection

The ACM6753 has built-in OVLO function block. The hysteresis of OVLO threshold is 0.5V. The device is locked out when VCC is up to 22V and woke up at 21.5V. The OVLO fault bit (Register address 0x03 bit 2) is set during over-voltage shutdown.

9.3.2.4 Over-current Protection

The over-current protection function acts to protect the device if the current, as measured from the MOSFETs, exceeds the $I_{OC\text{-}limit}$ threshold. It protects the device from phase-to-phase short-circuit conditions; ACM6753 places the output drivers into a high-impedance state and maintains this condition until the over-current is no longer present. The over-current status bit (Register address 0x03 bit 0) is set.
The ACM6753 also provides lock detection current limit functions to protect the device and motor (Register address 0x30, bit 5:3).

9.3.2.5 Lock Detection

When the motor is blocked or stopped by an external force, the lock protection is triggered, and the device stops driving the motor immediately. After the lock release time (~5s), the ACM6753 resumes driving the motor again. If the lock condition is still present, it enters the next lock protection cycle until the lock condition is removed. With this lock protection, the motor and device does not get overheated or damaged due to the motor being locked.
During lock condition, the LOCK_FAULT status bit (Register address 0x04, bit 5) is set.

9.3.3 Motor Speed Control

The ACM6753 offers five methods for indirectly controlling the seed of the motor by adjusting the output voltage amplitude. This can be accomplished by varying the supply voltage (VCC) or by controlling the Speed Command. The Speed Command can be controlled in one of four ways. The user can set the Speed Command on the SPEED pin by adjusting either the duty cycle of PWM input (SPEED pin configured for PWM mode) or clock of PWM input (CLOCK_MODE been enabled in Speed loop) or the analog input (SPEED pin configured for analog mode), or by writing the Speed Command directly through the I²C serial port to Register 0x01 (MSB) and Register 0x02 (LSB). The Speed Command is used to determine the PWM duty cycle output.

The Speed Command may not always be equal to the PWM duty cycle because ACM6753 has implemented the VAS function, the acceleration current limit function and the closed loop acceleration function to optimize the control performance. These functions can limit the PWM duty cycle, which affects the output amplitude.

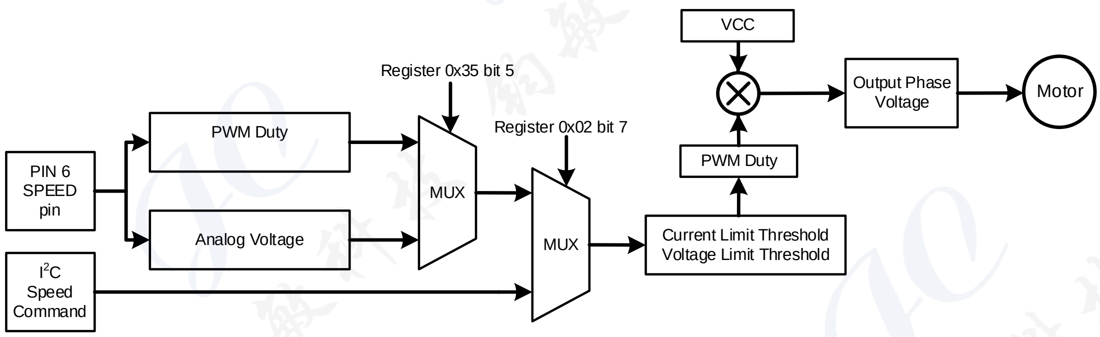


Figure 2 Speed Control

When any phase is measured with respect to ground, the waveform is sinusoidally coupled with third-order harmonics. This encoding technique permits one phase to be held at ground while the other two phases are pulse-width modulated.

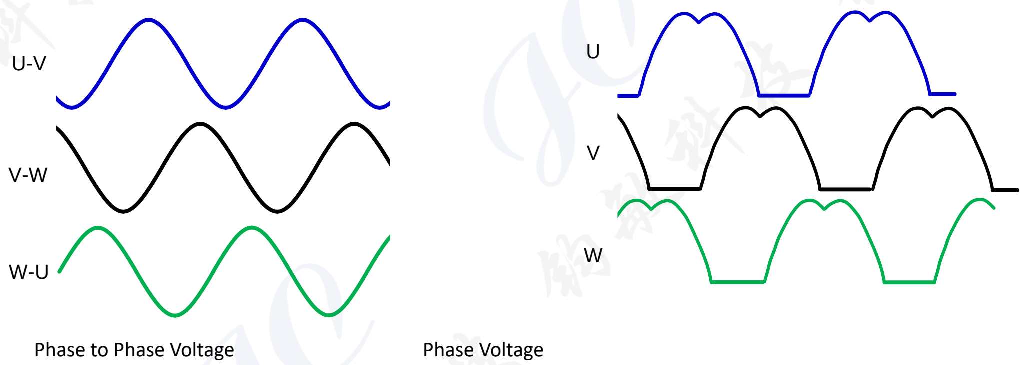


Figure 3 Phase to Phase Voltage

The output amplitude is determined by the magnitude of VCC and the PWM duty cycle output in one electrical cycle. The maximum amplitude is reached when PWM duty cycle is at 100%。 The peak output amplitude is VCC. When the PWM duty cycle is 50%, the peak amplitude is VCC/2.

9.3.4 Sleep or Standby Condition

The ACM6753 is available in either a sleep mode or standby mode version. The ACM6753 enters either sleep or standby to conserve energy. When the device enters either sleep or standby, the motor stops driving.

With register address 0x2c bit 2 set to 0 (default value), the device will **enter into Standby mode once the SPEED pin set to Zero Speed** or I²C Speed Command (Located in Register 0x00 and Register 0x02 bit 0) been set to 0. In I²C control mode, suggest to use standby mode as in standby mode, I²C communication still works.

With register address 0x2c bit 2 set to 1 , the device will **enter into Sleep mode once the SPEED pin set to Zero Speed.** The I²C speed command can not take the device out of the sleep condition because I²C communication is disabled during the sleep condition.

9.3.5 EFUSE program

The ACM6753 has an EFUSE memory, which are used to program the motor parameters as described in the register maps.

The procedure for programming the EFUSE is as follows. Recommends to perform the EFUSE programming without the motor spinning, power cycle after the EFUSE write, and read back the EFUSE to verify the programming is successful.

The programmed EFUSE data transfers to the register after power on and exit from sleep mode.

1. Set Register 0x19 bit2 MTP_LAHD_EN = 1
2. Write the desired motor parameters into the corresponding registers (address 0x20:0x36)
3. Write 11001010 (0xCA) to Register 0x18 , MTP_KEY register
4. Keep Register 0x19 bit2 MTP_LAHD_EN = 1, Set Register 0x19 bit 0 MTP_WRITE = 1 to start the EFUSE programming.

The programming time is about ~20 ms, and MTP_WRITE bit is reset to 0 when programming is done.

9.4 Device Function Modes

This section includes the logic required to be able to reliably start and drive the motor. It describes the processes used in the logic core and provides the information needed to effectively configure the parameters to work over a wide range of applications.

9.4.1 Motor Parameters

The motor phase resistance and the BEMF constant (Kt) are two important parameters used to characterize a BLDC motor. The ACM6753 requires these parameters to be configured in the register. The motor phase resistance is programmed by writing the values for RM [7:0] and RM [11:8] in Register 0x20 and 0x21 register. The BEMF constant is programmed by writing the values for Ke [11:8] and Ke [7:0] in Register 0x21 and 0x22.

9.4.1.1 Motor Phase Resistance

For a wye-connected motor, the motor phase resistance refers to the resistance from the phase output to the center tap, R_{PH_CT} must be converted to a 12 bits register value.

The LSB is 10mΩ.

Table 1 Motor Phase Resistance Setting

Register 0x21, RM [11:8]	Register 0x20, RM [7:0]	R_{PH_CT} (Ω)
0000	00000001	0.01
0000	00000010	0.02
0000	00000011	0.03
..	……..	..
0000	01100100	1.000
..	……..	..
1111	11111111	40.95

9.4.1.2 BEMF Constant

The BEMF constant, the motor phase-to-phase BEMF voltage as a function of the motor velocity.

The measured BEMF constant (Ke) needs to be converted to a 12-bit digital register value Ke [11:0] to program the

BEMF constant value.

Table 2 BEMF Constant Setting

Register 0x21, KE [11:8]	Register 0x22, KE [7:0]	K_E (mV/Hz)
0000	00000001	1
0000	00000010	2
….	……..	….
0000	10000000	128
….	……..	….
1111	11111111	4095

9.4.12 Application Schematic for software (I^2C) control mode

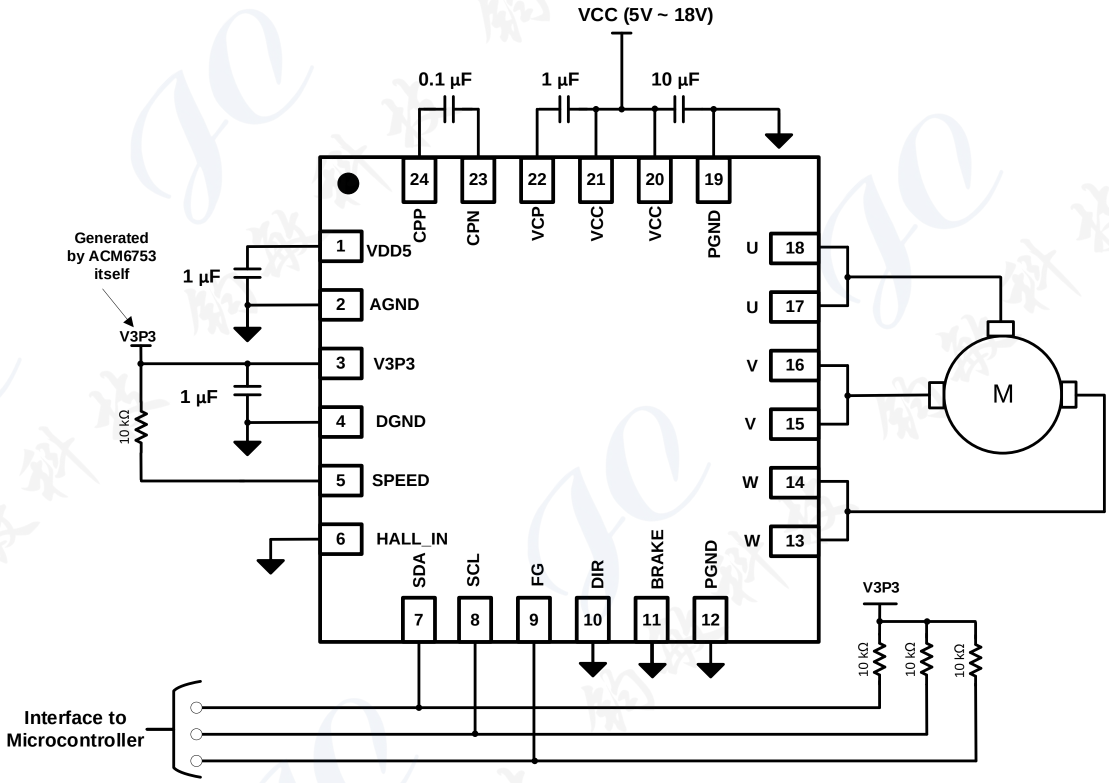


Figure 14 Application Schematic (Sensor-less)

Notes: Speed controlled by I^2C command, Direction/Brake also controlled by I^2C command.

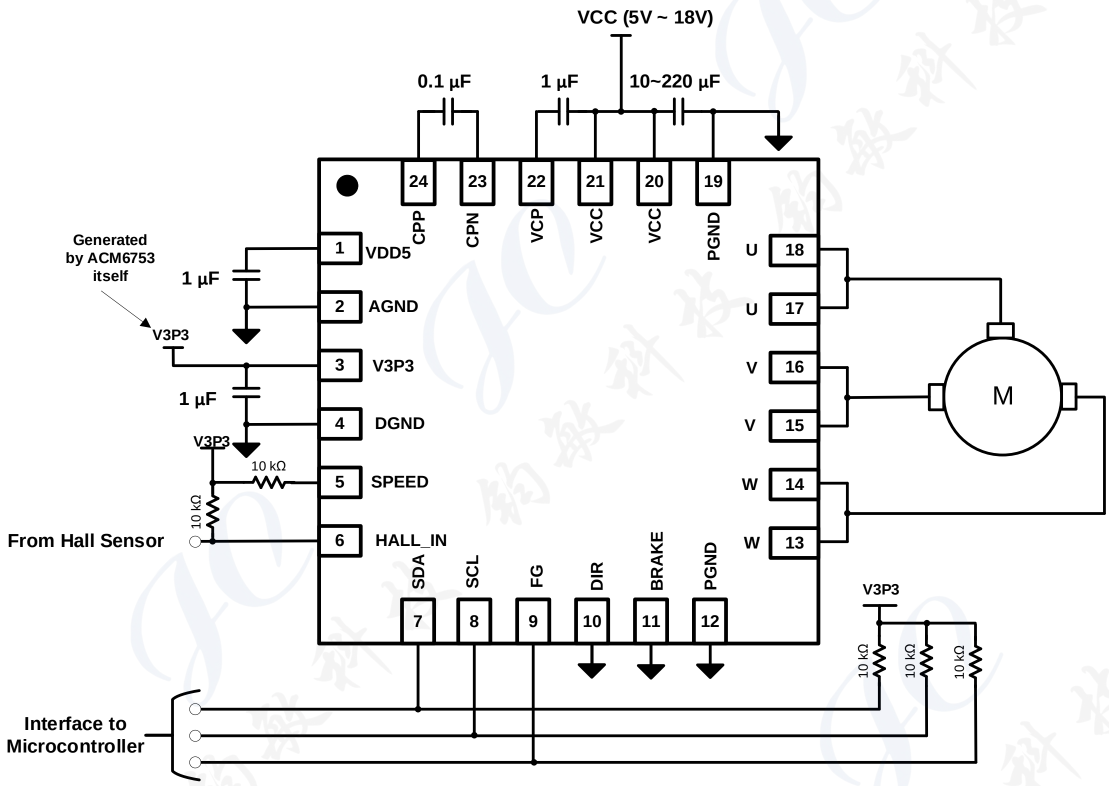


Figure 15 Application Schematic (Single Hall Control)

Notes: Speed controlled by I²C command, Direction/Brake also controlled by I²C command.

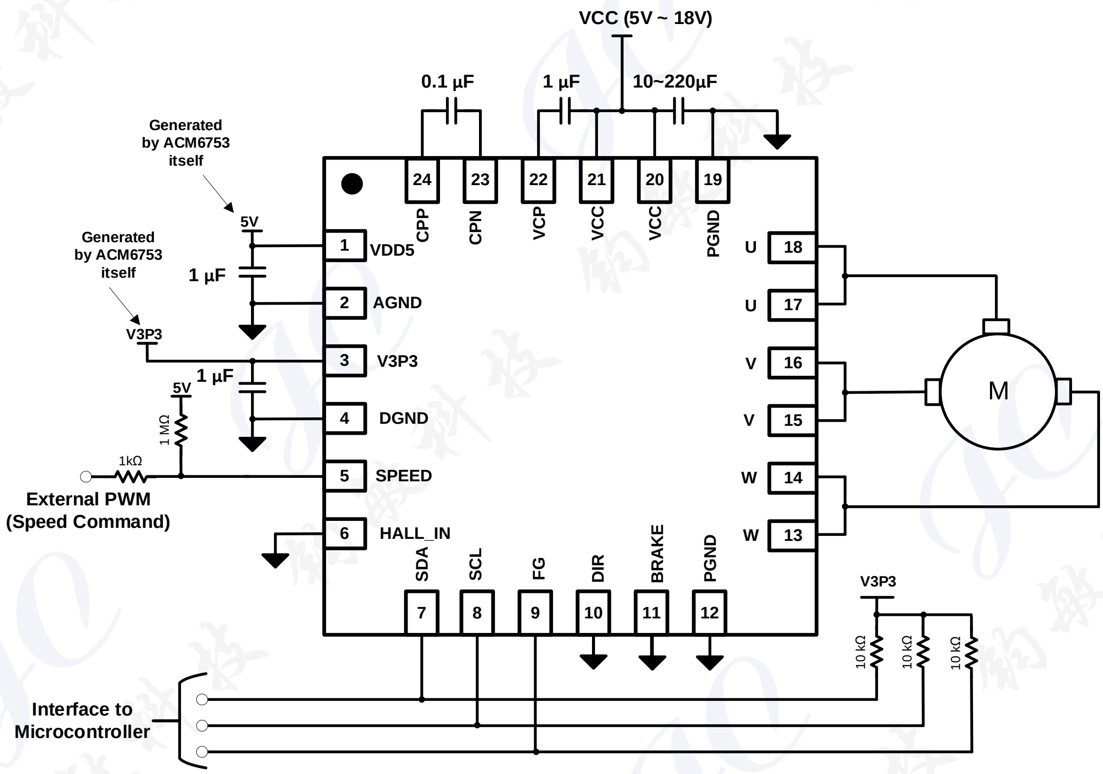


Figure 16 Application Schematic (Sensor-less Control)

Notes: Speed controlled by external PWM, Direction/Brake also controlled by I²C command.

9.4.13 Application Schematic for hardware control mode

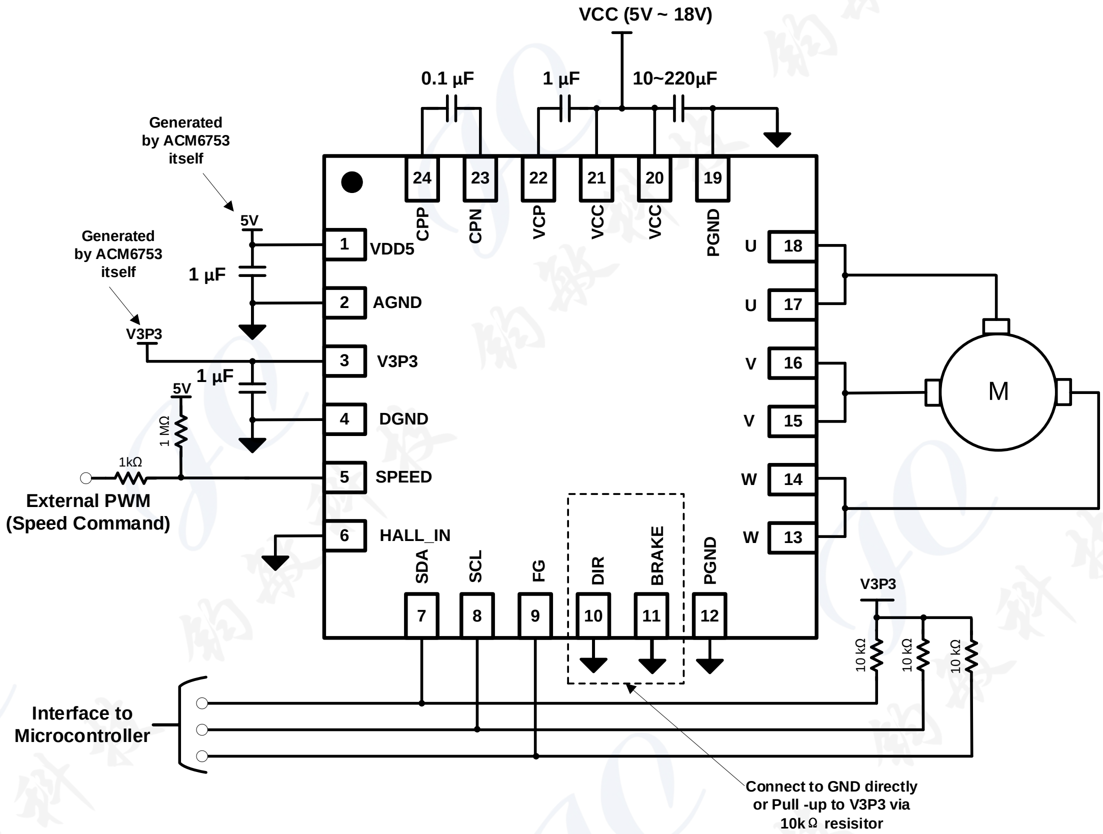


Figure 17 Application Schematic (Sensor-less)

Note: I²C just been used for programming the device at the first time

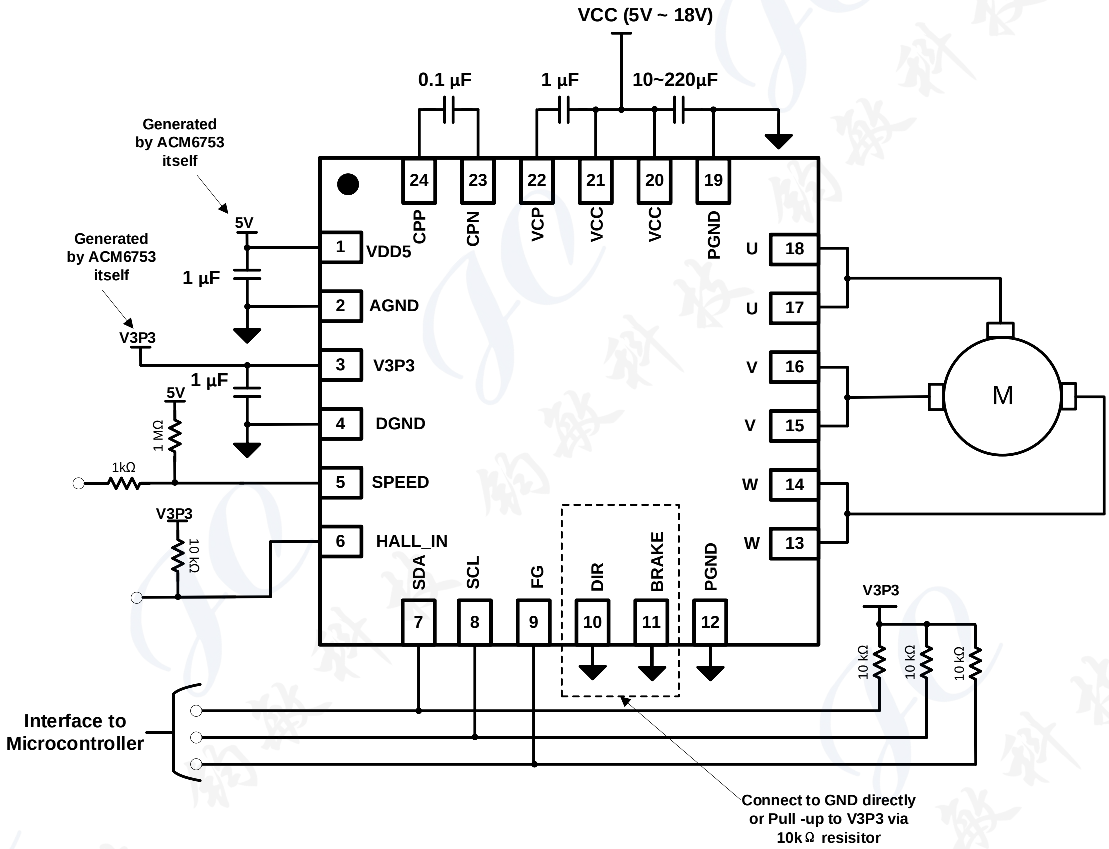


Figure 18 Application Schematic (Single-Hall Control)

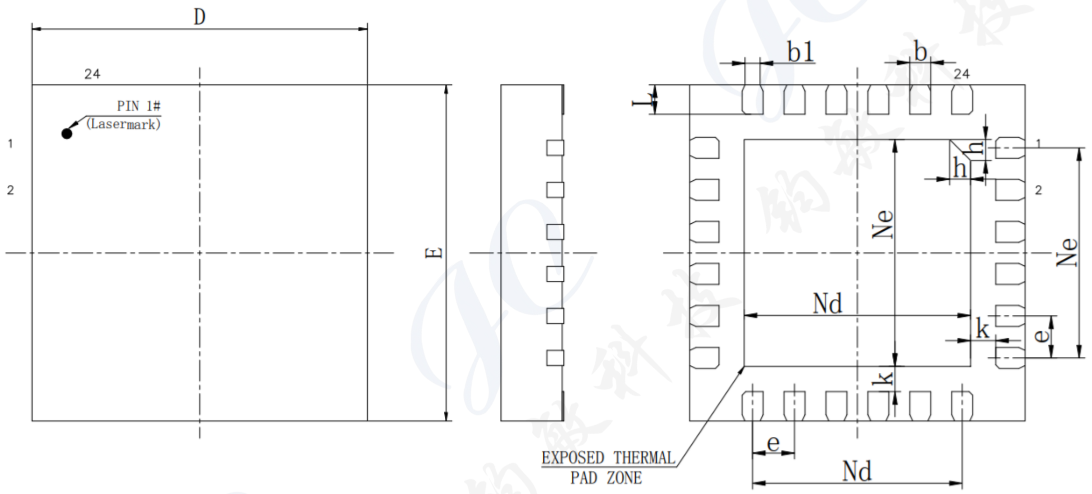
Note: I²C just been used for programming the device at the first time

10. Register Map

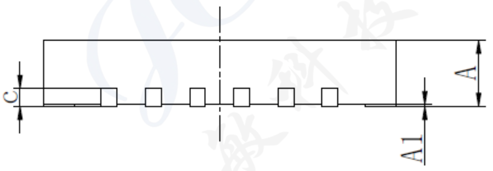
For more register control information, contact ACME application engineer for ACME motor control software.

11. Package Dimensions

Orderable Device	Package Type	MPQ	MOQ	Eco Plan	MSL Level	Device Marking
ACM6753	QFN (24 pin) Tape and Reel	5000	5000	RoHS Compliant Lead-Free Finish	MSL3	ACM6753



TOP VIEW BOTTOM VIEW



SIDE VIEW

SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	0.70	0.75	0.80
A1	0	0.02	0.05
b	0.20	0.25	0.30
b1	0.18REF		
c	0.203REF		
D	3.90	4.00	4.10
D2	2.60	2.70	2.80
e	0.50BSC		
Ne	2.50BSC		
Nd	2.50BSC		
E	3.90	4.00	4.10
E2	2.60	2.70	2.80
L	0.30	0.35	0.40
h	0.20	0.25	0.30
k	0.30REF		