**austriamicrosystems AG**

**is now**

# ams AG

The technical content of this austriamicrosystems application note is still valid.

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## 1    General Description

The AS5030 is a contactless magnetic rotary encoder for accurate angular measurement over a full turn of 360°.
It is a system-on-chip, combining integrated Hall elements, analog front end and digital signal processing in a single device.
To measure the angle, only a simple two-pole magnet, rotating over the center of the chip is required.
The absolute angle measurement provides instant indication of the magnet's angular position with a resolution of 8 bit = 256 positions per revolution. This digital data is available as a serial bit stream and as a PWM signal.
In addition to the angle information, the strength of the magnetic field is also available as a 6-bit code.
Data transmission can be configured for 1-wire (PWM), 2-wires (CLK, DIO) or 3-wires (CLK, DIO, CS).

A software programmable (OTP) zero position simplifies assembly as the zero position of the magnet does not need to be mechanically aligned.
A Power Down Mode together with fast startup- and measurement cycles allows for very low average power consumption and makes the AS5030 also suitable for battery operated equipment.
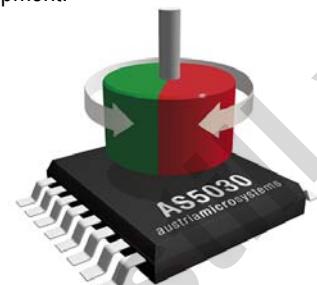
## 2    The AS5030 Adapterboard

### 2.1    Board description

The AS5030 adapter board is a simple circuit allowing to test and evaluate the AS5030 rotary encoder quickly without having to build a test fixture or PCB.
The PCB can be used as standalone unit or attached to a microcontroller.
The standalone operation requires only a 5V power supply, the magnet's angle can be read on the PWM or analog output.



JP1 connector
(Alarm, PWM, analog, power supply)

JP2 connector
(serial IO, power supply)

4 x 2.6mm mounting holes

P2 solder bridge
Close (default): 3 wire serial mode
Open: 2 wire serial mode

P1 solder bridge
Close (default): Sin/Cos output disabled
Open: Sin/Cos output enabled

AS5030 encoder

Analog Sin/Cos outputs
(P1 must be opened)
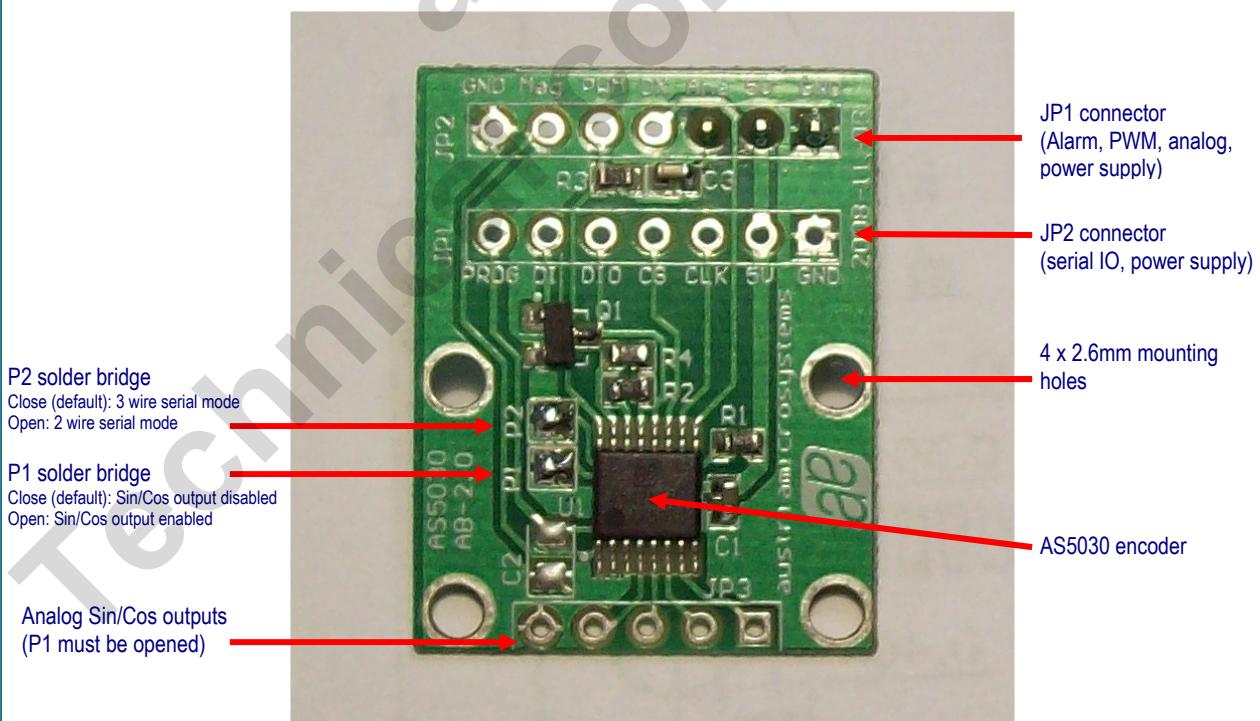
Figure 1: AS5030 Adapterboard

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## 2.2    Mounting the AS5030 adapter board



M2~M2.5 Screw + nut

Bearing

Casing

Rotating shaft and magnet holder
Not ferromagnetic (plastic, brass, copper,
stainless steel, aluminum…)

Magnet

0.5~2mm

AS5030

Spacer

AS5030-AB PCB

JP2 connector, 3 pin
(Analog out, 5V, GND)

22mm

| JP2 | GND | Mag | PWM | DX | Ana | 5V | GND |

| JP1 | Prog | DI | DIO | CS | CLK | 5V | GND |

28mm

4x2.6mm

Diametral
Magnet

11mm

P2

P1

N

S

AS5030

18mm
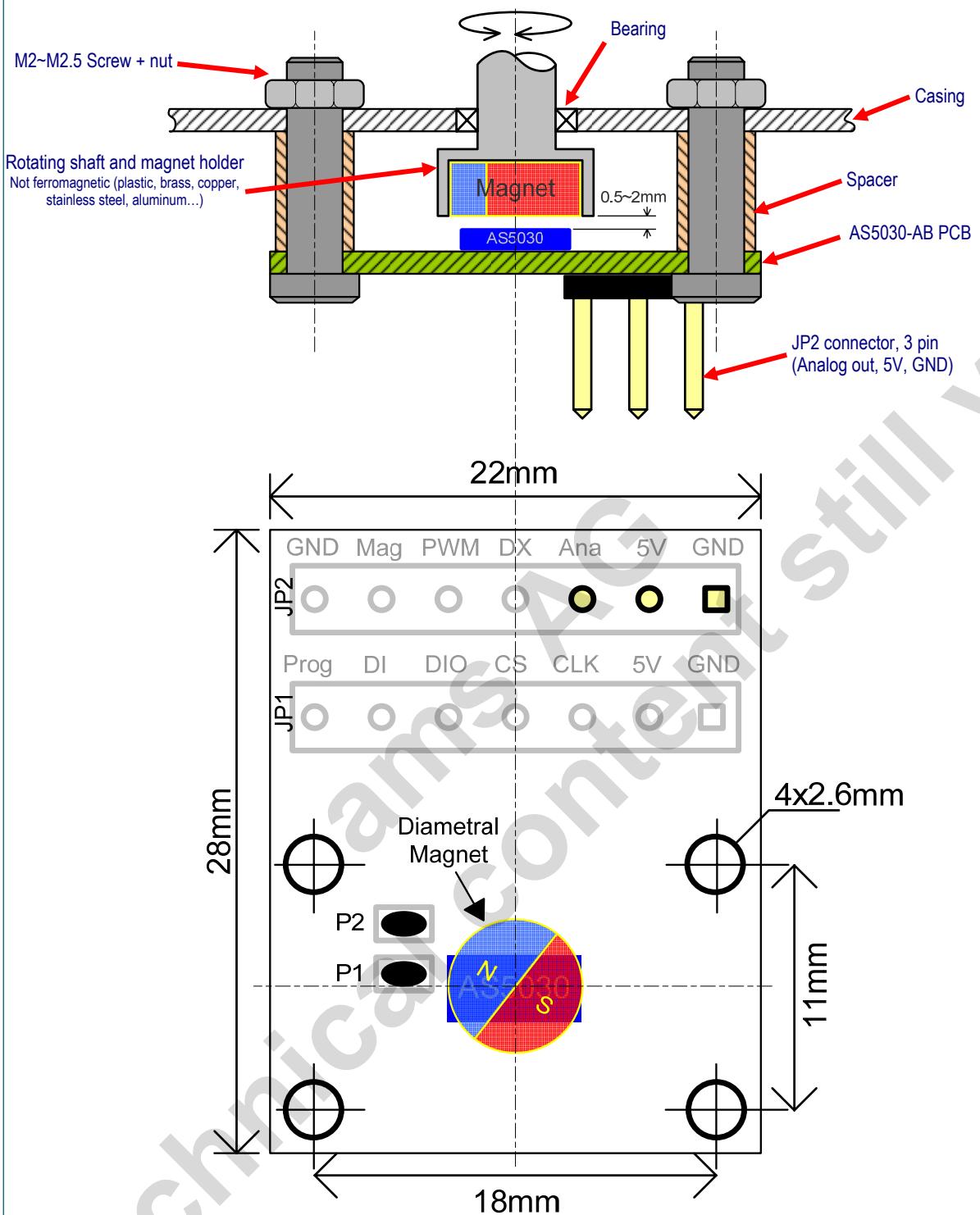
Figure 2: AS5030 adapter board mounting and dimension

A 6x2.5mm diametral magnet must be placed over on under the AS5030, and should be centered on the middle of the package with a tolerance of 0.5mm.
The airgap between the magnet and the AS5030 casing should be maintained in the range 0.5mm~2mm.

The magnet holder must not be ferromagnetic. Materials as brass, copper, aluminum, stainless steel are the best choices to make this part.

# 3   AS5030 and adapter board pinout
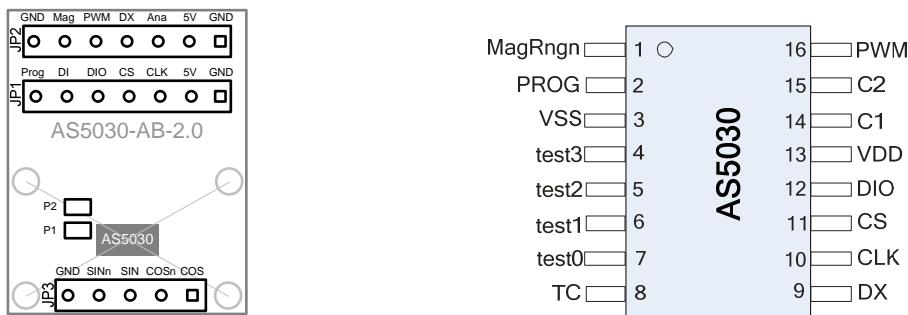
Figure 3: AS5030 adapter board connectors and encoder pinout

| Pin# Board | Pin# AS5030 | Symbol | Type | Description |
|---|---|---|---|---|
| JP1 - 1 | 3 | GND | S | Supply ground |
| JP1 - 2 | 13 | 5V | S | Positive supply voltage, 4.5V to 5.5V |
| JP1 - 3 | 10 | CLK | DI_ST | Clock Input of Synchronous Serial Interface; Schmitt-Trigger input |
| JP1 - 4 | 11 | CS | DI_ST | Chip Select for serial data transmission, active high; Schmitt-Trigger input, external pull-down resistor (~50kΩ) required in read-only mode |
| JP1 - 5 | 12 | DIO | DIO | Data output / command input for digital serial interface |
| JP1 - 6 | - | DI | DI | Command input for digital serial interface. Connect to GND if not used. |
| JP1 - 7 | 2 | PROG | S | OTP Programming voltage supply pin. Leave open or connect to VDD if not used |
| JP2 - 1 | 3 | GND | S | Supply ground |
| JP2 - 2 | 13 | 5V | S | Positive supply voltage, 4.5V to 5.5V |
| JP2 - 3 | - | Analog | - | 0~5V analog output. Generated by the PWM output and filtered. |
| JP2 - 4 | 9 | DX | DO | Digital output for 2-wire operation and Daisy Chain mode |
| JP2 - 5 | 16 | PWM | DO | Pulse Width Modulation output, 2.26µs pulse width per step (2.26µs ~ 512µs) |
| JP2 - 6 | 1 | MagRNG | DO_T | Push-Pull output. Is HIGH when the magnetic field strength is too weak, e.g. due to missing magnet |
| JP2 - 7 | 3 | GND | S | Supply ground |
| JP3 - 1 | 7 | COS | - | Must be left unconnected for normal operation. COS output in SIN/COS mode (P1 open) |
| JP3 - 2 | 6 | COSn | - | Must be left unconnected for normal operation. COSn output in SIN/COS mode (P1 open) |
| JP3 - 3 | 5 | SIN | - | Must be left unconnected for normal operation. SIN output in SIN/COS mode (P1 open) |
| JP3 - 4 | 4 | SINn | - | Must be left unconnected for normal operation. SINn output in SIN/COS mode (P1 open) |
| JP3 - 5 | 3 | GND | S | Supply ground |
| P1 bridge | 14 | C1 | DI | Configuration input for Sin/Cos output: <br> - Connect to VSS for normal operation (P1 closed, by default) <br> - High level (P1 open) to enable Sin/Cos outputs <br> This pin is scanned at power-on-reset and at wakeup from one of the Ultra Low Power Modes |
| P2 bridge | 15 | C2 | DI | Configuration input for serial wire mode: <br> - Connect to VSS for 3-wire operation (P2 closed, by default) <br> - High level (P2 open) for 2-wire operation <br> This pin is scanned at power-on-reset and at wakeup from one of the Ultra Low Power Modes |

Table 1: Pin description

Pin types:   S:        supply pin                                    DO:       digital output
                  DI_ST:   digital input / Schmitt-Trigger      DO_T:    digital output / tri-state
                  DIO:      bi-directional digital pin              DI:        digital input (standard CMOS; no pull-up or pull-down)

## 4    Operation use cases

### 4.1    Standalone Analog output mode
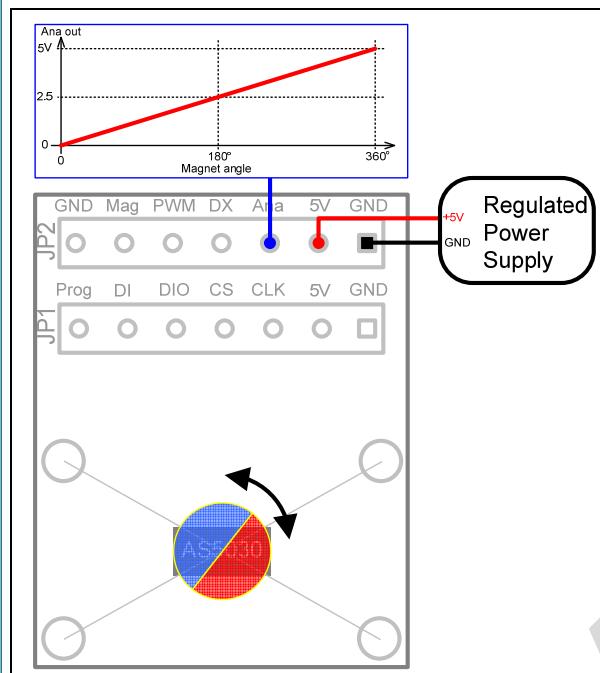


Figure 4: Using the analog output with the adapter board

The simplest setup to test the AS5030 is to use the adapter board in standalone mode. A 3-pin header connector is present on JP2.

A header connector is present on JP2 on pin 1, 2, 3. Connect a regulated power supply on 5V (pin #2) and GND (pin #1).

The "Ana" (pin #3) is an analog output, which is an RC filtered signal of the PWM output of the AS5030. The external device (AD converter, voltmeter…) connected on the "Ana" pin should have an input impedance >470kΩ, otherwise it should be buffered with an op. amp.

By rotating the magnet, a progressive analog voltage from 0 to 5V can be measured on the "Ana" pin (JP2 #3). Rotating the magnet clock wise (AS5030 chip on the top side) increases the Ana voltage, and counter clockwise will decrease the voltage.

Because of the RC filter, the response time of a jump 359°→0° (5V→0V) and 0°→359° (0V→5V) is 100ms.

### 4.2    Standalone PWM output mode
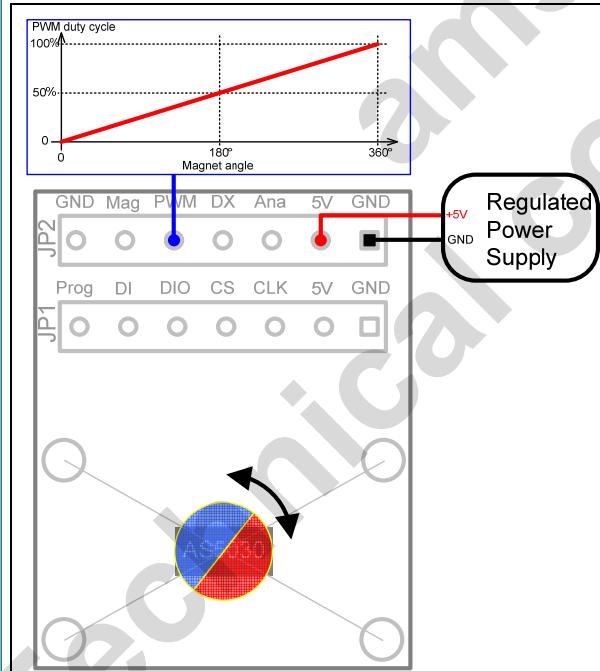


Figure 5: Using the PWM output with the adapter board

Instead of getting a proportional analog voltage increasing with the magnet's angle on the "Ana" output, a PWM signal (JP2 pin #5) with a period of 581us, 2.26us step and 5V pulse voltage can be connected to the capture/timer input of a microcontroller in order to decode the angle value.
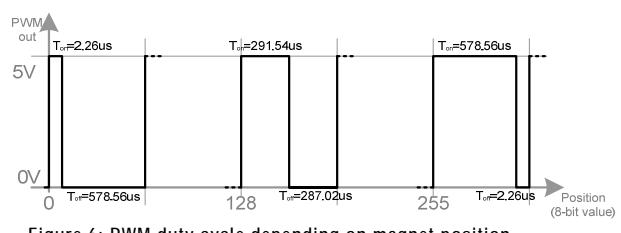


Figure 6: PWM duty cycle depending on magnet position

# 5    Using the serial interface with MCU

The most complete and accurate solution for a MCU to read the angle of a magnet is the serial interface.
The 8 bit value of the angle will be directly read, and some other indicators as AGC value or alarm bits can be read at the same time.

Serial commands can be sent to the AS5030 as well, like the low power mode, lock AGC or reset.

Note: The MCU must have 5V I/O connected to the AS5030 adapter board, the AS5030 is a 5V device.

The connection between the MCU and the adapter board can be made with 2, 3 or 4 wires.

## 5.1    2-wire serial interface

*Jumper configuration: P1 close, P2 open.*
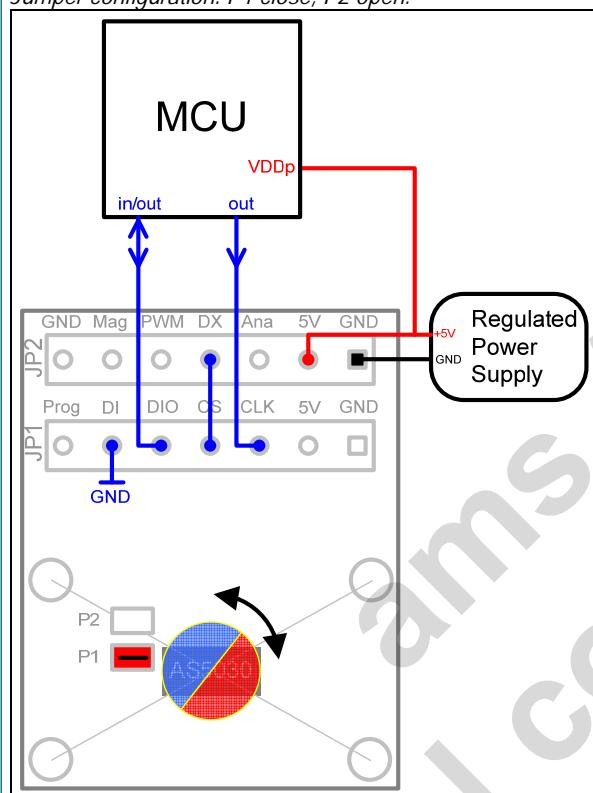
Figure 7: Bidirectional serial connection (2 wire)

By opening P2, the AS5030 is configured to 2-wire data transmission mode.
Only Clock (CLK) and Data (DIO) signals are required. A Chip Select (CS) signal is automatically generated by the DX output, when a time-out of CLK occurs (typ. 20µs).

See AS5030 datasheet chapter 4.15.

## 5.2    3-wire serial interface

*Jumper configuration: P1 and P2 close.*
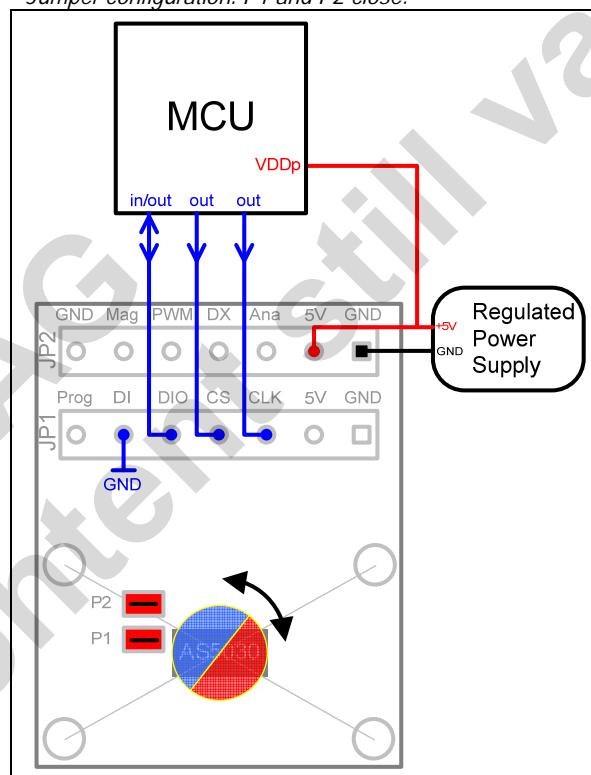
Figure 8: Bidirectional serial connection (3 wire)

The MCU GPIO used for the DIO data signal should be bi-directional: the MCU sends a 5 bit command first then receives a 16 bit value on the same line. The DI input of the adapter board must be connected to GND in this mode.

The C source code for reading an angle with this hardware configuration is described in *Chapter 7.*

## 5.3    4-wire serial interface

*Jumper configuration: P1 and P2 close.*
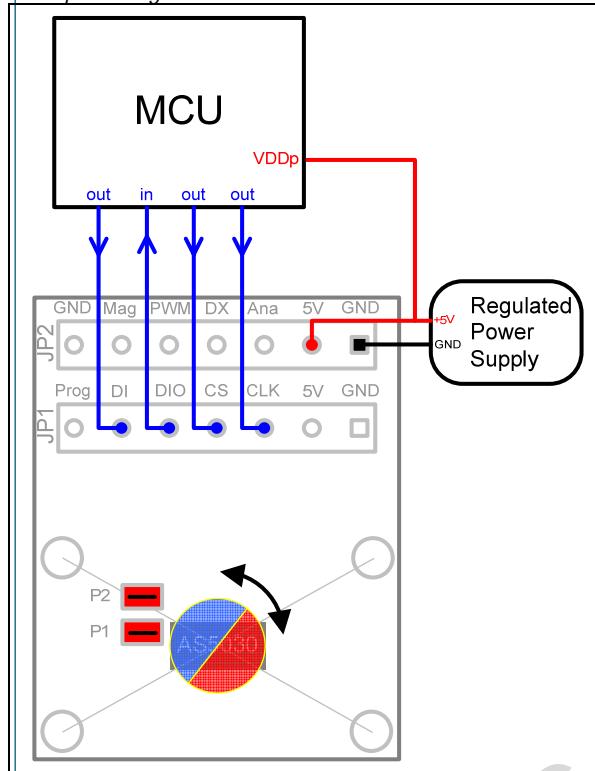


Figure 9: Bidirectional serial connection (4 wire)

The command line and data line are separated:
The command line is a MCU output connected to DI, the data line is an input of the MCU connected to DIO.

With this configuration, synchronous blocks like SPI can be easily used to receive the 16 bit data value from the AS5030. This communication method simplifies the firmware code as well.

## 5.4    Serial daisy chain mode

*Jumper configuration: P1 and P2 close.*
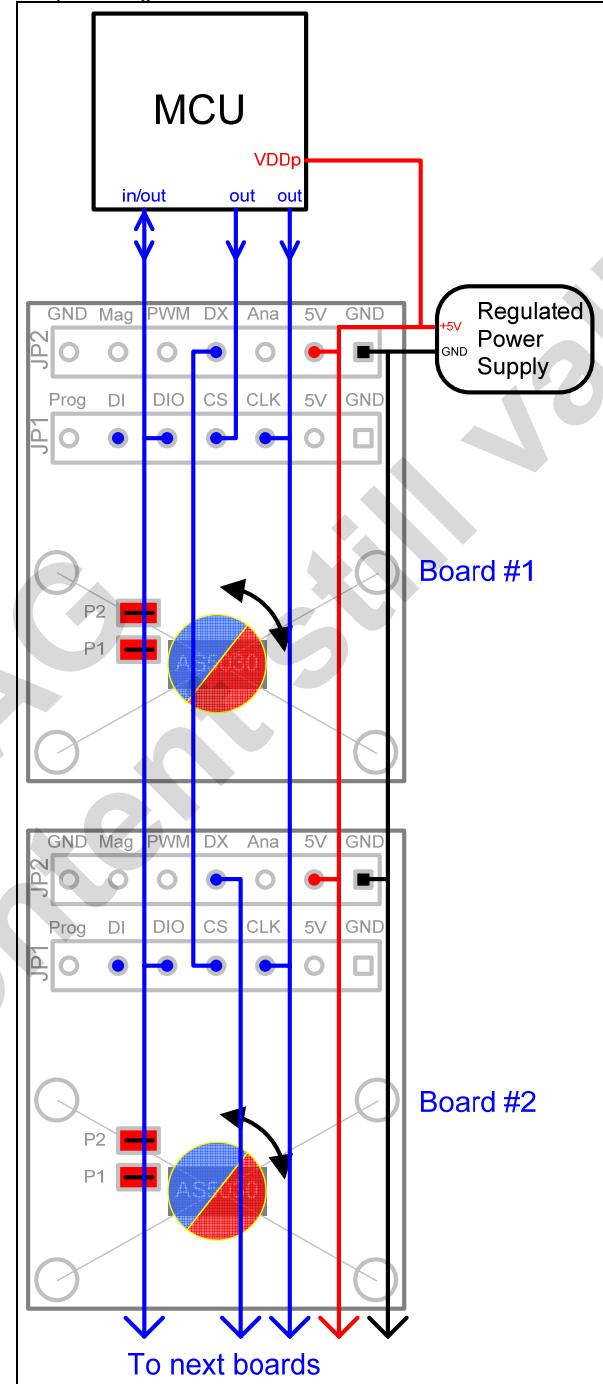


Figure 10: Daisy chain setup (3 wire)

The Daisy Chain mode allows connection of more than one AS5030 to the same MCU.
Independent of the number of connected devices, the interface to the controller remains the same with only three signals: CSn, CLK and DO.
In Daisy Chain mode, the data from the second and subsequent devices is appended to the data of the first device.

See AS5030 datasheet chapter 4.21.

# 6 AS5030 adapterboard hardware

## 6.1 AS5030-AB-2.0 schematics
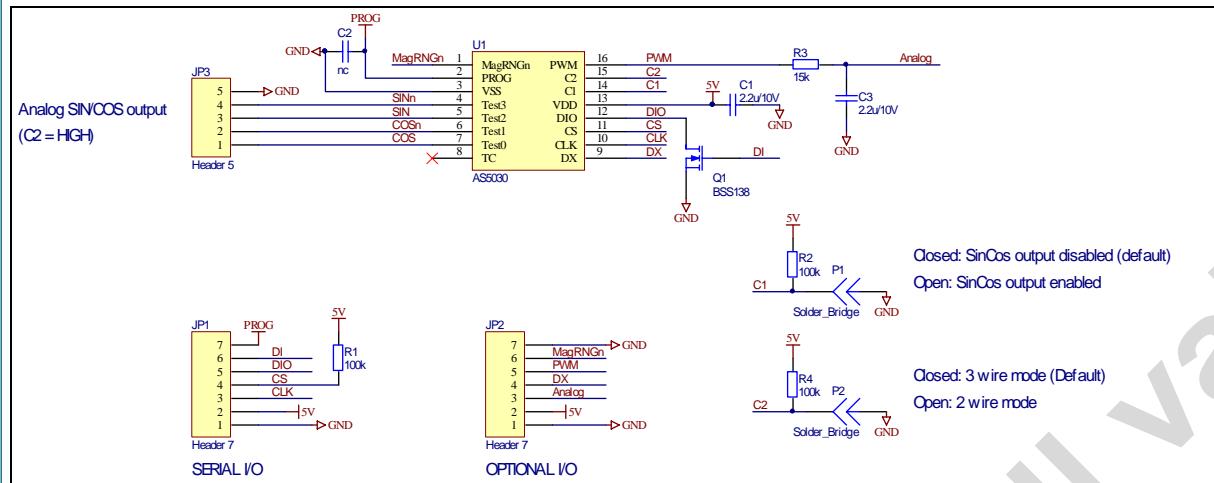


Figure 11: AS5030-AB-2.0 adapterboard schematics

## 6.2 AS5030-AB-2.0 PCB layout
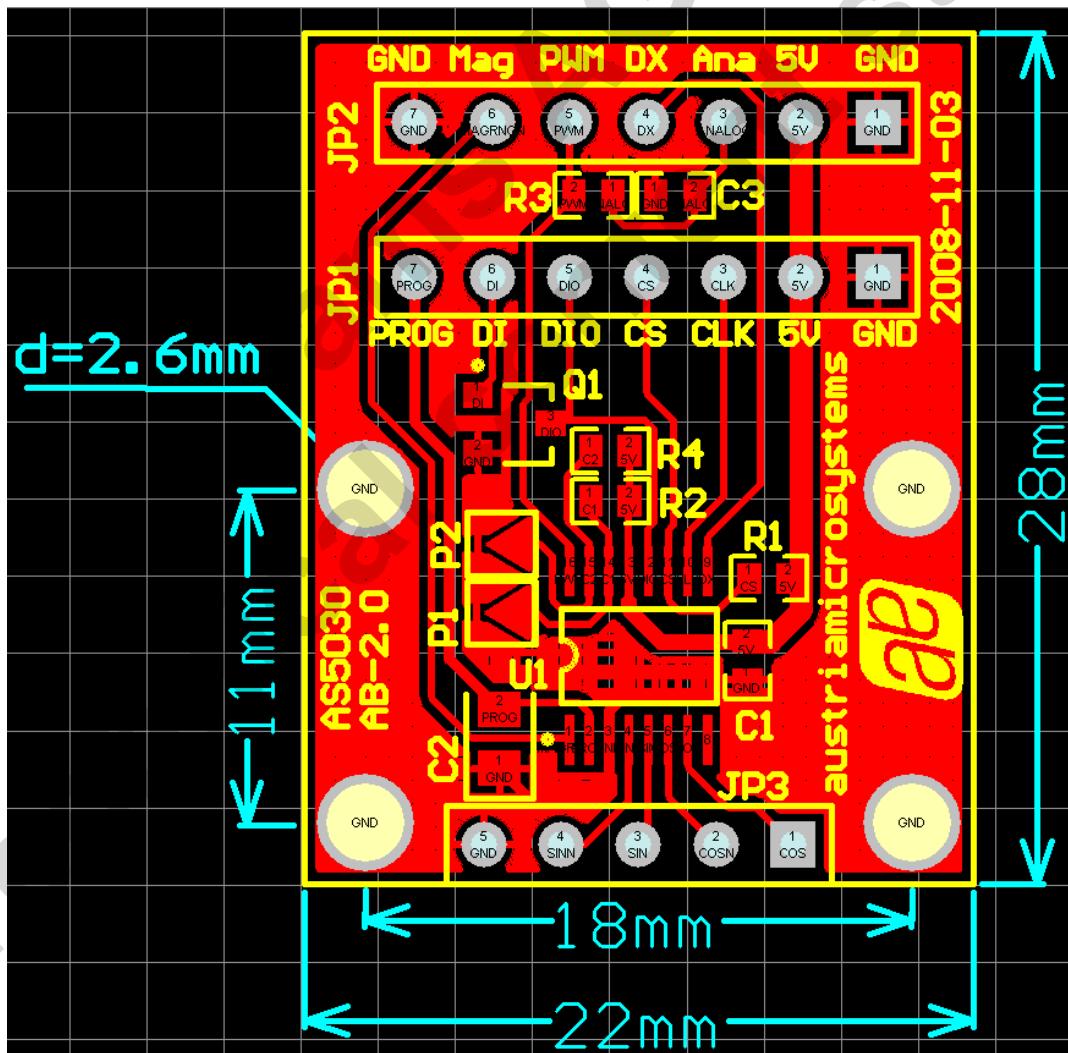


Figure 12: AS5030-AB-2.0 adapterboard layout

# 7  C-Source code, simple AGC & Angle read

```c
void main()      // This program reads the angle and AGC value from AS5030
{
        short SSI_Stream;              // 16-bit value where the serial result will be saved
        byte angle_value, agc_value;  // 8-bit results: Angle and AGC
        float angle_degree;           // Angle in degree

        SSI_Stream = SerialRead (0);  // Send command "READ" (command '00000')
                                      // and reads the 16-bit result from AS5030
        angle_value = (byte)(SSI_Stream & 0x00FF);        // Extract the angle value (8 bit)
        agc_value  = (byte)((SSI_Stream >> 8) & 0x3F);    // Extract the AGC value (6 bit)
        angle_degree = (float)value * (360/256);// Convert the 8-bit angle to degrees (0-360°)
}
```

```c
short SerialRead(unsigned char command)      // This function writes the command
{                                            // and receives the result from the AS5030
        short RX_buffer;

        SET_CS();                      // CS pin = '1', AS5030 selected
        delay_us(Delay_Serial);
        SSIwrite(command);             // Send the command (exemple "READ" command '00000')

        DIO_HIGH_IMP();                // DIO output high impedance (input mode), ready to read
        RX_buffer  = SSIread();        // Receive the 16bit result from the AS5030

        delay_us(Delay_Serial);
        CLEAR_CS();                    // CS pin = '0'

        return RX_buffer;
}
```

```c
short void SSIread()    // This function reads the 16-bit value from the AS5030 DIO pin
{
        xdata unsigned char current_bit;
        short result;

        result = 0;    // Is the shift buffer for the 16 bit data receive
        for (current_bit = 16; current_bit; current_bit--)   // 16 steps loop (16 bit data)
        {
                result <<= 1;  // Shift buffer value left 1 step (first time doesn't count)

                delay_us(Delay_Serial);       // Small delay to be get the correct level on DIO
                result += (VAL_DIO) ? 1 : 0;  // If '1' on DIO, store '1' on the LSB else '0'

                SET_CLK();                     // Generate a CLK pulse to shift the data on DIO
                delay_us(Delay_Serial);
                CLEAR_CLK();
        }
        return result;
}
```

```c
void SSIwrite(unsigned char command)  // This function writes the 5-bit command to
{                                     // the AS5030 DIO pin
        unsigned char current_bit;
        unsigned char this_bit

        for (current_bit = 5; current_bit; current_bit--)    // 5 steps loop (5 bit command)
        {
                this_bit = (command >> (current_bit-1)) & 0x01;     // Value of bit 5, then
                                                                    // bit 4, …, bit 0
                // If the current command bit is '1':
                if (this_bit) SET_DIO();      // then send '1' on DIO (push-pull output)
                else          CLEAR_DIO();    // Otherwise send '0' on DIO (push-pull output)

                if (current_bit == 1) // If Last Bit has been written
                {
                        delay_us(Delay_Serial);
                        SET_CLK();                    // Set Clock
                        delay_us(Delay_Serial);
                        DIO_HIGH_IMP();               // And DIO output of CPU in input mode
                        delay_us(Delay_Serial);
                        CLEAR_CLK();                  // Clear Clock (datasheet timings)

                }
                else    // Else generate a CLK pulse to shift the data on DIO
                {
                        delay_us(Delay_Serial);
                        SET_CLK();
                        delay_us(Delay_Serial);
                        CLEAR_CLK();
                }
        }
}
```

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