# MP6634

## 35V, 2A Peak, 3-Phase, Sensorless BLDC Motor Driver

## DESCRIPTION

The MP6634 is a 3-phase, sensorless brushless DC (BLDC) motor driver with integrated power MOSFETs. It features sensorless field-oriented control (FOC) for improved efficiency and low vibration, with up to 2A of peak current. The input voltage ($V_{IN}$) ranges between 4.5V and 35V.

The MP6634 controls the motor speed through the pulse-width modulation (PWM) signal with a PWM input frequency between 50Hz and 20kHz. The device also supports DC input speed control.

The MP6634 provides rotational speed detection. The rotational speed detector (the FG/RD pin) is an open-drain output. In addition, the direction can be controlled via the DIR pin's input.

Rich protections include input over-voltage protection (OVP), under-voltage lockout (UVLO), locked-rotor protection, phase-loss protection (PLOS), over-current protection (OCP), and thermal shutdown (TSD).

The MP6634 is available in a TQFN-12 (3mmx4mm) package with wettable flanks.

## FEATURES

- 4.5V to 35V Operating Input Voltage ($V_{IN}$) Range
- Up to Maximum 2A of Peak Current
- Sensorless Field-Oriented Control (FOC)
- Integrated MOSFETs: High-Side MOSFET (HS-FET) + Low-Side MOSFET (LS-FET) = 450mΩ
- Supports 0V to 3.3V DC Input or 50Hz to 20kHz Pulse-Width Modulation (PWM) Input
- Starting Duty Cycle Set with Hysteresis
- Curve Configurations
- Configurable Speed for Open-Loop and Closed-Loop Control
- Configurable Soft-Start Time ($t_{SS}$)
- Configurable Alignment Time
- Direction Control
- Power-Saving Mode
- 24kHz PWM Output Frequency
- Short-Circuit Protection (SCP)
- Over-Voltage Protection (OVP)
- Phase-Loss Protection (PLOS)
- Locked-Rotor Protection
- Selectable FG and RD Outputs
- Available in a TQFN-12 (3mmx4mm) Package with Wettable Flanks

## APPLICATIONS

- Automotive Fans
- Pumps
- Air Purifiers
- General Fans
- Small-Sized Motors

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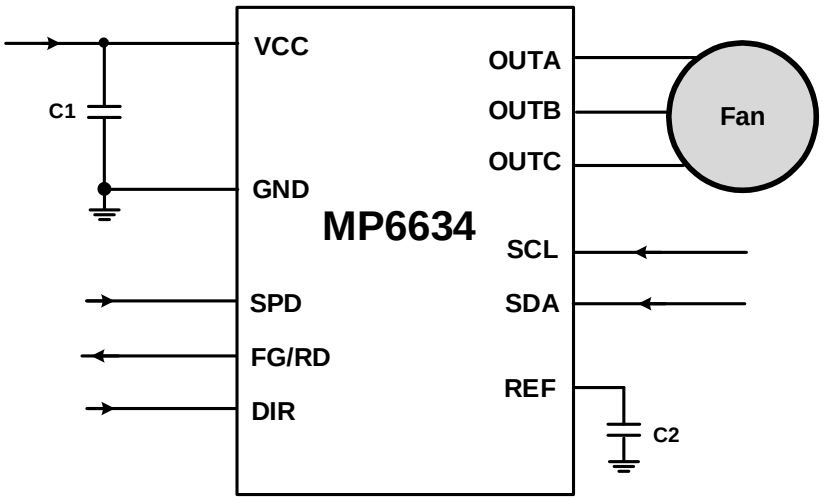
## TYPICAL APPLICATION





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## ORDERING INFORMATION

| Part Number* | Package | Top Marking | MSL Rating |
|---|---|---|---|
| MP6634GLTE-xxxx** | TQFN-12 (3mmx4mm) with Wettable Flanks | *See Below* | 1 |

For Tape & Reel, add suffix -Z (e.g. MP6634GLTE-xxxx-Z).

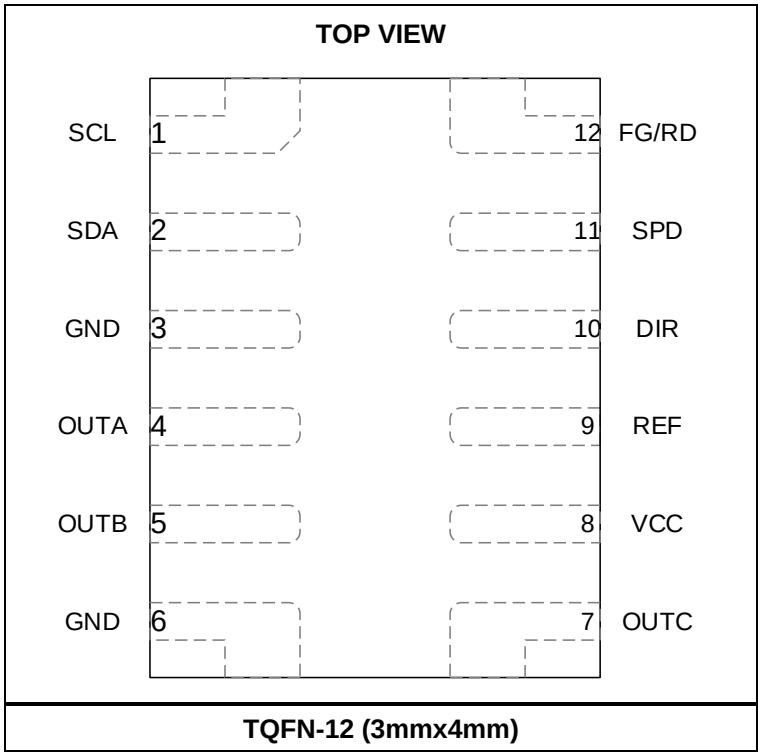
** “xxxx” is the configuration code identifier. The four digits of the suffix (xxxx) can be a hexadecimal value between 0 and F. Work with an MPS FAE to create this unique number to customize configuration. The default code is “0000”.

## TOP MARKING

MPYW
6634
LLL
E

MP: MPS prefix
Y: Year code
W: Week code
6634: Part number
LLL: Lot number
E: Wettable flank

## PACKAGE REFERENCE




TQFN-12 (3mmx4mm)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## PIN FUNCTIONS

| Pin # | Name | Description |
|---|---|---|
| 1 | SCL | **I²C interface (serial clock line).** |
| 2 | SDA | **I²C interface (serial data line).** |
| 3, 6 | GND | **Ground.** |
| 4 | OUTA | **Phase A terminal.** |
| 5 | OUTB | **Phase B terminal.** |
| 7 | OUTC | **Phase C terminal.** |
| 8 | VCC | **Power supply.** The VCC pin must be bypassed locally. |
| 9 | REF | **5V LDO output.** The REF pin must be bypassed locally. |
| 10 | DIR | **Direction control.** Pull the DIR pin high for reverse rotation; pull it low for forward rotation. This pin is pulled low internally. |
| 11 | SPD | **Speed control input.** The SPD pin supports a 50Hz to 20kHz PWM input frequency or a 0V to 3.3V DC input. This pin is internally pulled high with a 360kΩ resistor. |
| 12 | FG/RD | **Speed indicator (FG) and locked-rotor indicator (RD) output.** The FG/RD pin is an open-drain output that must be pulled up externally. |

## ABSOLUTE MAXIMUM RATINGS (1)

VCC, FG/RD .....-0.3V to +38V
OUTA, OUTB, OUTC.....-0.3V to $V_{CC}$ + 0.3V
All other pins .....-0.3V to +6V
Lead temperature .....260°C
Continuous power dissipation ($T_A$ = 25°C) (2)
..... 2.5W

### *ESD Ratings*

Human body model (HBM) ..... ±2000V
Charged-device model (CDM).....±1500V

### *Recommended Operating Conditions* (3)

Supply voltage ($V_{IN}$) .....4.5V to 35V
Operating junction temp ($T_J$).... -40°C to +125°C

### *Thermal Resistance* (4) $\theta_{JA}$ $\theta_{JC}$

TQFN-12-WF (3mmx4mm).....48…....11....°C/W

**Notes:**

1) Absolute maximum ratings are rated under room temperature, unless otherwise noted. Exceeding these ratings may damage the device.
2) The maximum allowable power dissipation is a function of the maximum junction temperature, $T_J$ (MAX), the junction-to-ambient thermal resistance, $\theta_{JA}$, and the ambient temperature, $T_A$. The maximum allowable continuous power dissipation at any ambient temperature is calculated by $P_D$ (MAX) = ($T_J$ (MAX) - $T_A$) / $\theta_{JA}$. Exceeding the maximum allowable power dissipation can produce an excessive die temperature, and the regulator may go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
3) The device is not guaranteed to function outside of its operating conditions.
4) Measured on a JESD51-7, 4-layer PCB.


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## ELECTRICAL CHARACTERISTICS

**$V_{CC}$ = 12V, $T_J$ = -40°C to +125°C, unless otherwise noted.**

| Parameter | Symbol | Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| VCC voltage ($V_{CC}$) under-voltage lockout (UVLO) rising threshold | $V_{UVLO_R}$ | | | 4.2 | 4.45 | V |
| $V_{CC}$ UVLO hysteresis | $V_{UVLO_HYS}$ | | 0.2 | 0.3 | | V |
| Operating supply current | $I_{CC}$ | SPD = high, no load | | 8.3 | 10 | mA |
| Standby current | $I_{STD}$ | SPD = low | | | 40 | μA |
| SPD input high threshold | $V_{PWM_H}$ | PWM input mode | 2 | | | V |
| SPD input low threshold | $V_{PWM_L}$ | PWM input mode | | | 0.8 | V |
| SPD internal pull-up resistance | $R_{SPD}$ | | | 360 | | kΩ |
| SPD DC input high threshold | $V_{DCH}$ | DC input mode | | 3.3 | | V |
| SPD DC input low threshold | $V_{DCL}$ | DC input mode | | 0 | | mV |
| DIR input high threshold | $V_{DIR_H}$ | | 2 | | | V |
| DIR input low threshold | $V_{DIR_L}$ | | | | 0.8 | V |
| DIR internal pull-low resistance | $R_{DIR}$ | | | 50 | 100 | kΩ |
| FG/RD output low level | $V_{FG_L}$ | $I_{FG/RD}$ = 3mA | | 0.3 | 0.5 | V |
| Switching frequency | $f_{SW}$ | $T_J$ = 25°C | 23.64 | 24 | 24.36 | kHz |
| | | $T_J$ = -40°C to +125°C | 23 | 24 | 24.84 | kHz |
| High-side MOSFET (HS-FET) on resistance | $R_{DS(ON)_HS}$ | $I_{OUT}$ = 100mA | | 300 | | mΩ |
| Low-side MOSFET (LS-FET) on resistance | $R_{DS(ON)_LS}$ | $I_{OUT}$ = 100mA | | 150 | | mΩ |
| Peak current limit | $I_{LIM}$ | | 2.4 | 3 | 3.6 | A |
| 5V LDO output voltage | $V_{5V}$ | | 4.75 | 5 | 5.25 | V |
| 5V LDO load capability | $I_{5V}$ | $I_{REF}$ = 30mA | 4.7 | | | V |
| Locked-rotor retry time | $t_{RE}$ | | | 5.5 | | s |
| Over-voltage protection (OVP) threshold | $V_{OVP_H}$ | OVP_EN = 1, UIN_SEL = 1 | | 33 | 35 | V |
| | $V_{OVP_L}$ | OVP_EN = 1, UIN_SEL = 0 | | 19 | 21 | V |
| OVP hysteresis | $V_{OVP_HYS}$ | | | 2 | 3 | V |
| Thermal shutdown threshold | $T_{ST}$ | | | 175 | | °C |
| Thermal shutdown hysteresis | $T_{ST_HYS}$ | | | 20 | | °C |
| **$I^2C$ Interface** | | | | | | |
| Input logic low | $V_{IL}$ | | | | 0.8 | V |
| Input logic high | $V_{IH}$ | | 2 | | | V |
| Output logic low | $V_{OL}$ | $I_{LOAD}$ = 3mA | | | 0.4 | V |
| SCL clock frequency | $f_{SCL}$ | | | | 400 | kHz |


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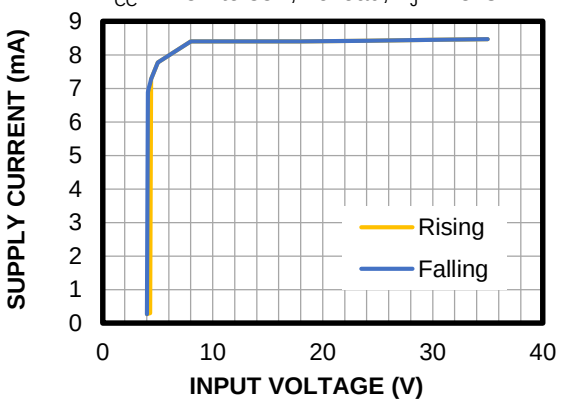
## TYPICAL CHARACTERISTICS

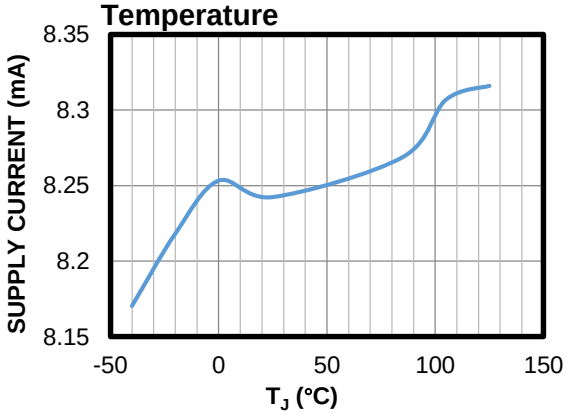
**$V_{CC}$ = 12V, $T_J$ = -40°C to +125°C, unless otherwise noted.**

**Supply Current Vs. Input Voltage**

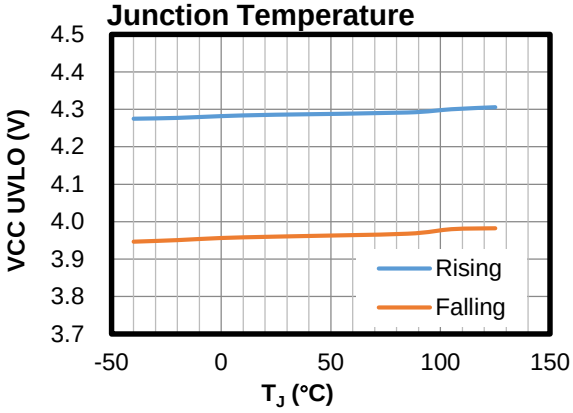
$V_{CC}$ = 4.5V to 35V, no load, $T_J$ = 25°C



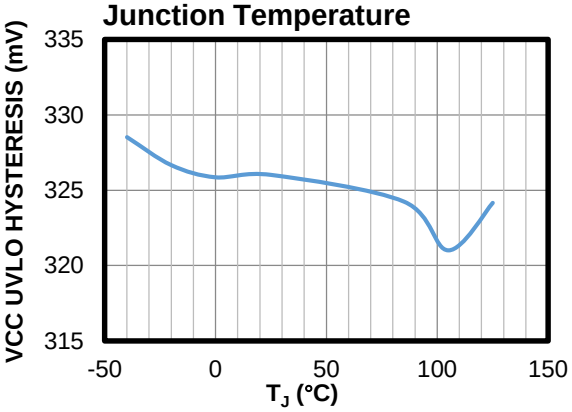

**Supply Current vs. Junction Temperature**



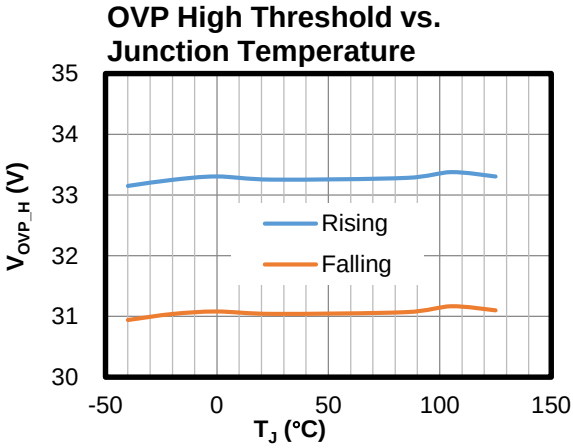

**VCC UVLO Threshold vs. Junction Temperature**



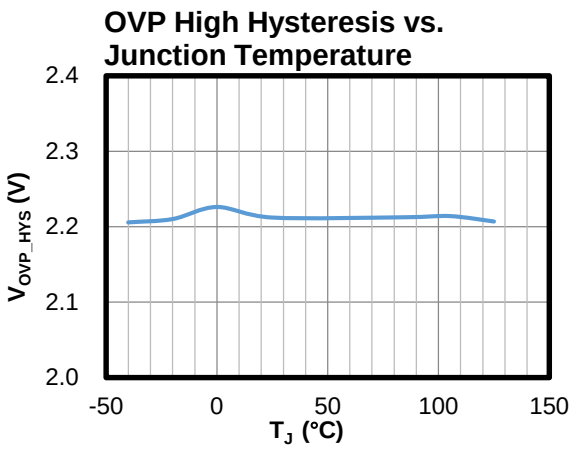

**VCC UVLO Hysteresis vs. Junction Temperature**




**OVP High Threshold vs. Junction Temperature**




**OVP High Hysteresis vs. Junction Temperature**





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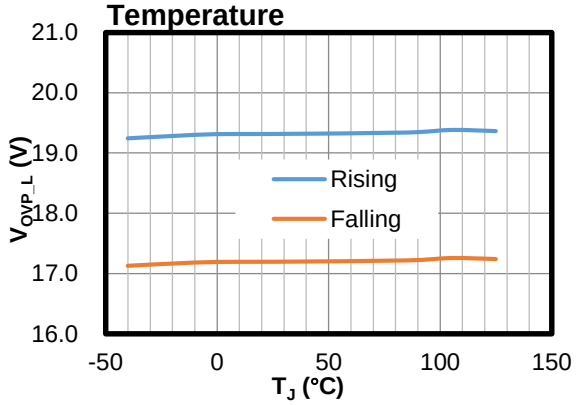
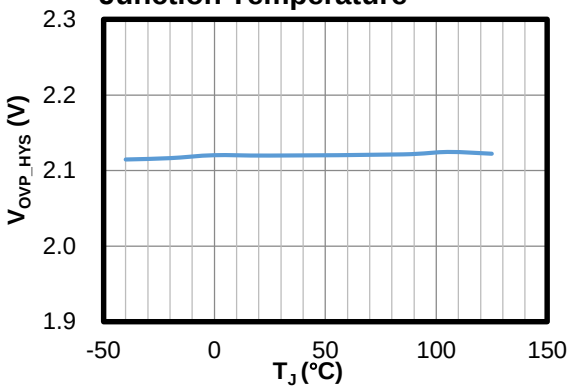
## TYPICAL CHARACTERISTICS *(continued)*

**$V_{CC}$ = 12V, $T_J$ = -40°C to +125°C, unless otherwise noted.**

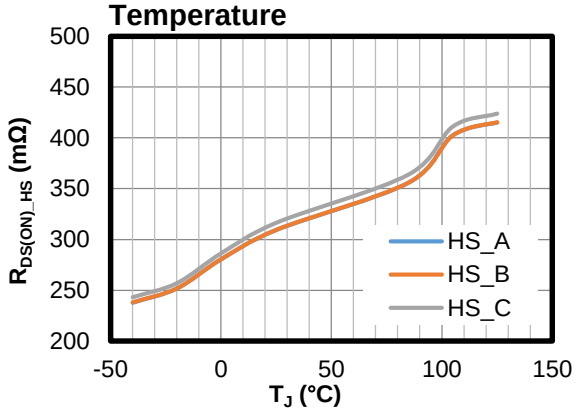
**OVP Low Threshold vs. Junction Temperature**



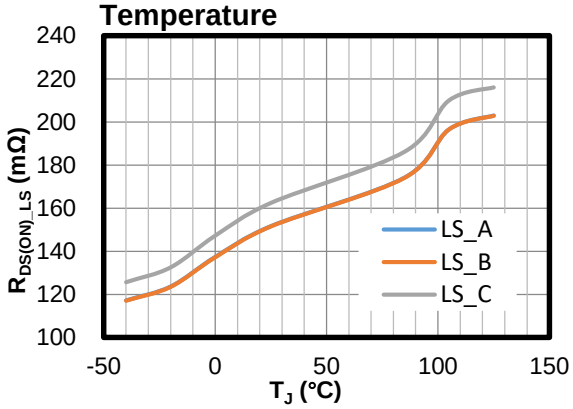

**OVP Low Hysteresis vs. Junction Temperature**




**High-Side MOSFET On Resistance vs. Junction Temperature**

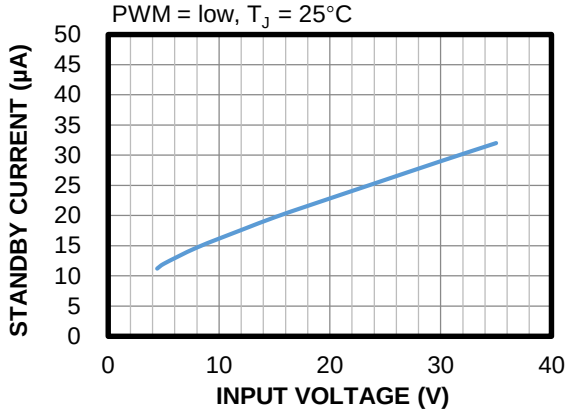



**Low-Side MOSFET On Resistance vs. Junction Temperature**

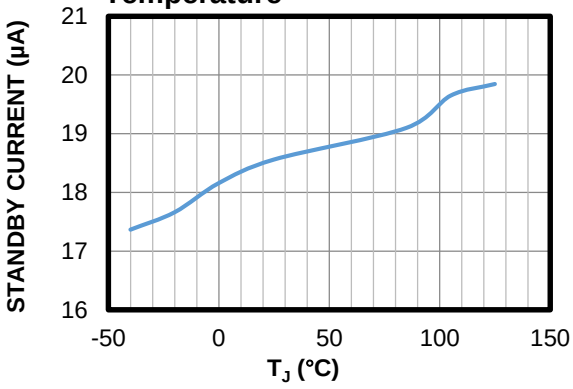



**Standby Current vs. Input Voltage**

PWM = low, $T_J$ = 25°C




**Standby Current vs. Junction Temperature**





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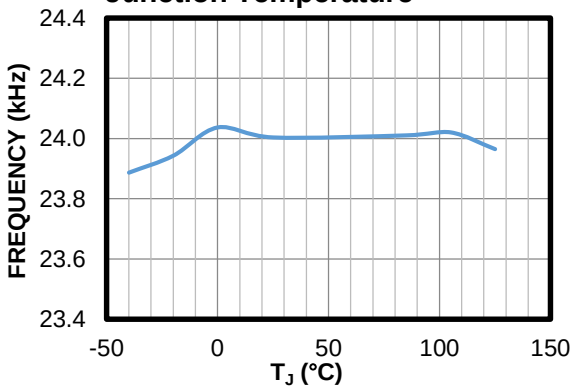
## TYPICAL CHARACTERISTICS *(continued)*

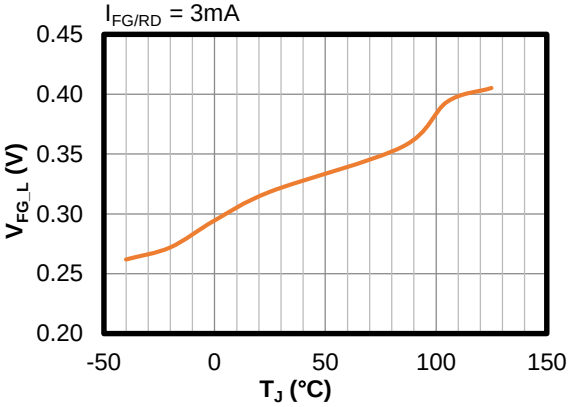
**$V_{CC}$ = 12V, $T_J$ = -40°C to +125°C, unless otherwise noted.**

**PWM Output Frequency vs. Junction Temperature**




**FG/RD Output Low Level vs. Junction Temperature**

$I_{FG/RD}$ = 3mA





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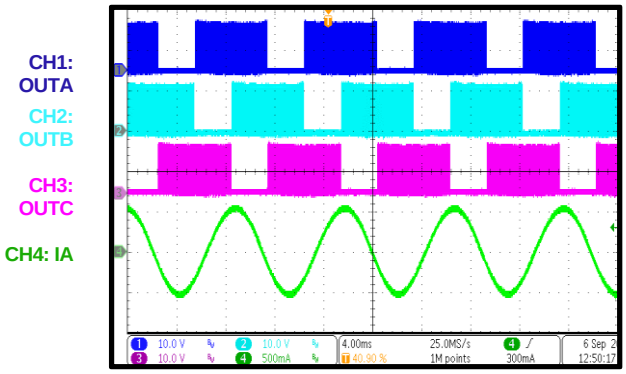
# TYPICAL PERFORMANCE CHARACTERISTICS

**Performance waveforms are tested on the evaluation board. $V_{IN}$ = 12V, PWM input frequency = 100Hz, load = seat fan, unless otherwise noted.**

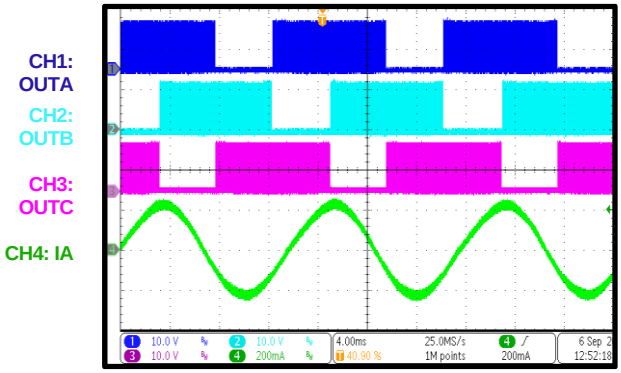
### Steady State

PWM duty cycle = 100%, DIR = low



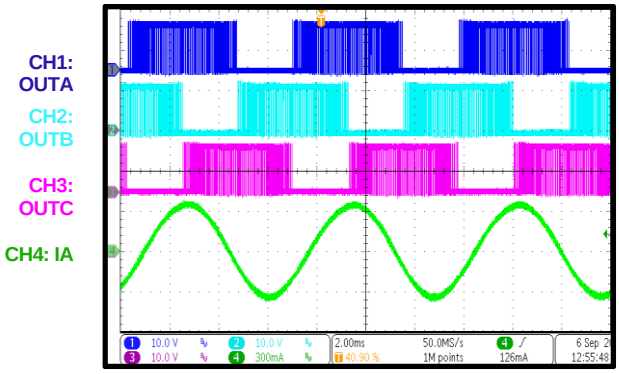

### Steady State

PWM duty cycle = 50%, DIR = low



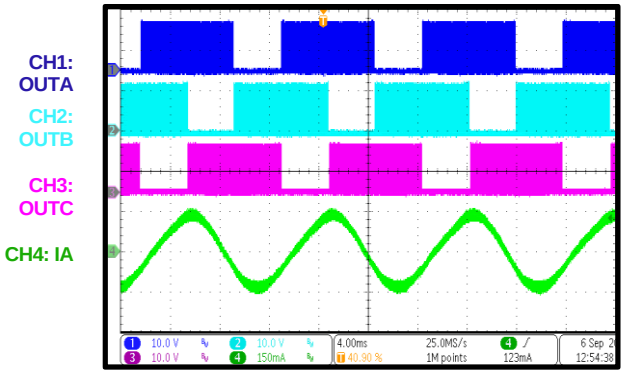

### Steady State

PWM duty cycle = 100%, DIR = high



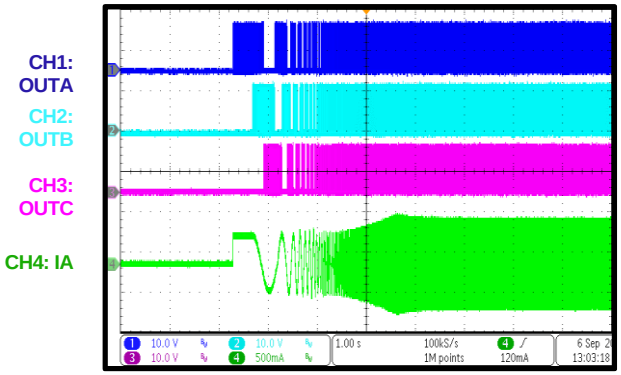

### Steady State

PWM duty cycle = 50%, DIR = high



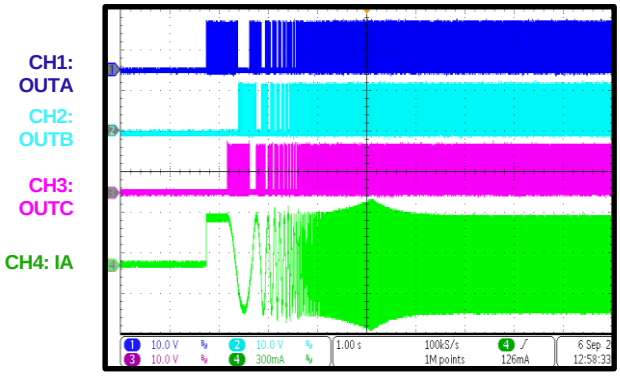

### PWM On

PWM duty cycle = 0% to 100%, DIR = low




### PWM On

PWM duty cycle = 0% to 100%, DIR = high





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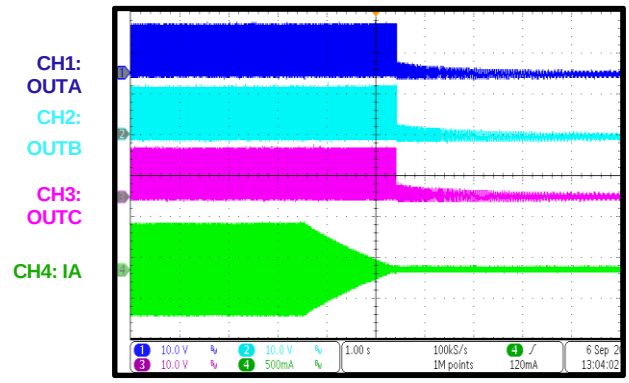
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**Performance waveforms are tested on the evaluation board. $V_{IN}$ = 12V, PWM input frequency = 100Hz, load = seat fan, unless otherwise noted.**

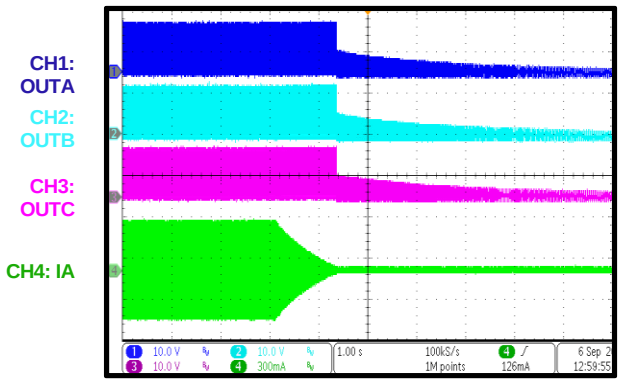
### PWM Off

PWM duty cycle = 100% to 0%, DIR = low



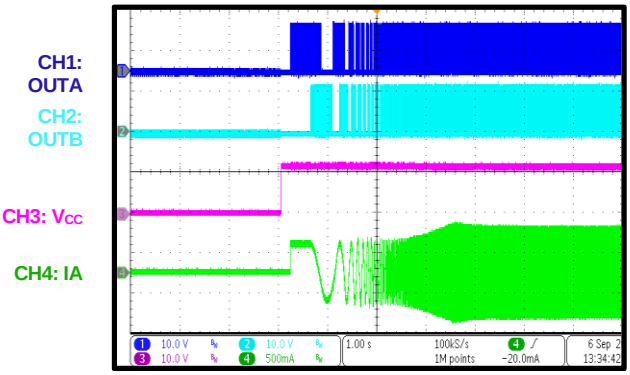

### PWM Off

PWM duty cycle = 100% to 0%, DIR = high



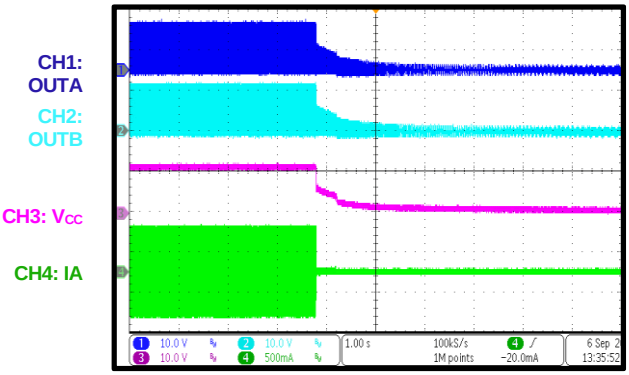

### Start-Up via VCC

$V_{CC}$ = 0V to 12V, PWM duty cycle = 100%, DIR = low



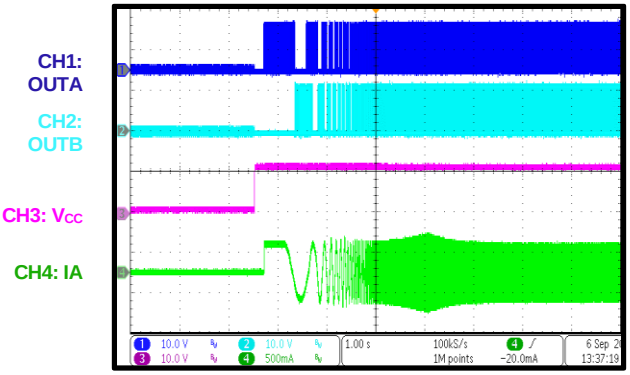

### Shutdown via VCC

$V_{CC}$ = 12V to 0V, PWM duty cycle = 100%, DIR = low



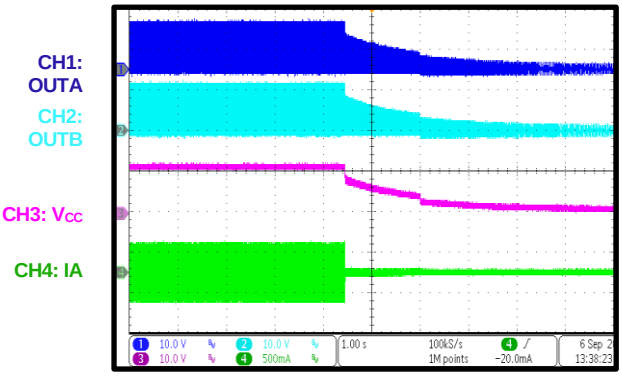

### Start-Up via VCC

$V_{CC}$ = 0V to 12V, PWM duty cycle = 100%, DIR = high




### Shutdown via VCC

$V_{CC}$ = 12V to 0V, PWM duty cycle = 100%, DIR = high





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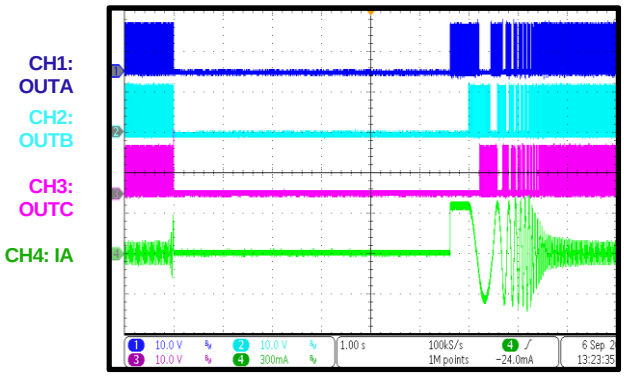
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**Performance waveforms are tested on the evaluation board. $V_{IN}$ = 12V, PWM input frequency = 100Hz, load = seat fan, unless otherwise noted.**

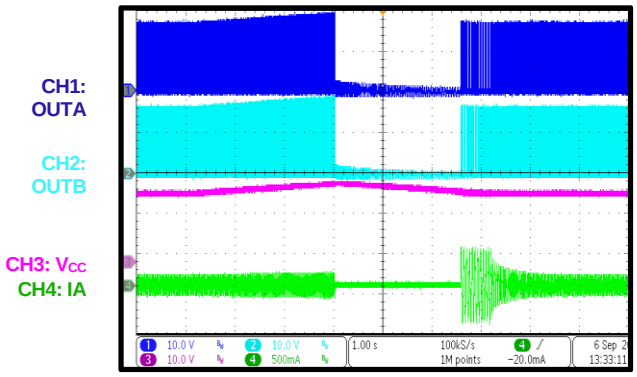
### Rotor L0ock and Retry

PWM duty cycle = 20%, enable RD_MODE1 and RD_MODE2



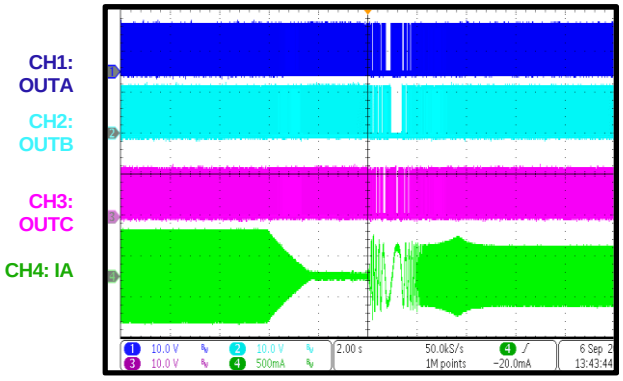

### OVP

PWM duty cycle = 20%, UIN_SEL = 0




### Direction Change

PWM duty cycle = 100%, enable SOFT_DOWN, DIR = low to high





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# FUNCTIONAL BLOCK DIAGRAM

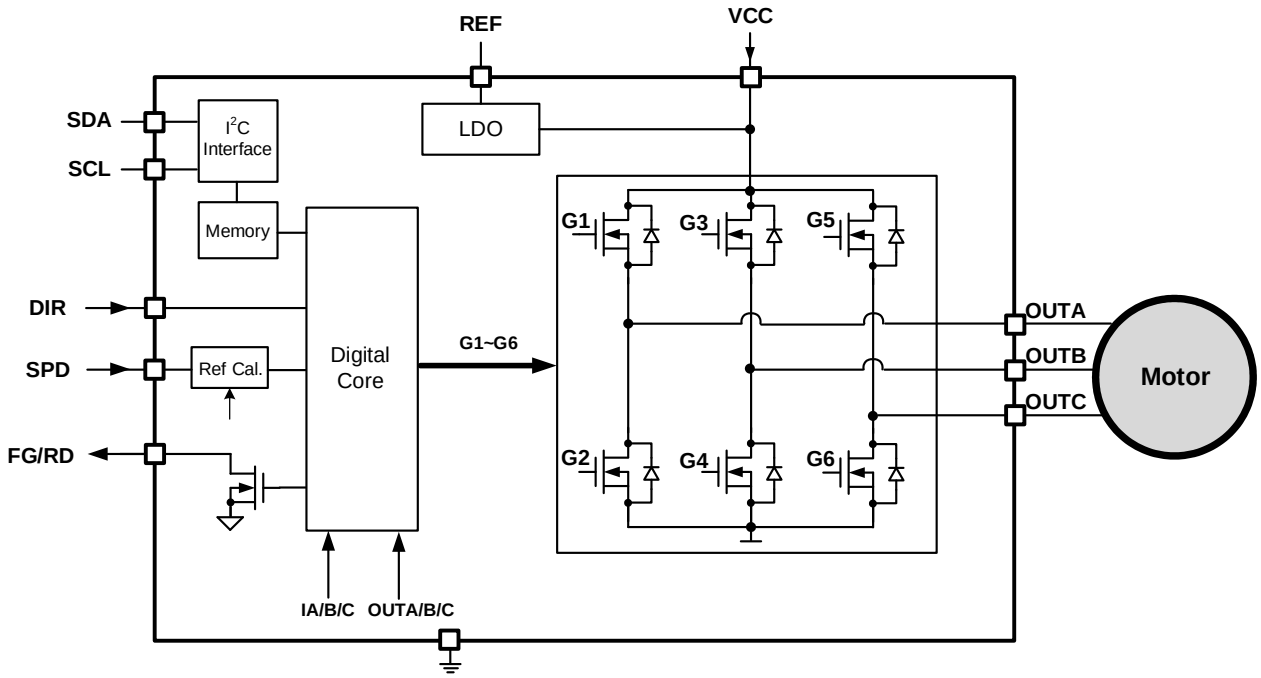


**Figure 1: Functional Block Diagram**


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# OPERATION

The MP6634 is a 3-phase, sensorless brushless DC (BLDC) motor driver with integrated power MOSFETs. It features sensorless field-oriented control (FOC) for better efficiency and low vibration with up to 2A of peak current. The input voltage ($V_{IN}$) ranges between 4.5V and 35V.

Figure 2 shows the sensorless FOC drive.

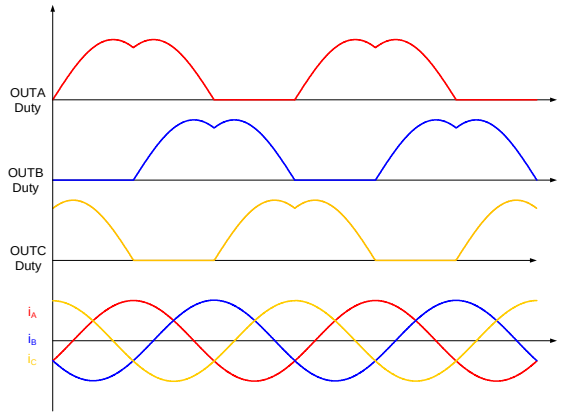


**Figure 2: Sensorless FOC Drive**

## Speed Control

The SPD pin controls the motor speed in open-loop and closed-loop operation by applying a pulse-width modulation (PWM) signal or a DC voltage to SPD, respectively. It accepts a wide 50Hz to 20kHz input frequency range, or a 0V to 3.3V voltage.

If PWM_DC = 1, the motor speed is controlled by the DC voltage on the SPD pin. If PWM_DC = 0, the motor speed is controlled by the input PWM signal duty cycle. Due to the SPD absolute maximum rating being 6V, it is recommended to add a 4.7V Zener diode on the SPD pin to avoid the SPD voltage ($V_{SPD}$) exceeding the absolute maximum rating.

## Direction Control

The rotation direction is controlled by the polarity of the DIR pin's input and internal DIR bit.

By default, when the DIR input is low the MP6634 operates in forward rotation (OUTA to OUTB to OUTC to OUTA…). When the DIR input is high, the device operates with reverse rotation (OUTA to OUTC to OUTB to OUTA…).

Register CFR_2, bit[7] can reverse the polarity of DIR input. If this bit is set, the motor rotates in reverse when the DIR input is low, and it rotates in the forward direction when the DIR input is high.

When the rotating direction changes during operation (by changing the DIR input polarity or setting CFR_2, bit[7]), the output's duty cycle decreases first to slow down the motor speed; then the motor is driven in the commanded rotating direction.

## Rotor Alignment

If the motor is stationary, a certain voltage vector is applied for a configurable time to align the rotor to the certain position. The voltage vector amplitude is configured via the MAX_SPEED_2/U_START register, bits[3:0]. START_UP, bits[1:0] sets the different alignment times for different motors.

## Open-Loop Acceleration

After rotor alignment, the motor accelerates openly by increasing the driven vector amplitude and frequency.

The minimum output duty cycle at the beginning of the start-up stage, the acceleration ramp, the acceleration target for the electrical frequency, and the open-loop to closed-loop handoff threshold can be configured via registers MAX_SPEED_2/U_START, bits[3:0] and START_UP, bits[7:2] for different types of motors.

Figure 3 shows the electrical frequency in the voltage/frequency (V/F) stage.

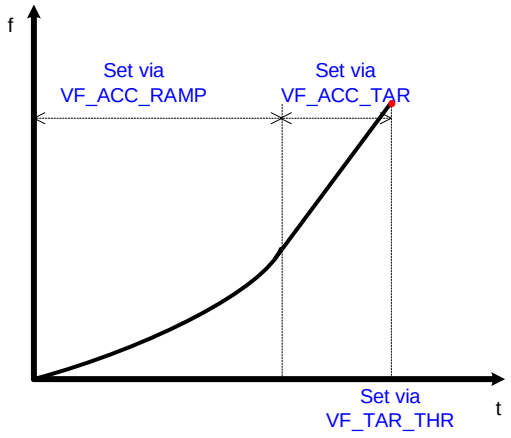


**Figure 3: Electrical Frequency in the V/F Stage**


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Once the motor reaches the handoff speed, the MP6634 enters the sensorless FOC stage.

### Open-/Closed-Loop Speed Control

The MP6634 supports open-loop and closed-loop speed control, as configured via the V_LOOP bit.

In closed-loop speed mode (V_LOOP = 1), the IC internally detects the speed and sends feedback to the control loop, which adjusts the output PWM duty cycle in a closed loop. In closed-loop control, the motor speed follows the reference exactly.

In open-loop speed mode (V_LOOP = 0), the output duty cycle directly depends on the PWM input's duty cycle.

### Starting Duty Cycle and Stopping Duty Cycle

The input starting duty cycle can be configured via SPEED_CURVE_1, bits[7:0]. The stopping duty cycle depends on CFR_1, bit[5] when the SPD_HZERO function is enabled.

When the input duty cycle is below the starting duty cycle, the operation mode is configured by CFR_1, bit[4].

If SPD_LZERO = 0, then the speed and output duty cycle maintain the setting from SPEED_CURVE_6, bits[7:0] (see Figure 4).

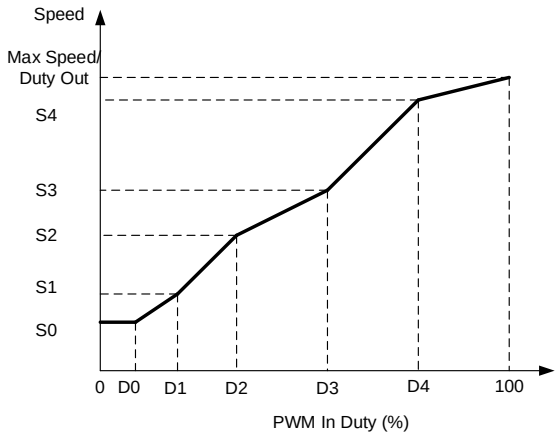


**Figure 4: Curve Configuration (SPD_LZERO = 0)**

If SPD_LZERO = 1, then the fan stops (see Figure 5).

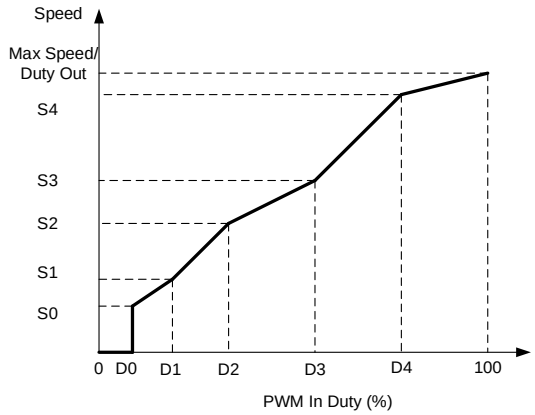


**Figure 5: Curve Configuration (SPD_LZERO = 1)**

The MP6634 can be configured for fan shutdown when the input duty cycle exceeds the stopping duty cycle, as set via CFR_1, bit[5].

- If SPD_HZERO = 1, the speed is at 0 (see Figure 6).
- If SPD_HZERO = 0, the speed and output duty cycle follow the configured curve (see Figure 7 on page 15).
- The stopping duty cycle threshold is configured via CFR_4, bit[5].

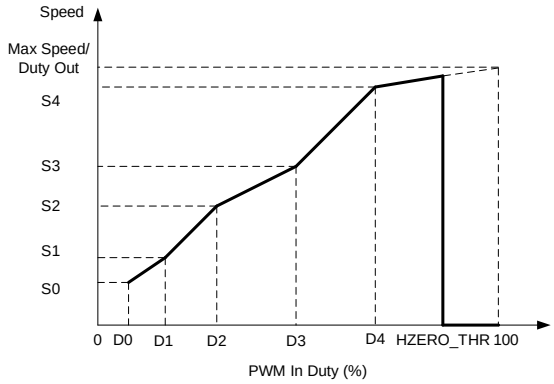


**Figure 6: Curve Configuration (SPD_HZERO = 1)**

### Curve Configurations

The MP6634 provides a curve configuration function. Both the input duty cycle and output duty cycle/speed can be configured via the MAX_SPEED and SPEED_CURVE registers (see Figure 7 on page 15).

The SPD_MAX[11:0] commands (MAX_SPEED_1, bits[7:0] and MAX_SPEED_2/U_START, bits[7:4]) support six configurations for the maximum speed in closed-loop speed control.


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MAX_SPEED_1, bits[7:0] configure the output duty cycle during open-loop speed control when the input duty cycle is 100%.

The SPEED_CURVE_6, bits[7:0] set the speed and output duty cycle when the input duty cycle is D0, which is set by SPEED_CURVE_1, bits[7:0].

Table 1 and Figure 7 shows which command sets the speed and output duty cycle depending on which command sets the input duty cycle.

**Table 1: Speed and Duty Cycle Setting Commands**

| Speed and Output Duty Cycle Setting Command | Input Duty Cycle Setting Command |
|---|---|
| SPEED_CURVE_7, bits[7:0] | SPEED_CURVE_2, bits[7:0] |
| SPEED_CURVE_8, bits[7:0] | SPEED_CURVE_3, bits[7:0] |
| SPEED_CURVE_9, bits[7:0] | SPEED_CURVE_4, bits[7:0] |
| SPEED_CURVE_10, bits[7:0 | SPEED_CURVE_5, bits[7:0] |

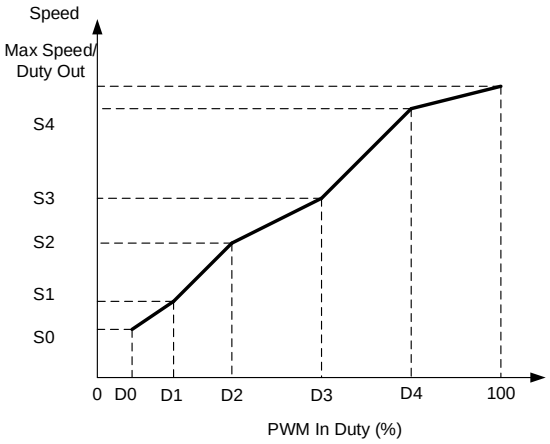


**Figure 7: Curve Configurations**

## Standby Mode

If the VCC voltage ($V_{CC}$) exceeds its under-voltage lockout (UVLO) rising threshold and the SPD pin stays low for more than 85ms after the IC stops switching, the IC enters standby mode. When entering standby mode, the low-dropout (LDO) regulator's output is controlled via the CFR_3, bit[2]. Once the PWM input signal is detected or power is cycled, the IC exits standby mode.

## Rotor Speed Indication (FG)

The FG/RD pin can be configured for speed indication, locked-rotor indication, or fault indication:

- If FGRD_SEL = 00, the FG/RD pin outputs 1 cycle in each electrical cycle.
- If FGRD_SEL = 01, the FG/RD pin outputs 2 cycles in each electrical cycle.
- If FGRD_SEL = 10, the FG/RD pin outputs RD (the lock protection indicator).
- If FGRD_SEL = 11, the FG/RD pin is a fault indicator.

## Protection Circuits

The MP6634 offers comprehensive protections in the event of over-voltage (OV), under-voltage (UV), over-current (OC), and over-temperature (OT) conditions.

## Short-Circuit Protection (SCP)

The MP6634 features internal overload and short-circuit protection (SCP) by detecting the current flowing through each MOSFET. If the current flowing through any MOSFET exceeds the over-current protection (OCP) threshold (typically 3A) after a set blanking time, all MOSFETs turn off immediately. After a locked retry time, the MOSFETs and resume operation.

## Over-Current Protection (OCP)

During normal switching, if the current flowing through the MOSFET exceeds the threshold set via CFR_2, bit[2] after a blanking time, the output duty cycle decreases to limit the output current ($I_{OUT}$). The OCP threshold can be set to 1A or 2A. OCP can be disabled via CFR_4, bit[3].

## Thermal Shutdown (TSD)

Thermal monitoring is also integrated into the MP6634. If the die temperature exceeds 175°C, all MOSFETs turn off. Once the die temperature drops to the lower threshold (155°C), the IC restarts and resumes normal operation.

## Under-Voltage Lockout (UVLO)

If $V_{CC}$ falls below the UVLO threshold, all circuitry in the device is disabled and the internal logic is reset. Once $V_{CC}$ exceeds the UVLO threshold, the IC restarts and resumes normal operation.


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### Rotor Dead-Lock Protection (RD)

The MP6634 features rotor dead-lock protection. If this protection is triggered, the MP6634 turns off the MOSFETs. By default, the IC resumes normal operation after a 5.5s lock-retry time. The protection behavior can be configured to latch-off mode or retry mode via CFR_2, bit[3].

### Over-Voltage Protection (OVP)

The MP6634 employs two OVP thresholds for different applications. The OVP threshold can be configured via the UIN_SEL bit.

If $V_{CC}$ exceeds its OV threshold (typically 19V or 33V), the IC turns off all MOSFETs. Once $V_{CC}$ drops below the OVP falling threshold, the IC restarts and resumes normal operation.

OVP can be disabled via CFR_2, bit[1].

### Phase-Loss Protection (PLOS)

The MP6634 monitors each phase's voltage and current. If phase-loss protection (PLOS) is triggered, the IC stops switching and latches off.

PLOS can be disabled via CFR_4, bit[2].

### Fault Diagnosis

The OCP, SCP, TSD, OVP, PLOS, and rotor dead-lock protections have relative fault bits to indicate the fault. The fault bit(s) can be reset after being read.

### Test Mode and Factory Mode

To configure the internal registers, the MP6634 supports test mode. In test mode, all internal registers can be read and written. After the design is finalized, the register value can be configured to the non-volatile memory (NVM), which can be configured twice. Refer to the MPS Fan Driver GUI software to easily change parameters and configure the memory. (5)

**Note:**

5) Contact an MPS FAE to obtain the MPS Fan Driver GUI software.


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## REGISTER MAP

| Add | D[7] | D[6] | D[5] | D[4] | D[3] | D[2] | D[1] | D[0] |
|---|---|---|---|---|---|---|---|---|
| 00h (OTP/REG) | SPEED_CONST | | | | | | | |
| 01h (OTP/REG) | KC | | | | | | | |
| 02h (OTP/REG) | KU | | | | | | | |
| 03h (OTP/REG) | SPD_MAX[7:0] | | | | | | | |
| 04h (OTP/REG) | SPD_MAX[11:8] | | | | U_START | | | |
| 05h (OTP/REG) | KI | | | | KP | | | |
| 06h (OTP/REG) | SPD KI | | | | ID_KI | | | |
| 07h (OTP/REG) | VF_TAR_THR | | VF_ACC_RAMP | | VF_ACC_TAR | | ALIGN_TIME | |
| 08h (OTP/REG) | UIN_COM | SOFT_ DOWN | SPD_ HZERO | SPD_ LZERO | FGRD_SEL | | TSS | |
| 09h (OTP/REG) | DIR_POR | PWM_POR | PWM_MD | PWM_DC | RETRY | OC_THR | OVP_EN | V_LOOP |
| 0Ah (OTP/REG) | RD_MODE2 | RD_ MODE1 | RD_THR | UIN_SEL | RESERVED | SLP_ REF | GAIN | |
| 0Bh (OTP/REG) | D0 | | | | | | | |
| 0Ch (OTP/REG) | D1 | | | | | | | |
| 0Dh (OTP/REG) | D2 | | | | | | | |
| 0Eh (OTP/REG) | D3 | | | | | | | |
| 0Fh (OTP/REG) | D4 | | | | | | | |
| 10h (OTP/REG) | S0 | | | | | | | |
| 11h (OTP/REG) | S1 | | | | | | | |
| 12h (OTP/REG) | S2 | | | | | | | |
| 13h (OTP/REG) | S3 | | | | | | | |
| 14h (OTP/REG) | S4 | | | | | | | |
| 15h (OTP/REG) | RESERVED | | HZERO_ THR | DIR_BRK | OCP_EN | PL_EN | RESERVED | OMOD |


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### SPEED_CONST (00h)

The SPEED_CONST command sets the internal calculation coefficient.

| Bits | Access | Bit Name | Default | Description |
|---|---|---|---|---|
| 7:0 | R/W | SPEED_CONST | 0x00 | Used for internal calculation. Must be configured via the GUI. |

### KC (01h)

The KC command sets the internal calculation coefficient.

| Bits | Access | Bit Name | Default | Description |
|---|---|---|---|---|
| 7:0 | R/W | KC | 0x00 | Used for internal calculation. Must be configured via the GUI. |

### KU (02h)

The KU command sets the internal calculation coefficient.

| Bits | Access | Bit Name | Default | Description |
|---|---|---|---|---|
| 7:0 | R/W | KU | 0x00 | Used for internal calculation. Must be configured via the GUI. |

### MAX_SPEED_1 (03h)

The MAX_SPEED_1 command sets the lower 8 bits for the maximum speed in closed-loop control, or the output duty cycle in open-loop control when the PWM input duty cycle is 100%.

| Bits | Access | Bit Name | Default | Description |
|---|---|---|---|---|
| 7:0 | R/W | SPD_MAX[7:0] | 0x00 | Sets the lower 8 bits for the maximum speed in closed-loop control, or the output duty cycle in open-loop control when the PWM input duty cycle is 100%.<br>For closed-loop speed control, the electrical speed = 22rpm/LSB.<br>For open-loop speed control, the output duty cycle = SPD_MAX[7:0] / 255. |

### MAX_SPEED_2/U_START (04h)

The MAX_SPEED_2/U_START command sets the upper 4 bits for the maximum speed in closed-loop control, as well as the initial start-up voltage.

| Bits | Access | Bit Name | Default | Description |
|---|---|---|---|---|
| 7:4 | R/W | SPD_MAX[11:8] | 0000 | Sets the higher 4 bits for the maximum speed when the input duty cycle is 100%. These bits are combined with SPD_MAX[7:0] to set the maximum speed (electrical speed). |
| 3:0 | R/W | U_START | 0000 | Sets the initial voltage during the alignment stage. The U_START voltage can be calculated with the following equation:<br>U_START Voltage = U_START x 32 / VOL_OUT_GAIN<br>If UIN_SEL = 0, VOL_OUT_GAIN = 94.85.<br>If UIN_SEL = 1, VOL_OUT_GAIN = 48.79.<br>Select a suitable initial voltage to ensure that the motor can start up reliably. |


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### KP/KI (05h)

The KP/KI command sets the gain parameters for the internal calculation.

| Bits | Access | Bit Name | Default | Description |
|---|---|---|---|---|
| 7:4 | R/W | KI | 0000 | Must be configured via the GUI. |
| 3:0 | R/W | KP | 0000 | Must be configured via the GUI. |

### SPD_KI/ID_KI (06h)

The SPD_KI/ID_KI command sets separate parameters for internal loop configuration.

| Bits | Access | Bit Name | Default | Description |
|---|---|---|---|---|
| 7:4 | R/W | SPD_KI | 0000 | Must be configured via the GUI. |
| 3:0 | R/W | ID_KI | 0000 | Must be configured via the GUI. |

### START_UP (07h)

The START_UP command sets parameters and thresholds for V/F mode.

| Bits | Access | Bit Name | Default | Description |
|---|---|---|---|---|
| 7:6 | R/W | VF_TAR_THR | 00 | Sets the speed handoff threshold from V/F to sensorless control.<br><br>During open-loop control, these bits set *N*. The handoff speed = 30.5 x $V_{CC}$ x VOL_OUT_GAIN x N / SPEED CONST. See the MAX_SPEED_2/U_START (04h) register on page 18 for more details.<br><br>00: *N* = 1<br>01: *N* = 2<br>10: *N* = 4<br>11: *N* = 8<br><br>During closed-loop control, these bits set VF_TAR_THR. The handoff speed = SPD_MAX x VF_TAR_THR.<br><br>00: 3.125%<br>01: 6.25%<br>10: 12.5%<br>11: 25% |
| 5:4 | R/W | VF_ACC_RAMP | 00 | Sets the electrical frequency acceleration ramp during the V/F stage.<br><br>00: 754rpm/s$^2$<br>01: 1509rpm/s$^2$<br>10: 3018rpm/s$^2$<br>11: 6035rpm/s$^2$ |
| 3:2 | R/W | VF_ACC_TAR | 00 | Sets the electrical frequency acceleration target during the V/F stage.<br><br>00: 515rpm/s<br>01: 1030rpm/s<br>10: 2060rpm/s<br>11: 3605rpm/s |
| 1:0 | R/W | ALIGN_TIME | 00 | Sets the alignment time before entering the V/F stage.<br><br>00: 0.35s<br>01: 0.7s<br>10: 1.4s<br>11: 2s |


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### CFR_1 (08h)

The control function register (CFR_1) sets the UIN compensation, soft start and soft dynamic adjustment, start-up duty cycle and stopping duty cycle, and the FG/RD pin's output.

| Bits | Access | Bit Name | Default | Description |
|---|---|---|---|---|
| 7 | R/W | UIN_COM | 0 | Enables UIN compensation. This is only for open-loop applications.<br>0: Disabled<br>1: Enabled |
| 6 | R/W | SOFT_DOWN | 0 | Enables the soft dynamic adjustment function to ensure that there is no reverse current during the dynamic process.<br>0: Disabled<br>1: Enabled |
| 5 | R/W | SPD_HZERO | 0 | Enables stopping the output switching function when the input PWM duty cycle exceeds the HZERO_THR setting.<br>0: Disabled<br>1: Enabled |
| 4 | R/W | SPD_LZERO | 1 | Enables stopping the output switching function when the input PWM duty cycle is below the D0 setting.<br>0: Disabled<br>1: Enabled |
| 3:2 | R/W | FGRD_SEL | 00 | Sets the FG/RD pin's output.<br>00: FG<br>01: 2 x FG<br>10: RD<br>11: Fault indicator (nFT) |
| 1:0 | R/W | TSS | 00 | Sets the start-up time for the duty reference to change from 0% to 100%, or from 100% to 0%.<br>00: 2.6s<br>01: 5.4s<br>10: 7s<br>11: 10.5s |

### CFR_2 (09h)

The CFR_2 command sets the direction polarity and PWM input polarity, PWM input mode, restart mode, over-current protection (OCP) threshold, over-voltage protection (OVP), and loop configuration.

| Bits | Access | Bit Name | Default | Description |
|---|---|---|---|---|
| 7 | R/W | DIR_POR | 0 | Sets the direction polarity.<br>0: Keep the DIR pin's default input<br>1: Reverse the DIR pin's input |
| 6 | R/W | PWM_POR | 0 | Sets the PWM input polarity, which is only for PWM signal mode applications.<br>0: Keep the PWM input<br>1: Reverse the PWM input |
| 5 | R/W | PWM_MD | 0 | Sets the PWM input frequency.<br>0: 50Hz to 1kHz<br>1: 1kHz to 20kHz |


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| | | | | |
|---|---|---|---|---|
| 4 | R/W | PWM_DC | 0 | Sets the PWM input mode.<br>0: PWM signal input<br>1: DC voltage |
| 3 | R/W | RETRY | 0 | Sets the restart mode after triggering locked-rotor protection and short-circuit protection (SCP).<br>0: Repeat<br>1: Latch-off |
| 2 | R/W | OC_THR | 0 | Sets the over-current (OC) threshold.<br>0: 2A<br>1: 1A |
| 1 | R/W | OVP_EN | 0 | Enables OVP.<br>0: Disabled<br>1: Enabled |
| 0 | R/W | V_LOOP | 0 | Sets the speed loop control.<br>0: Open-loop control<br>1: Closed-loop control |

### CFR_3 (0Ah)

The CFR_3 command sets the rotor dead-lock protection threshold, input voltage, LDO status under sleep mode, and loop gain.

| Bits | Access | Bit Name | Default | Description |
|---|---|---|---|---|
| 7 | R/W | RD_MODE2 | 0 | Determines whether the motor is stalled in mode 2. It is recommended to enable RD_MODE1 and RD_MODE2 when it is difficult for the motor to enter rotor-lock protection.<br>0: Disabled<br>1: Enabled |
| 6 | R/W | RD_MODE1 | 0 | Determines whether the motor is stalled in mode 1.<br>0: Disabled<br>1: Enabled |
| 5 | R/W | RD_THR | 0 | Sets the rotor dead-lock protection threshold, which is only for RD_MODE1 applications.<br>1: Level 1. This configuration is recommended for most applications<br>0: Level 2. If a level 1 configuration makes it difficult to trigger rotor-lock protection, use this configuration instead |
| 4 | R/W | UIN_SEL | 0 | Sets the maximum $V_{IN}$.<br>0: 18V<br>1: 36V |
| 3 | NA | RESERVED | 0 | Reserved. |
| 2 | R/W | SLP_REF | 0 | Sets the LDO working status when entering sleep mode.<br>0: Disable the LDO<br>1: Enable the LDO |
| 1:0 | R/W | GAIN | 00 | Sets the loop gain for the internal calculation. Must be configured via the GUI.<br>00: Max<br>01: High<br>10: Mid<br>11: Low |


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### SPEED_CURVE_1 (0Bh)

The SPEED_CURVE_1 command sets the input PWM duty cycle (D0).

| Bits | Access | Bit Name | Default | Description |
|---|---|---|---|---|
| 7:0 | R/W | D0 | 0x00 | Sets the input PWM duty cycle (D0), which can be calculated with the following equation:<br>Input PWM Duty Cycle = D0, bits[7:0] / 256 |

### SPEED_CURVE_2 (0Ch)

The SPEED_CURVE_2 command sets the input PWM duty cycle (D1).

| Bits | Access | Bit Name | Default | Description |
|---|---|---|---|---|
| 7:0 | R/W | D1 | 0x40 | Sets the input PWM duty cycle (D1), which can be calculated with the following equation:<br>Input PWM Duty Cycle = D1, bits[7:0] / 256 |

### SPEED_CURVE_3 (0Dh)

The SPEED_CURVE_3 command sets the input PWM duty cycle (D2).

| Bits | Access | Bit Name | Default | Description |
|---|---|---|---|---|
| 7:0 | R/W | D2 | 0x80 | Sets the input PWM duty cycle (D2), which can be calculated with the following equation:<br>Input PWM Duty Cycle = D2, bits[7:0] / 256 |

### SPEED_CURVE_4 (0Eh)

The SPEED_CURVE_4 command sets the input PWM duty cycle (D3).

| Bits | Access | Bit Name | Default | Description |
|---|---|---|---|---|
| 7:0 | R/W | D3 | 0XC0 | Sets the input PWM duty cycle (D3), which can be calculated with the following equation:<br>Input PWM Duty Cycle = D3, bits[7:0] / 256 |

### SPEED_CURVE_5 (0Fh)

The SPEED_CURVE_5 command sets the input PWM duty cycle (D4).

| Bits | Access | Bit Name | Default | Description |
|---|---|---|---|---|
| 7:0 | R/W | D4 | 0xFF | Sets the input PWM duty cycle (D4), which can be calculated with the following equation:<br>Input PWM Duty Cycle = D4, bits[7:0] / 256 |

### SPEED_CURVE_6 (10h)

The SPEED_CURVE_6 command configures the speed or output duty cycle when the input PWM duty cycle is D0, as set via SPEED_CURVE_1 (0Bh).

| Bits | Access | Bit Name | Default | Description |
|---|---|---|---|---|
| 7:0 | R/W | S0 | 0x20 | Sets the speed or output duty cycle when the input PWM duty cycle = D0. For open-loop control, sets the output duty cycle. The output duty cycle can be calculated with the following equation:<br>Output Duty Cycle = S0, bits[7:0] / 256<br>For closed-loop control, sets the reference speed. The speed can be calculated with the following equation:<br>Speed = S0, bits[7:0] / 256 x SPD_MAX, bits[11:0] |


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### SPEED_CURVE_7 (11h)

The SPEED_CURVE_7 command configures the speed or output duty cycle when the input PWM duty cycle is D1, as set via SPEED_CURVE_2 (0Ch).

| Bits | Access | Bit Name | Default | Description |
|---|---|---|---|---|
| 7:0 | R/W | S1 | 0x40 | Sets the speed or output duty cycle when the input PWM duty cycle = D1. For open-loop control, sets the output duty cycle. The output duty cycle can be calculated with the following equation:<br>Output Duty Cycle = S1, bits[7:0] / 256<br>For closed-loop control, sets the reference speed. The speed can be calculated with the following equation:<br>Speed = S1, bits[7:0] / 256 x SPD_MAX, bits[11:0] |

### SPEED_CURVE_8 (12h)

The SPEED_CURVE_8 command configures the speed or output duty cycle when the input PWM duty cycle is D2, as set via SPEED_CURVE_3 (0Dh).

| Bits | Access | Bit Name | Default | Description |
|---|---|---|---|---|
| 7:0 | R/W | S2 | 0x80 | Sets the speed or output duty cycle when the input PWM duty cycle = D2. For open-loop control, sets the output duty cycle. The output duty cycle can be calculated with the following equation:<br>Output Duty Cycle = S2, bits[7:0] / 256<br>For closed-loop control, sets the reference speed. The speed can be calculated with the following equation:<br>Speed = S2, bits[7:0] / 256 x SPD_MAX, bits[11:0] |

### SPEED_CURVE_9 (13h)

The SPEED_CURVE_9 command configures the speed or output duty cycle when the input PWM duty cycle is D3, as set via SPEED_CURVE_4 (0Eh).

| Bits | Access | Bit Name | Default | Description |
|---|---|---|---|---|
| 7:0 | R/W | S3 | 0xC0 | Sets the speed or output duty cycle when the input PWM duty cycle = D3. For open-loop control, sets the output duty cycle. The output duty cycle can be calculated with the following equation:<br>Output Duty Cycle = S3, bits [7:0] / 256<br>For closed-loop control, sets the reference speed. The speed can be calculated with the following equation:<br>Speed = S3, bits[7:0] / 256 x SPD_MAX, bits[11:0] |


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### SPEED_CURVE_10 (14h)

The SPEED_CURVE_10 command configures the speed or output duty cycle when the input PWM duty cycle is D4, as set via SPEED_CURVE_5 (0Fh).

| Bits | Access | Bit Name | Default | Description |
|---|---|---|---|---|
| 7:0 | R/W | S4 | 0xFF | Sets the speed or output duty cycle when the input PWM duty cycle = D4. For open-loop control, sets the output duty cycle. The output duty cycle can be calculated with the following equation:<br>Output Duty Cycle = S4, bits[7:0] / 256<br>For closed-loop control, sets the reference speed. The speed can be calculated with the following equation:<br>Speed = S4, bits[7:0] / 256 x SPD_MAX, bits[11:0] |

### CFR_4 (15h)

The CFR_4 command sets the stopping duty threshold and brake function when the motor runs in reverse rotation; in addition, it enables over-current protection (OCP), phase-loss protection (PLOS), and the over-modulation function.

| Bits | Access | Bit Name | Default | Description |
|---|---|---|---|---|
| 7:6 | NA | RESERVED | 00 | Reserved. |
| 5 | R/W | HZERO_THR | 0 | Sets the stopping threshold when the input PWM duty cycle exceeds HZERO_THR. This function takes effect when SPD_HZERO configuration is enabled.<br>0: 98%<br>1: 88% |
| 4 | R/W | DIR_BRK | 0 | Enables the brake function when the motor works in reverse rotation.<br>0: Disabled<br>1: Enabled |
| 3 | R/W | OCP_EN | 0 | Enables OCP.<br>0: Disabled<br>1: Enabled |
| 2 | R/W | PL_EN | 0 | Enables PLOS.<br>0: Disabled<br>1: Enabled |
| 1 | NA | RESERVED | 0 | Reserved. |
| 0 | R/W | OMOD | 0 | Enables the over-modulation function.<br>0: Disabled<br>1: Enabled |


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# APPLICATION INFORMATION

### Selecting the Input Capacitor

Place an input capacitor ($C_{IN}$) near VCC to keep $V_{IN}$ stable and reduce the input switching voltage noise and ripple. The $C_{IN}$ impedance must be low at the switching frequency ($f_{SW}$).

Ceramic capacitors with X7R dielectrics are recommended for their low-ESR characteristics. Ensure that the ceramic capacitance is dependent on the voltage rating. The DC biased voltage can lose more than 50% of its capacitance at the ceramic capacitors' rated voltage.

Leave a sufficient voltage rating margin when selecting the component. For most applications, a 10µF ceramic capacitor is sufficient.

If required for the application, add an additional, larger-value, electrolytic capacitor to absorb inductor energy.

A voltage-clamping TVS diode is recommended to avoid high-voltage spikes that result when the energy stored in the motor charges back to input side.

### Selecting the Input Snubber

Due to $C_{IN}$'s energy charge and discharge during the phase transition soft switching, the input current ($I_{IN}$) has switching cycle ringing. If required, add an RC snubber (a 2Ω resistor in series with a 1µF capacitor) in parallel with $C_{IN}$. This prevents switching cycle ringing.

### Selecting the REF Output Capacitor

The REF pin must be locally bypassed with a capacitor to provide power for the gate driver. A minimum 1µF ceramic capacitor with X7R or X5R dielectrics is recommended.

### Communication Connection

The MP6634 has an individual $I^2C$ communication interface; in addition, the MP6634 can use the SPD and FG/RD pins to act as the $I^2C$ interface to read and write the internal register bits.

Users do not need to enter test mode to use the individual SDA and SCL lines to cooperate with the external controller to send and receive data.

However, when using SPD and FG/RD for the communication interface, users must be in test mode. In test mode, the SPD pin acts as the data input and output, and the FG/RD pin acts as the clock signal input.

### System-Level ESD Enhancement

Some fan products must pass system-level ESD testing. System-level ESD follows the IEC 61000-4-2 standard. There are two different modes for the IEC 61000-4-2 ESD test: air discharge and contact discharge. Contact discharge mode is the first choice for testing.

Figure 8 shows the equivalent circuit of an HBM ESD circuit.

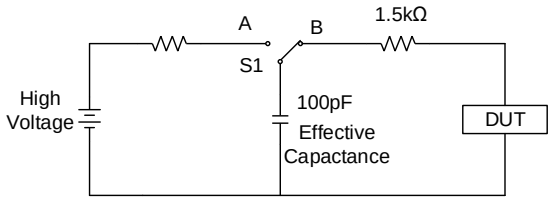


**Figure 8: Equivalent Circuit of HBM ESD Circuit**

Figure 9 shows that the IEC 61000-4-2 sets the equivalent circuit.

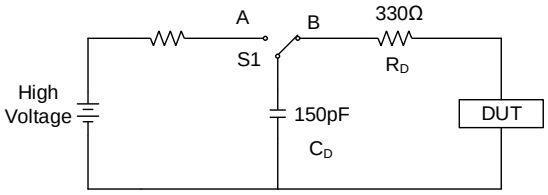


**Figure 9: Equivalent Circuit of System-Level ESD**

Compared to the HBM ESD ratings, the discharge capacitance exceeds the human body's effective capacitance, and the discharge resistance of the IEC-level ESD is much smaller.

To pass ±8kV for IEC 61000-4-2 contact discharge mode, an external circuit may be required to enhance the ESD capability. Figure 10 on page 26 shows an example to enhance the ESD capability with external components. Due to the difference between components, the test results may vary slightly.


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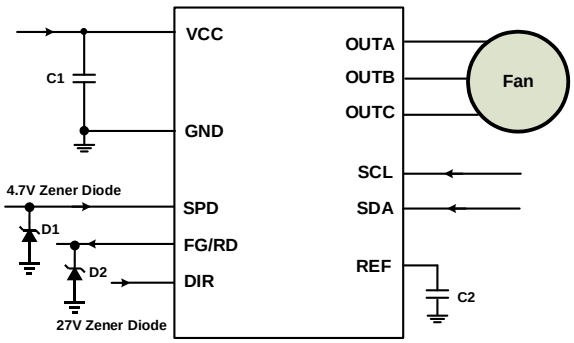


**Figure 10: External ESD-Enhanced Circuit**

## Motor Parameters Measurement

The motor phase resistance and phase inductance are two important parameters for sensorless FOC. The motor's phase resistance and inductance refer to the resistance and inductance from the phase output to the center tap, respectively.

To obtain the phase resistance, measure the resistance between two phase terminals using a multimeter or LCR meter, then divide the value by 2.

The phase inductance is measured by measuring the inductance between two phase terminals via the LCR meter, then dividing this value by 2. The LCR frequency and voltage setting are referenced to the 1kHz and 1V measurement.

## PCB Layout Guidelines

Efficient PCB layout is critical for stable operation and excellent performance. For the best results, refer to Figure 11 and follow the guidelines below:

1. Place $C_{IN}$ as close as possible to the VCC and GND pins.
2. Place the VREG bypass capacitor as close as possible to the VREG and GND pins.

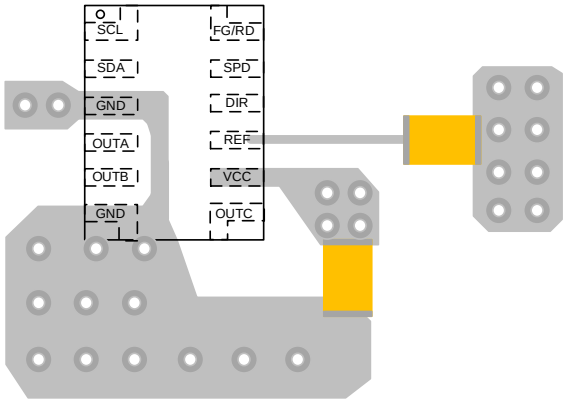


**Figure 11: Recommended PCB Layout**


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## TYPICAL APPLICATION CIRCUIT

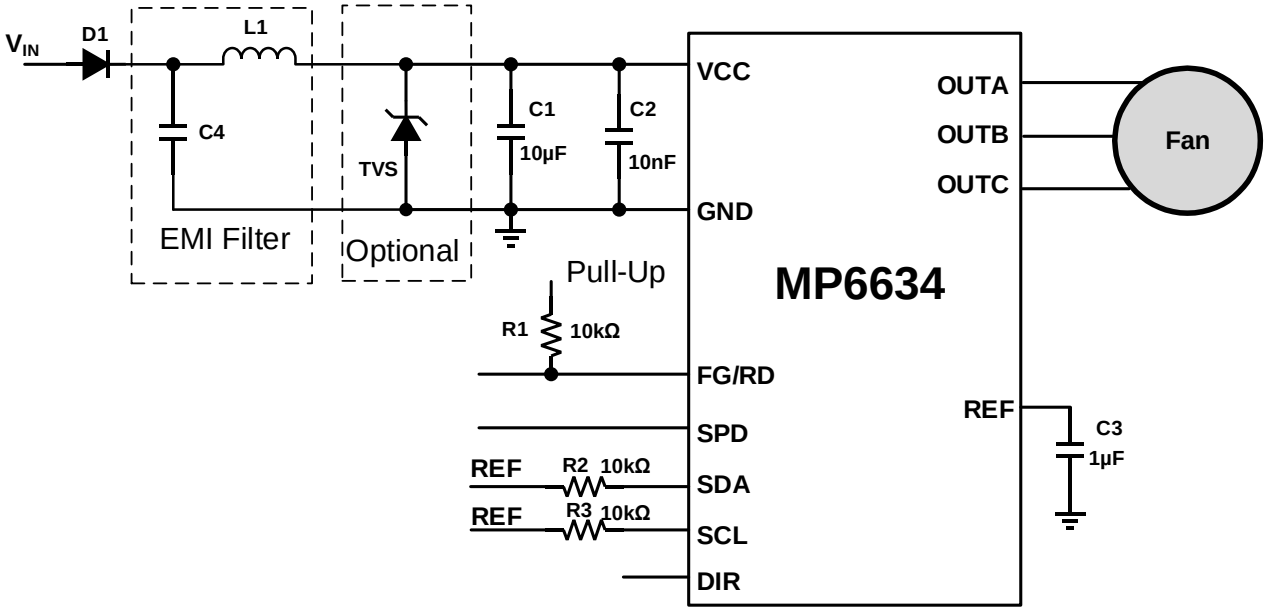


**Figure 12: Typical Application Circuit**


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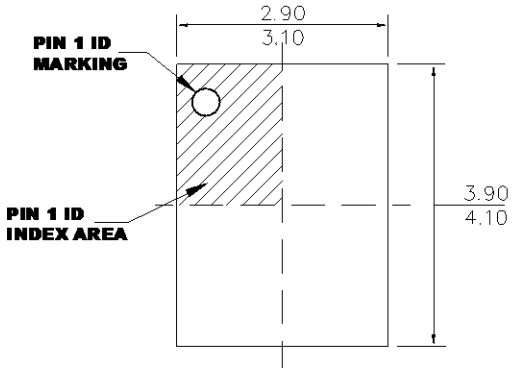
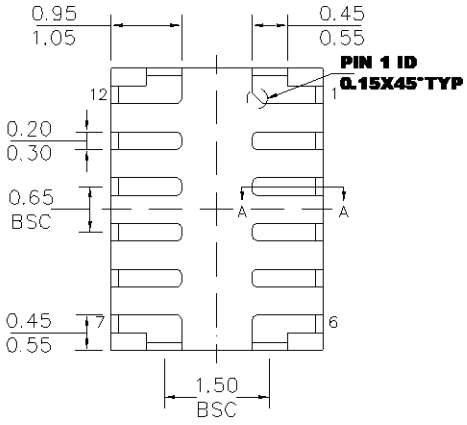
# PACKAGE INFORMATION

## TQFN-12 (3mmx4mm)

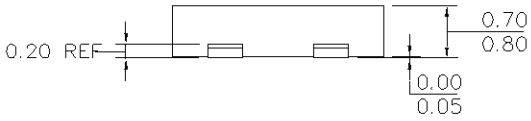
### Wettable Flank



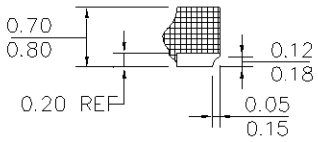

**TOP VIEW**



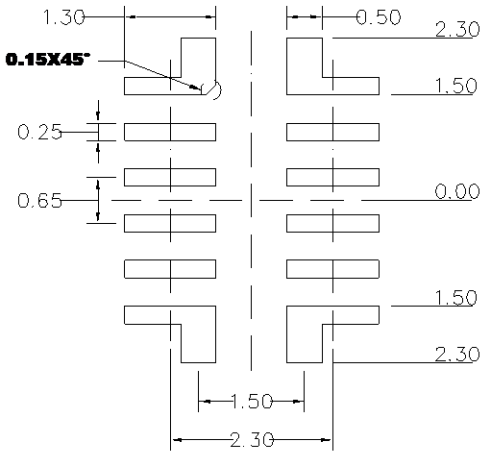

**BOTTOM VIEW**




**SIDE VIEW**




**SECTION A-A**




**RECOMMENDED LAND PATTERN**

**NOTE:**

1) THE LEAD SIDE IS WETTABLE.
2) ALL DIMENSIONS ARE IN MILLIMETERS.
3) LEAD COPLANARITY SHALL BE 0.08 MILLIMETERS MAX.
4) JEDEC REFERENCE IS MO-220.
5) DRAWING IS NOT TO SCALE.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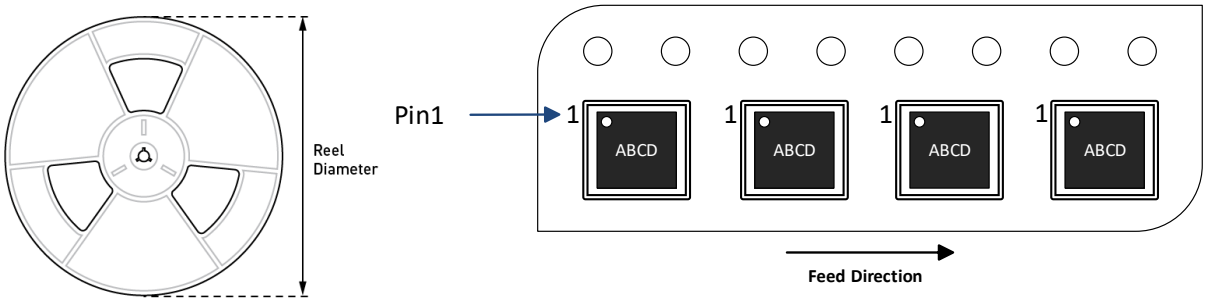
## CARRIER INFORMATION




| Part Number | Package Description | Quantity/ Reel | Quantity/ Tube | Quantity/ Tray | Reel Diameter | Carrier Tape Width | Carrier Tape Pitch |
|---|---|---|---|---|---|---|---|
| MP6634GLTE-xxxx-Z | TQFN-12 WF (3mmx4mm) | 5000 | N/A | N/A | 13in | 12mm | 8mm |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## REVISION HISTORY

| Revision # | Revision Date | Description | Pages Updated |
|---|---|---|---|
| 1.0 | 8/20/2024 | Initial Release | - |

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