



## **SBGC32\_I2C\_Drv expansion module reference manual**

ver. 0.2 – 28.03.2015 – first edition

ver. 0.3 – 11.04.2015 – Add “Q&A”, “Flashing MCU” sections.

ver. 0.4 – 27.12.2017 – Add “API and examples” section

ver.0.5 – 05.09.2018 – The list of supported encoders was extended by new models; text was updated to conform with the latest GUI and firmware versions;

## Overview

This module is intended to work as a part of the SimpleBGC32 camera stabilizer system, performing a motor driver function. Unlike regular scheme, where all motors and encoders are connected to the main board and driven by the single MCU, in the modular scheme each motor is driven by its own MCU, that lets to optimize cabling: encoder is integrated into the PCB for each module, and motor's cable goes to it by the shortest way. See [Appendix A](#) for an example of connection. Schematics, firmware and other resources you can find on the product's page: [https://www.basecamelectronics.com/sbgc32\\_i2c\\_drv/](https://www.basecamelectronics.com/sbgc32_i2c_drv/)

This expansion module is supported only in the encoder-enabled version of the SimpleBGC32 firmware: <https://www.basecamelectronics.com/encoders/>

## Features:

- **Flexibility** - This module can replace one or two motor+encoder pairs. Using it for all three motors is possible, but not recommended because I2C transfer on 400kHz rate will not fit into 800us cycle time. There is an option to increase I2C speed to 800kHz for small systems.
- **Low cost** - Each module consists of entry-level STM32F051 series MCU, cheap magnetic or analog encoder, a FET- or IC-based motor driver and a minimal number of other components.
- **Better cabling** - a 5-wire cable is required to connect main MCU with the I2C\_Drv modules and IMU sensor, all connected in parallel.
- **Compact size** - MCU is available in the UFQFPN32 package, allowing ultra-compact design and installation into small motors.
- **Reliable, low power consumption** - rotary encoders allow to apply advanced FOC algorithm for driving motors
- **Software compatibility** - fully compatible with SimpleBGC32 software stack (including GUI, mobile applications, Serial API, etc.)

## Motor driver output circuit

Module provides 6 PWM outputs to drive 3 half-bridges at ultra-sonic frequency. 300-400ns dead-time is inserted. It lets to use simple FET-based output circuit, or use integrated circuits like DRV8839, DRV8313, and any other IC that encloses 3 half-bridges and all protection circuits. Several output driver circuits are provided in the schematics, as an example.

## Encoder

One of the purposes of this module is to let to integrate encoder and motor driver into single PCB to minimize overall size of a system. For this purpose, a compact-sized magnetic encoder will be the best choice.

List of supported encoders with its props and cons:

<i>Model</i>	<i>Installation</i>	<i>Interface</i>	<i>Props</i>	<i>Cons</i>
AS5048A	on-axis	SPI	small size, high resolution (14bit), high update rate, perfect integration	expensive compared to other magnetic ICs
AS5048B	on-axis	I2C	small size, high resolution (14bit), high update rate, perfect integration	expensive; compatible with the 48- or 64-pin MCU only;
AMT203	on-axis in housing	SPI	shaft with pass-through hole is possible; easy installation on a shaft	big size; medium update rate; external mounting only; expensive
MA3 (10bit, 12bit)	on-axis in housing	PWM		external mounting only; slow update rate; expensive
Analog	?	analog	low cost, good integration, high update rate	full 360 degree rotation is not possible; friction reduces a life-cycle;
AS5600	on-axis	I2C	low cost, good integration, high update rate	compatible with the 48- or 64-pin MCU only;
AS5050A	on-axis	SPI	low cost, good integration	medium update rate; low resolution
AS5055A	on-axis	SPI	low cost, good integration	medium update rate
RLS "Orbis"	off-axis PCB w/out housing	SPI	<b>pass-through hole</b>	expensive
<b>MA730</b>	<b>on-axis</b>	<b>SPI</b>	<b>low cost; high resolution 14bit; ultra-compact size; high update rate;</b>	
AM4096	on-axis	I2C	low noise, true 12bit	big size of IC package; compatible with the 48- or 64-pin MCU only;

Notes:

1. Update rate is not crucial parameter for general application of the SimpleBGC system, so all types of supported encoders suit well.
2. With the on-axis encoder, a special effort is required when designing a system that should support an infinite 360-degrees rotation of a motor. When using sliprings, pay special attention to normal work of the I2C bus. It may be required to use I2C signal extenders / amplifiers.

More information about using and configuring encoders in the SimpleBGC32 system you can find in this document: [https://www.basecamelectronics.com/files/SimpleBGC\\_32bit\\_Encoders.pdf](https://www.basecamelectronics.com/files/SimpleBGC_32bit_Encoders.pdf)

### **Notes on schematics**

We provide a reference schematics, which contains a circuits for some types of supported encoders, several examples of output motor driver circuits and several packages of MCU (you can chose from LQFP32, UFQFPN32, LQFP48, UFQFPN48, UFBGA64 case, 32k or more FLASH).

There are 2 options for flashing MCU: via SWD port and ST-Link utility, or via UART port and integrated bootloader. For the second option, additional components are required, as shown on the schematics.

For the I2C encoders, 32-pin MCU case is not applicable. Use 48- or 64-pin case.

### **Flashing MCU**

To upload firmware, you can use UART port and **Flash Loader Demonstrator** tool from ST company, or any other flashing tool that can communicate with standard STM32 bootloader, including our GUI "Upgrade" tab in the manual mode. Second option is SWD port and **ST-Link** tool and utility (can be bought separately or found as a part of some "STM32Discovery" boards). Both interfaces are shown in the schematics, choose one that you like.

### **Configuring SimpleBGC 32bit controller to work with the expansion modules**

1. Open SimpleBGC GUI , go to "Advanced" tab, "Motor outputs" group. Chose "SBGC32\_I2C\_drv#1..4" module in the drop-down list for any axis you want. Number 1..4 is configured by setting ADDR0, ADDR1 jumpers on the module: solder jumper to connect address pin to VDD for high level, or leave it floating to set low level (pin is pulled-down internally).

<i>Role</i>	<i>ADDR0</i>	<i>ADDR1</i>
SBGC32_I2C_drv#1	0 (low)	0 (low)
SBGC32_I2C_drv#2	1 (high)	0 (low)
SBGC32_I2C_drv#3	0 (low)	1 (high)
SBGC32_I2C_drv#4	1 (high)	1 (high)

2. In the “Encoders” tab, chose the same module for corresponding axis. Select a type of encoder, installed on the module, in the drop-down list below.



3. It's better to increase the I2C speed by selecting the “I2C high speed” option in the “Hardware” tab, to minimize delays caused by the I2C data transfer. But it may be required to decrease overall resistance of pullups on SDA, SCL lines to 1..2k, otherwise I2C errors may come. Please pay attention to this fact when designing your own system.

4. Second (frame) IMU is not required for the encoder-enabled gimbal design and may be omitted.

All other settings for motor output and encoder are remain the same as in regular system. You can find further instructions in the "SBGC32 User Manual" and the "Encoders" manual, available to download from our web-site:

[https://www.basecamelectronics.com/files/v3/SimpleBGC\\_32bit\\_manual\\_2\\_6x\\_eng.pdf](https://www.basecamelectronics.com/files/v3/SimpleBGC_32bit_manual_2_6x_eng.pdf)

[https://www.basecamelectronics.com/files/SimpleBGC\\_32bit\\_Encoders.pdf](https://www.basecamelectronics.com/files/SimpleBGC_32bit_Encoders.pdf)

## **Licensing**

Binary firmware and schematics for SBGC32\_I2C\_Drv module are provided free of charge, limited to use only as a part of the SimpleBGC 32bit controller-based system. Source code is a property of Basecamelectronics and is not published. It is available for our partners upon a request.

## **Q&A**

*Q: How does it identify the motor pitch and the motor roll?*

A: There are 2 ADDR pins to chose I2C slave device address from four options. Set any unique address for each module, that defines them as “module 1..4”, than choose corresponding module in the GUI. More information can be found in the section "Configuring SimpleBGC 32bit controller to work with the expansion modules".

*Q: I cannot find a circuit diagram of the main controller to be used in a modular scheme. What can*

*I refer to in order to find it?*

A: The main controller is based on the regular 32bit board reference schematics. You can remove unused motor drivers and connectors to optimize its size, and add other service electronics like LiPo charger, bluetooth module, smart power switch, etc., that are not present in the original SBGC32 reference design. All functions and interfaces of the main controller are available as before, and you can still use main controller to drive any motor directly, or drive it via I2C\_Drv.

*Q: Is it possible to apply DRV8313 instead of the original motor driver, shown in the schematics? If it is not possible, how can we get increased motor power?*

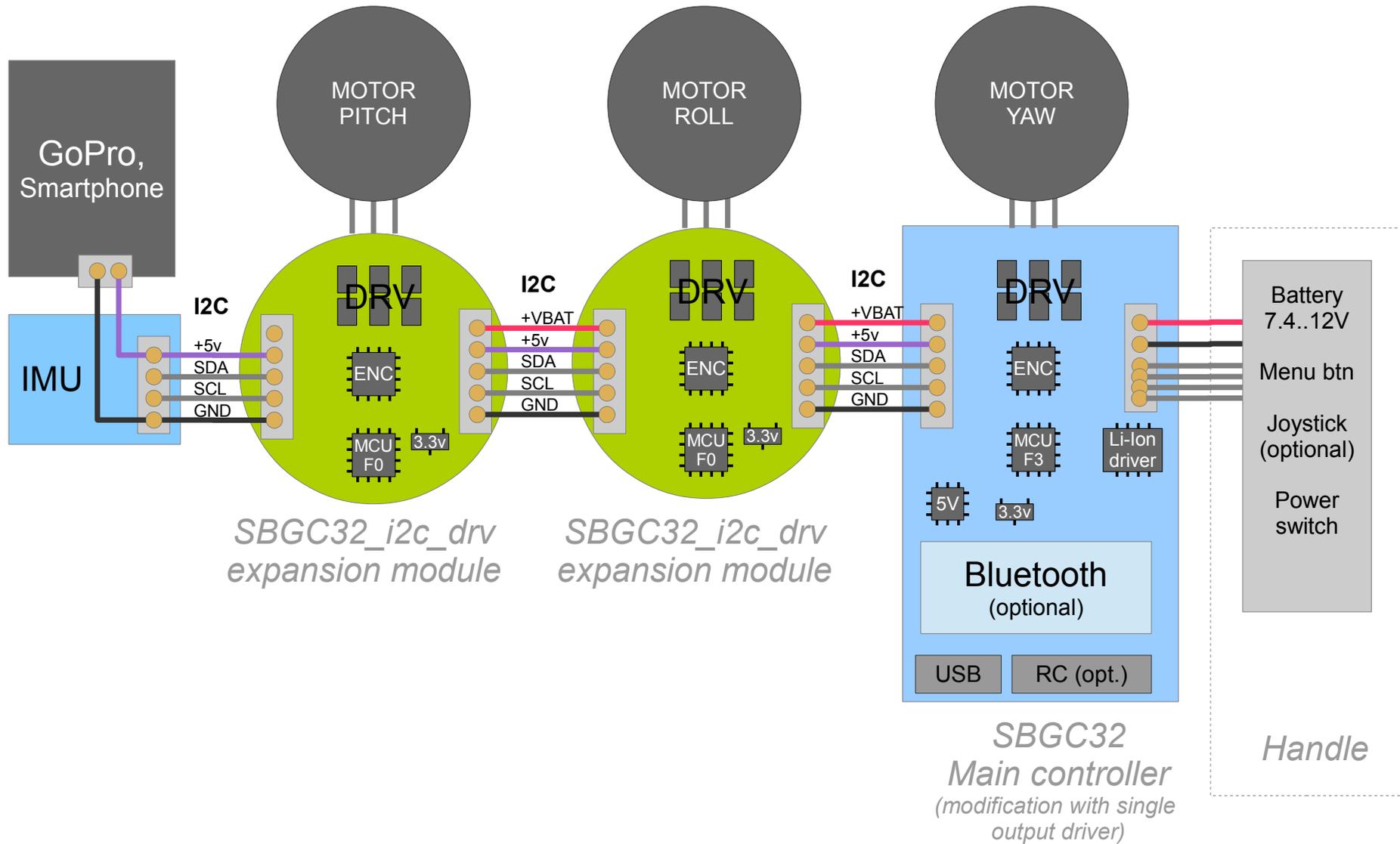
A: Yes, you can apply DRV8313 or any other suitable motor driver that has 3 independent full-bridges with the 3x PWM inputs and ENABLE input, compatible with the 3V-level logic.

*Q: I want to use I2C\_Drv with the encoder that is not present in the list. Is it possible?*

A: You can send a request to the Basecamelectronics team for adding a support of a new model of encoder in the I2C\_Drv firmware. Note that it should have I2C or SPI-compatible interface, and should be absolute. Incremental encoders are not supported! Also consider using the "CAN Driver" module, that acts similar to the I2C\_Drv module, but has more advanced motor control algorithms and provides more connection options

[https://www.basecamelectronics.com/can\\_driver/](https://www.basecamelectronics.com/can_driver/)

## Appendix A: SBGC32\_I2C\_Drv connection diagram



## Appendix B: I2C\_Drv API and examples

The API consists of the definition of I2C registers. The master controller reads and writes them to operate the module.

### I2C\_Drv.h

```
/*
  This is a part of SimpleBGC project source code
  Copyright (c) 2015 Aleksei Moskalenko

  SBGC32_i2c_drv - expansion board with brushless driver, encoder and I2C interface
*/
#define I2C_DRV_H_
#define I2C_DRV_H_

// Device address (7bit)
#define I2C_DRV_START_ADDR 0x19

// Device identifier. Check it when discovering
#define I2C_DRV_DEVICE_ID 0x14

/***** Register map *****/
/* Note that though registers are 16bit, lower byte can be read/written by 8bit
transactions */
// Encoder
#define I2C_DRV_REG_ENC_RAW_ANGLE 40
#define I2C_DRV_REG_ENC_ANGLE 41
#define I2C_DRV_REG_ENC_INFO 6
#define I2C_DRV_REG_ENC_ERR_CNTR 42

// Motor driver
#define I2C_DRV_REG_SET_POWER_ANGLE 0
#define I2C_DRV_REG_SET_POWER 0
#define I2C_DRV_REG_SET_ANGLE 1
#define I2C_DRV_REG_SET_FORCE_POWER 2
#define I2C_DRV_REG_SET_ENABLE 3

// Configuration
#define I2C_DRV_REG_ENC_TYPE 4
#define I2C_DRV_REG_ENC_CONF 5
#define I2C_DRV_REG_ENC_FLD_OFFSET 7

// Device info
#define I2C_DRV_REG_DEVICE_ID 39
#define I2C_DRV_REG_FIRMWARE_VER 32
#define I2C_DRV_REG_MCU_ID 33
#define I2C_DRV_MCU_ID_SIZE 6
#define I2C_DRV_REG_I2CS_ERR_CNTR 43

// Misc. functions
#define I2C_DRV_REG_RESET_MODE 8
```

```
/******
```

```
// Types of supported encoders
#define I2C_DRV_ENC_TYPE_AS5048A 1
#define I2C_DRV_ENC_TYPE_AS5048B 2
#define I2C_DRV_ENC_TYPE_AMT203 3
#define I2C_DRV_ENC_TYPE_MA3_10BIT 4
#define I2C_DRV_ENC_TYPE_MA3_12BIT 5
#define I2C_DRV_ENC_TYPE_ANALOG 6
#define I2C_DRV_ENC_TYPE_AS5600 7
#define I2C_DRV_ENC_TYPE_AS5050A 8
#define I2C_DRV_ENC_TYPE_AS5055A 9
```

```
#endif /* I2C_DRV_H_ */
```

## Example of using I2C\_Drv

```
uint8_t OutputI2CDrv::init(uint8_t _out_port, uint8_t _axis)
{
    addr = (I2C_DRV_START_ADDR - 3) + _out_port;
    cur_power = 0;

    // Check if I2C board is connected (wait 2 sec)
    i2c::select_line(I2C_LINE_A);
    for(uint8_t i=0; i<100; i++) {
        if(i2c::read_reg_byte(addr, I2C_DRV_REG_DEVICE_ID) == I2C_DRV_DEVICE_ID) { //
check device ID
            return 1;
        }
    }

    return 0;
}

void OutputI2CDrv::write_reg_byte(uint8_t reg, uint8_t val) {
    i2c::select_line(I2C_LINE_A);
    i2c::write_reg_byte(addr, reg, val);
}

void OutputI2CDrv::powerOn() {
    write_reg_byte(I2C_DRV_REG_SET_ENABLE, 1);
}

void OutputI2CDrv::powerOff() {
    write_reg_byte(I2C_DRV_REG_SET_ENABLE, 0);
}

void OutputI2CDrv::output16(uint16_t el_angle) {
    i2c::select_line(I2C_LINE_A);
    uint16_t buf[2] = { cur_power, el_angle };
    i2c::write_reg_buf(addr, I2C_DRV_REG_SET_POWER_ANGLE, (void*)buf, sizeof(buf));

    // TODO: We can write force power, if encoder fld.offset is calibrated
    // (not yet implemented in the I2C_DRV firmware)
```

```

}

// Search for the I2C_Drv-connected encoder
void Encoder::_init_i2c_drv(uint8_t type) {
    i2c.addr = (I2C_DRV_START_ADDR - ENC_TYPE_I2C_DRV1) + type;

    i2c::select_line(I2C_LINE_A);

    if(i2c::read_reg_byte(i2c.addr, I2C_DRV_REG_DEVICE_ID) == I2C_DRV_DEVICE_ID) {
        // Get firmware version, if required
        //uint16_t frw_ver;
        //i2c::read_reg_buf(addr, I2C_DRV_REG_FIRMWARE_VER, &frw_ver, 2);

        // Configure the type of internal encoder
        if(i2c::write_reg_byte(i2c.addr, I2C_DRV_REG_ENC_TYPE, cfg)) {
            // Read it back to confirm activation. Wait max. 50ms
            for(uint8_t i=0; i<50 && !encoder_type; i++) {
                Time::delay_us(1000);
                if(i2c::read_reg_byte(i2c.addr, I2C_DRV_REG_ENC_TYPE) == cfg) {
                    encoder_type = type;
                    // configure field calibration
                    //i2c::write_reg_buf(addr, I2C_DRV_REG_ENC_FLD_OFFSET,
&(params.encoder_fld_offset[axis]), 2);

                    // Configure encoder
                    //     bits 0..3: LPF factor
                    //     bit 4: I2C fast mode
                    uint16_t conf = 5;
                    i2c::write_reg_buf(i2c.addr, I2C_DRV_REG_ENC_CONF, &conf,
sizeof(conf));
                }
            }
        }
    }

    i2c::errors_count = 0;
}

uint16_t Encoder::_read_i2c_drv() {
    uint16_t angle;

    i2c::select_line(I2C_LINE_A);
    if (i2c::read_reg_buf(i2c.addr, I2C_DRV_REG_ENC_ANGLE, &angle, 2)) {
        read_error = 0;

        return angle;
    }

    return 0;
}

void Encoder::_request_info_i2c_drv(uint8_t info[4]) {
    // info[0] - encoder error counter
    // info[1] - I2C slave error counter
    // Sub-type AS5048A, AS5048B:

```

```
// info[2] - magnitude
// info[3] - diagnostic register

i2c::select_Line(I2C_LINE_A);
info[0] = i2c::read_reg_byte(i2c.addr, I2C_DRV_REG_ENC_ERR_CNTR);
info[1] = i2c::read_reg_byte(i2c.addr, I2C_DRV_REG_I2CS_ERR_CNTR);

// Write any data to ENC_INFO reg to queue information from encoder
if(i2c::write_reg_byte(i2c.addr, I2C_DRV_REG_ENC_INFO, 0)) {
    Time::delay_ms(50); // wait a bit to let device to read information
    i2c::read_reg_buf(i2c.addr, I2C_DRV_REG_ENC_INFO, &info[2], 2);
}
}
```