CAN_Drv module configuration reference manual

Version: 1.01
Edit: 18. Dec. 2017

Introduction

CAN_Drv is a DC brushless motor driver with the CAN-bus interface, that is intended to be used with the CAN-enabled SimpleBGC32 controller in a camera stabilization system, replacing the on-board drivers. Currently, only the Extended and Pro controllers have a CAN-bus interface. A new smaller version of the controller without the integrated drivers will be available later.
CAN-driver allows to build a 3-axis stabilizer based on a modular scheme (example: https://www.basecamelectronics.com/files/SBGC_CAN_Modular_System_Connection_Diagram.pdf). System supports up to four additional motors for the other tasks. Such modular scheme benefits by the optimized wiring between modules that is perfectly immune to EMI noise, and better motor control algorithm compared to conventional SimpleBGC32 controllers with the integrated drivers.
The module specifications and pin-out could be found on the product page: https://www.basecamelectronics.com/can_driver/ This manual describes the configuration and calibration of CAN-driver.

Assigning drivers to the stabilization axes

Before configuring each driver, you must assign which physical driver will match each of the stabilization axes. Each driver has a unique identifier and must have a unique address on the CAN bus. In the SimpleBGC32 system, the addresses are denoted as CAN_Drv # 1..7. The address can be set by the hardware-specific jumpers on the driver card. The address is from 1 to 7. If the jumpers are not soldered, then the software address assignment is allowed. To do this, start scanning all connected modules (it can last long enough, wait until the end). Then assign the addresses to the modules and write these settings to the EEPROM. To determine which module exactly matches the ones found in the list, you can sequentially connect the modules to the bus one at a time and assign them addresses.

When modules received addresses from the list CAN_Drv # 1..7, you can use them wherever the outputs to the motors are assigned. For the three main stabilization axes, it can be done in the section “Hardware” → “Motor configuration” → “Motor outputs”.

Address selection by jumpers:

SW3	SW2	SW1	Address
0	0	0	software-assigned
0	0	1	drv#1
0	1	0	drv#2
0	1	1	drv#3
1	0	0	drv#4
1	0	1	drv#5
1	1	0	drv#6
1	1	1	drv#7

Settings

If the CAN driver is used to stabilize one of the main axes (YAW, PITCH, ROLL), then some parameters are taken from other GUI tabs. These fields can be left blank in the "CAN Modules" tab; the system doesn't use them.

CAN_Drv parameter	The preemptive parameter from the other tabs
Number of poles	Hardware → NUM.POLES
Encoder type	Encoders → Encoder type
Encoder/motor gear ratio	Encoders → Motor/encoder gearing ratio
Encoder El. field offset	Encoders → El. field offset
Encoder Zero angle offset	Encoders → Offset
Heat model - heating factor	Encoders → Heating factor
Heat model - cooling factor	Encoders → Cooling factor
Max. effective power	Hardware → Motor Power Settings → Power
Magnetic link of rotor to stator	Hardware → MAGNETIC LINK.

In the "CAN Modules" tab there are two types of settings: the “CAN Driver software configuration” - parameters for a particular motor, and the “CAN Driver hardware configuration” - parameters for a particular board schematics version. **WARNING!** It is not recommended to make changes to the “CAN Driver hardware configuration” in case the driver works correctly, because entering incorrect values can destroy the board.

Motor parameters (soft parameters)

Parameter	Min	Max	Description
Module to edit			Select a module for editing parameters.
Motor resistance (single phase), Ohm	0	655,35	The resistance of motor phase in Ohms (resistance between two motor leads divided by two).
Motor inductance Ld (single phase), mH	0	-	Ld (d-axis inductance) of the motor phase in mH. (the smallest inductance of the motor between the two motor leads divided by two). It is unlimited when editing, usually less than 100 mH.
Motor inductance Lq/Ld ratio	1	100	Inductance Lq - is the biggest inductance of the motor. Lq / Ld is the ratio of the inductances.
Number of poles	1	255	Number of motor poles.
Current loop bandwidth, rad/s	0	15000	It determines the bandwidth of the closed-loop system. The higher the value, the greater is the PI current control gain, the more accurate and faster reaction rate, but the greater is the acoustic noise from the current loop.
Current loop I-term gain	0	255	The P/I ratio for the PI current regulator. The range 0..255 corresponds to the ratios from 0.1 to 10 with the exponential scale, where 127 = 1.0.
Max. average current, A	0	655	RMS value of software current limit at which protection will trigger.

Over-temperature protection (int. sensor), C	0	124	The threshold for over-temperature protection, where temperature is measured on the driver's PCB.
Over-temperature protection (ext. sensor), C	0	124	The threshold for over-temperature protection, where temperature is measured (or estimated by the model) on the motor.
Heat model - heating factor	0	255	If the motor temperature sensor is not connected, the simple model will be used to estimate a temperature. This parameter determines how quickly the motor warms up, depending on the current applied to it.
Heat model - cooling factor	0	255	In the model, this parameter determines how quickly the motor cools down due to difference with the environment temperature.
PWM frequency, kHz	18	64	PWM frequency of the power stage FETs. The higher is the value, the higher are losses on the keys and their heating, but the lower is resolution. Also it defines the requirements for the capacitance of the filtering capacitors. For low-resistance motors it may be useful to set the frequency higher.
Encoder type	-	-	The list of the supported encoders. For more information on using encoders please refer to the manual https://www.basecamelectronics.com/files/SimpleBGC_32bit_Encoders.pdf
Encoder/motor gear ratio	-	-	The ratio of the encoder's angle of rotation to the angle of the motor, and the inversion (positive value - encoder is non-inverted, negative - it is inverted).
Encoder El. field offset	-32767	32767	Electrical angle offset. It is calibrated by the system.
Encoder Zero angle offset	-32767	32767	Used for a servo-mode only (position control loop) and defines the position where angle is zero.

Max. effective power	0	255	Maximum power applied to the motor.
Max. speed limit, RPM	0	65535	The motor speed limit for a servo-mode.
Magnetic link of rotor to stator	0	655.35	A running motor generates a back-EMF. To correct it, specify this constant. Standard dimension: Ke = V*s/rad (Volt * second / radian) Conversion into our units: Ke_basecam = Ke *18,70328124*NumPoles
PID controller gains. Over speed/ Over Angle: P I LPF frequency, Hz	0 0 0	655.35 655.35 500	The parameters of the PI regulator over speed and position, proportional and integral parts. They are used for a servo-mode only. If speed control mode is used, there is no need to fill in the "Over Angle" parameters. In the position control mode, the parameters of both PI-loops are required. Additionally, a low-pass filter may be used to cut off high-frequency noise.

Notch filters Center frequency, Hz Width, Hz Gain, Db	0 0 -127	500 255 127	Filters can greatly improve the quality of PID controller operation in some cases. These filters can reject narrow bandwidth resonances in case when the system has a pronounced mechanical resonance. It allows to increase the feedback gain and get more accurate and stable response of the PI regulator. But this filter will be useless if oscillations appear in the broad frequency range. In this case, consider using a low-pass filter. With the parameter **Gain,** you can control the effect of the notch filter. Positive value to reject, negative value to amplify. *Hint*: you can detect the resonance frequency by the oscilloscope or by the audio spectroscope on smartphone, if vibration is audible.

CAN Drv board parameters (hard parameters)

Note: In most cases they should not be changed, unless you are a developer of the CAN_Drv board.

FET drive output type	Driver output Type: 6-channel complementary PWM (high and low side with dead-time - separate channels for controlling low-side and high-side gate of the transistor with dead-time) 3-channel PWM with three driver turn-on outputs
PWM output polarity	The polarity of the timer output for the low-side and high-side gate is separate. It can take two values: "high" and "low". "High" - the transistor is open at a high logic level at the microcontroller pin, "low" - at a low level.

Dead-time, ns	A dead-time control circuit eliminates shoot-through currents through the main power FETs during switching transitions and provides high efficiency for the buck regulator. It is a delay between the opening/closing of a low-side gate and the closing/opening of the high-side.
Op-amp type	Type of operational amplifier: Internal - built-in in the MCU External - external circuit None (gain = 1) - current sensor is used
Op-amp gain	The gain of an operational amplifier.
Shunt resistance, mOhm ICS sensitivity, mV/A	In the case of using the op-amp, the value of this field indicates the resistance of the shunt. In the case of using a current sensor - it indicates its sensitivity.
Current sensor R offset ratio	The ratio of resistive divider that adds a voltage offset for a current sensing circuit. *Divider shifts the output of the op-amp to make it equal about half of the MCU supply voltage, when no current flows through the shunt resistor.*
ADC rise pulse delay, ns	The time delay adds after switching transitions before current digitizing.
ADC sampling time factor	The factor of the duration of current digitizing.
Battery voltage sensor R divider	The voltage divider ratio.
Max PWM duty cycle, %	The maximum permissible PWM modulation factor is specified for the 18kHz frequency. The higher is the PWM frequency, the lower is the ratio. Inside the driver, a calculation is made using the formula (MMI - max modulation index): MMI = 1 - (PWM Freq in kHz)/18 * (1 - (Max PWM duty cycle in %/100))
Over-current protection threshold, A	A threshold for a current at which the short-circuit protection will trigger.

Calibration

LR calibration

***WARNING**: It is recommended to remove the camera from the gimbal during this calibration, because generated vibrations can adversely affect the camera.*

Firstly, the resistance is calibrated, when the motor is supplied with a constant voltage. The stator is locked to the rotor by some force. Approximate duration is about a second. Then the inductance is measured, when the stator moves freely relative to the rotor. You need to slowly rotate it by hands to 20-40 degress so that system can find the minimum and maximum inductance. The measurement lasts about 10 seconds.

B-EMF constant calibration.

Before starting the calibration, it is necessary to check the correctness of the stator resistance parameter and the number of motor poles - otherwise the constant will be calculated incorrectly. It is necessary to rotate the motor by hands to perform the calibration. Do fast enough rotations in both directions. If possible, use a drill/screwdriver to increase the value of the generated EMF and thereby increase the signal-to-noise ratio. It’s more important for the motor with small inductance of the windings. When calibrating, peak values are displayed in GUI. When a particular speed of rotation is reached, the constant ceases to grow - this is the required value.

Initialization and modes of work

If the battery isn’t connected, but the main board has 5V power supply - e.g., a USB cable is connected, and the driver's power is off, - the board will be in the search mode. When the drivers get the power, they will be initialized by the main board. If there is a power failure, an error will occur.

There are three main modes of the driver:

- The asynchronous operation, setting the specified electrical angle. The system works in this mode if the parameter “Encoder El. field offset” (electrical angle offset) is not specified. ATTENTION! In this mode, the motor is continuously supplied with a full current, which can cause overheating of the motor and/or driver. Watch the temperature and adjust the max. power parameter for safe operation. This mode is intended only for doing the encoder calibration.

- With the encoder enabled and calibrated, but current loop disabled (parameters “Motor inductance Ld(single phase), mH” and “Current loop bandwidth, rad/s” is set to 0). This mode is similar to the mode of a conventional SimpleBGC32 controller with encoders.
- A full-featured FOC with current feedback when all motor parameters are set.

The main controller can use CAN-drivers to stabilize a camera (one driver per axis) with the feedback from the main IMU sensor, or as external servo-controllers with the feedback from the encoder, in closed loop over torque, speed or position. A support for additional motors in servo mode will be added to the firmware in the future. Some examples when additional motors may be used together with the gimbal controller::

- The motor driver of the 4th axis, which intended to maintain the three main axes in the "normal" (i.e., orthogonal) state, extending the range of working angles of the system
- The focus, zoom and iris drives based on brushless motors (silent, fast and precise), linked to the SimpleBGC32 controller and controlled remotely or by scripts.
- Motion controller - pre-programmed camera rotations and simultaneous movement in 3D space built completely with the brushless motors..
- Additional motors with reaction massess to increase the precision of stabilization for long-range cameras.
- .. and so on. Your ideas are welcome!

Protection systems

CAN_Drv module has several types of protection:

- Fast hardware under-voltage protection is implemented using an integrated comparator. When the voltage level is less than 6V, the protection is triggered, and the PWM is switched off. The approximate hysteresis value is 100 mV, i.e., after reaching ~ 6.1V, PWM will be turned on.
- Slow software under-voltage protection - the threshold specified by the parameter “Service → Battery Monitoring → Low voltage threshold,V (stop motors)”, reduced by 5%. When the voltage drops below threshold, motors are turned OFF; when the level is restored back (with some hysteresis applied), the error will be reset and the driver resumes operation.

- Fast hardware over-current protection is implemented using an integrated comparator. It protects the board from short circuit. The level is specially overestimated since even a short surge current will cause triggering of protection. It is determined by the max. impulse current characteristic of the transistor from the datasheet. To resume normal operation, system should be restarted.
- Slow software over-current protection. It triggers when the average current in the motor exceeds the specified threshold. To resume normal operation, system should be restarted.
- Protection by the signal on the “Emergency stop” port. The input is pulled up internally. The switch is normally open, and to trigger a protection it connects to the ground. To resume normal operation, system should be restarted.
- Protection against loss of communication. If the board does not receive a synchronization message within ~20ms, the motor torque is set to zero.
- Protection against overheating of the driver board. The temperature is read by the built-in temperature sensor. If it exceeds the specified limit, system stops working. To resume normal operation, system should be restarted.
- Protection against motor overheating. It is possible to use a temperature sensor DS18B20 (1-GND, 2-DQ, 3-Vdd) to monitor the temperature of the motor. The common sensor lead (DQ) must be connected to the corresponding terminal of the board. The Vdd is connected to + 5V, or connected to pin 2 (DQ) (parasitic power - only two wires are used). If the motor temperature sensor is not connected, a simple model may be used. This model estimates the temperature of a motor taking into account consumed power and dissipated power and must be configured to provide adequate results.
- FOC duration. Occurs when the period of the FOC cycle is abnormal.

Modes of LED operation.

1. **Fast blinking orange** - bootloader mode is active, starts when power is applied. During auto-search, it can briefly light up green.
2. **Continuously red** when the power is turned on - it is an internal error of the bootloader firmware. You need to update the firmware with an external adapter. Contact manufacturer of the module for details.
3. **Slowly blinking green** - the board is in the operating mode, but not initialized.
4. **Constantly green** - the board is in the normal operating mode and initialized.

5. **Blinking red** - an error has occurred. Depending on the type of blinking, you can determine the reason of error (also it can be found in the GUI). Frequent blinking means that there are several errors. Denoting "•" for a short blink, "-" for a long blink:

Overcurrent protection:	A:	• -
Undervoltage protection:	B:	- • • •
Emergency pin:	C:	- • - •
FOC duration:	D:	- • •
MCU overheat:	E:	•
DRV overheat:	F:	• • - •
Overcurrent software	G:	- - •
CAN Bus off:	H:	• • • •
Encoder not found:	I:	• •