# Three-Phase BLDC Motor Commutation Sequence

Table 1 - MOSFET states ON

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | A High | A Low | B High | B Low | C High | C Low |
| 1 | **ON** | OFF | OFF | **ON** | OFF | OFF |
| 2 | **ON** | OFF | OFF | OFF | OFF | **ON** |
| 3 | OFF | OFF | **ON** | OFF | OFF | **ON** |
| 4 | OFF | **ON** | **ON** | OFF | OFF | OFF |
| 5 | OFF | **ON** | OFF | OFF | **ON** | OFF |
| 6 | OFF | OFF | OFF | **ON** | **ON** | OFF |

Table 2 - Phase states ON

|  |  |  |  |
| --- | --- | --- | --- |
|  | A | B | C |
| 1 | HIGH | LOW | **FLOATING** |
| 2 | HIGH | **FLOATING** | LOW |
| 3 | **FLOATING** | HIGH | LOW |
| 4 | LOW | HIGH | **FLOATING** |
| 5 | LOW | **FLOATING** | HIGH |
| 6 | **FLOATING** | LOW | HIGH |

Table 3 - Signal states for L6393 ON

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | SD\_A | PHASE\_A | SD\_B | PHASE\_B | SD\_C | PHASE\_C |
| 1 | HIGH | HIGH | HIGH | LOW | LOW | LOW |
| 2 | HIGH | HIGH | LOW | LOW | HIGH | LOW |
| 3 | LOW | LOW | HIGH | HIGH | HIGH | LOW |
| 4 | HIGH | LOW | HIGH | HIGH | LOW | LOW |
| 5 | HIGH | LOW | LOW | LOW | HIGH | HIGH |
| 6 | LOW | LOW | HIGH | LOW | HIGH | HIGH |

Table 4 - MOSFET states OFF

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | A High | A Low | B High | B Low | C High | C Low |
| 1 | **ON** | OFF | **ON** | OFF | OFF | OFF |
| 2 | OFF | **ON** | OFF | OFF | OFF | **ON** |
| 3 | OFF | OFF | **ON** | OFF | **ON** | OFF |
| 4 | OFF | **ON** | ON | **ON** | OFF | OFF |
| 5 | **ON** | OFF | OFF | OFF | **ON** | OFF |
| 6 | OFF | OFF | OFF | **ON** | ON | **ON** |

Table 5 - Phase states OFF

|  |  |  |  |
| --- | --- | --- | --- |
|  | A | B | C |
| 1 | HIGH | HIGH | **FLOATING** |
| 2 | LOW | **FLOATING** | LOW |
| 3 | **FLOATING** | HIGH | HIGH |
| 4 | LOW | LOW | **FLOATING** |
| 5 | HIGH | **FLOATING** | HIGH |
| 6 | **FLOATING** | LOW | LOW |

Table 6 - Signal states for L6393 OFF

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | SD\_A | PHASE\_A | SD\_B | PHASE\_B | SD\_C | PHASE\_C |
| 1 | HIGH | HIGH | HIGH | HIGH | LOW | LOW |
| 2 | HIGH | LOW | LOW | LOW | HIGH | LOW |
| 3 | LOW | LOW | HIGH | HIGH | HIGH | HIGH |
| 4 | HIGH | LOW | HIGH | LOW | LOW | LOW |
| 5 | HIGH | HIGH | LOW | LOW | HIGH | HIGH |
| 6 | LOW | LOW | HIGH | LOW | HIGH | LOW |

Possible improvements:

* Connect all three brake inputs together instead of tying them to logic HIGH to simplify changing the motors direction; drawback – can’t use PORTC, because it doesn’t have any free pins on ATMEGA168

# ESC Processes

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Timing | Frequency | Period | Step | Source | Prescaler |
| Clock | 16 MHz | 62.5 ns | 62.5 ns | Crystal | 1 |
| ADC Clock | 125 kHz | 8 µs | - | Clock | 128 |
| Timer1 | 244.1 Hz | 4.096 ms | 62.5 ns | Clock | 1 |
| Timer0 | 7.843 kHz | 127.5 µs | 0.5 µs | Clock | 8 |

|  |  |  |  |
| --- | --- | --- | --- |
| Process | Frequency | Period | Execution |
| Control Signal | 50 Hz | 20 000 µs | ? |
| Commutation | < 700 Hz | > 14 000 µs | ? |
| Throttle | > 20 000 Hz | < 50 µs | ? |
| Current | ? | ? | > 112 µs |

Control Signal:

* 50 Hz square wave
* D+ determines throttle percentage
* Typical D+ 1000…2000 µs; Typical step count – 16 000
* Shouldn’t be missed (Priority 2)

Commutation:

* Dependent on current motor speed
* Mostly below 700 Hz (42 000 rpm)
* Triggered by pin change interrupt from zero crossing comparator
* Can’t be missed (Priority 1)

Throttle:

* Dependent on control signal
* Should be above 20 000 Hz (out of audible range)
* Typical step count below 100 or frequency above 60 kHz
* PWM where D+ is equal to throttle percentage
* Shouldn’t be missed (Priority 3)

Current:

* Single ADC measurement
* ADC clock – 125 000 Hz; Single measurement 9 615 Hz
* Can be missed (Priority 4)

1. Start spinning the motor
2. Interrupt ZC\_A
   1. Set commutation flag
3. Finish throttle cycle
4. Switch to state 1
5. Start throttle cycle
6. Interrupt ZC\_C
   1. Set commutation flag
7. Finish throttle cycle
8. Switch to state 2