

# Product Document



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**is now**

**ams AG**

The technical content of this austriamicrosystems document is still valid.

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## 1 The AS5040 adapter PCB:

The AS5040 adapter PCB is a simple circuit allowing customers to test and evaluate the AS5040 rotary encoder rapidly without having to build their own test fixture or PCB.

The PCB can be used as standalone unit or plugged onto the AS5040 demoboard as external encoder. For Standalone operation, it can be supplied with 3.3V, 5V or 7.5...12V DC supply voltages.

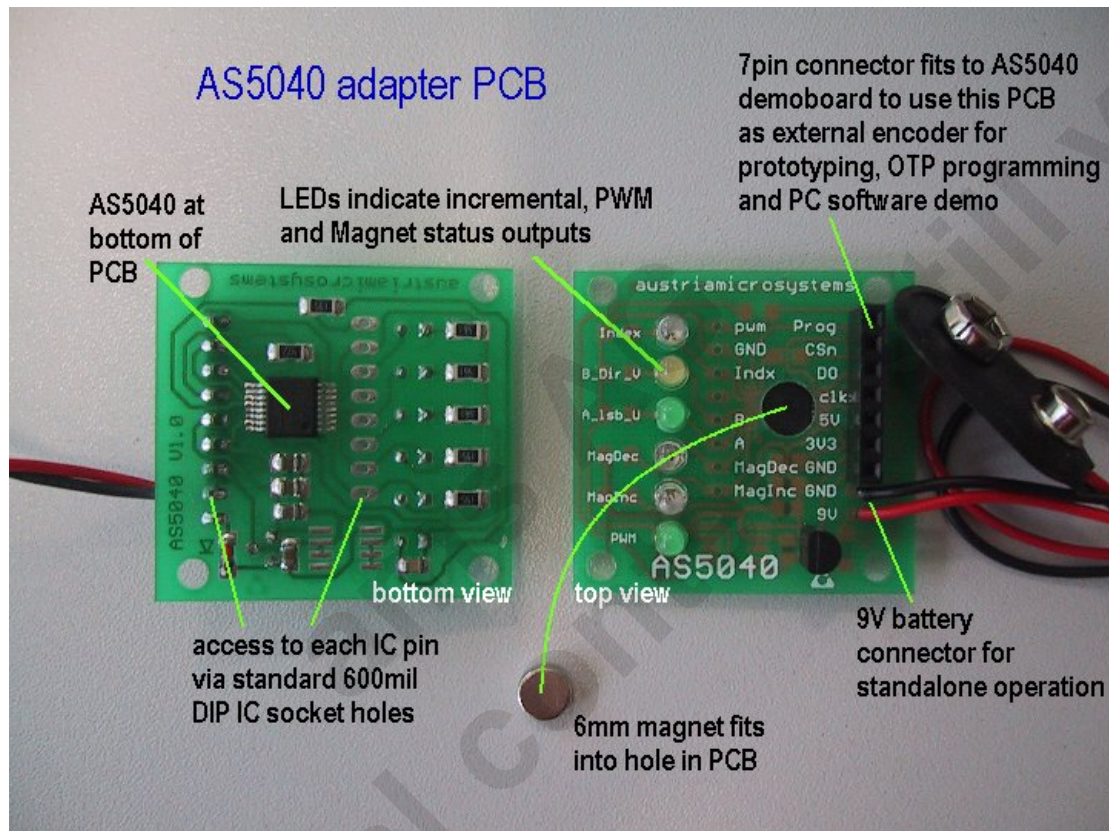


Figure 1: AS5040 Adapter PCB: top and bottom view

### Features:

- 100mil connector for direct connection to AS5040 demoboard
- Provision for a 600mil DIP socket
- Hole in PCB to center a 6mm magnet at the bottom of the IC
- LEDs for Incremental outputs A,B, Index
- LED for PWM output
- LEDs for magnet status outputs MagInc, MagDec
- On-board 5V linear voltage regulator for 7.5...12V supplies
- 9V battery connector for standalone operation
- Dimensions: 35mm x 37mm (1.38 x 1.46 inch)



## 2 General Description

The AS5040 is a system-on-chip, combining integrated Hall elements, analog front end and digital signal processing in a single device. It provides incremental output signals and the absolute angular position of a magnet that is placed either above or below the device.

The AS5040 can be configured to specific customer requirements by programming the integrated OTP (one time programmable) register. An internal voltage regulator allows the AS5040 to operate at either 3.3 V or 5 V supplies.

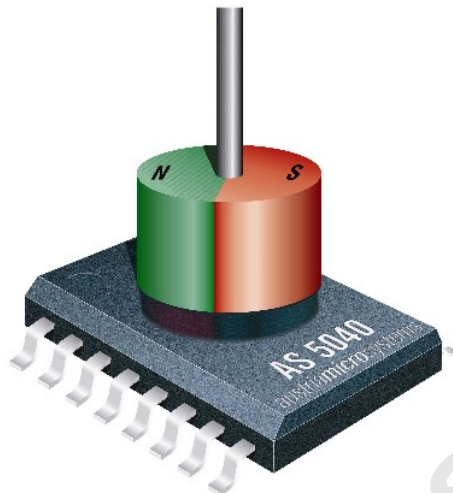


Figure 2: Typical arrangement AS5040 and magnet

## 3 Pin Configuration

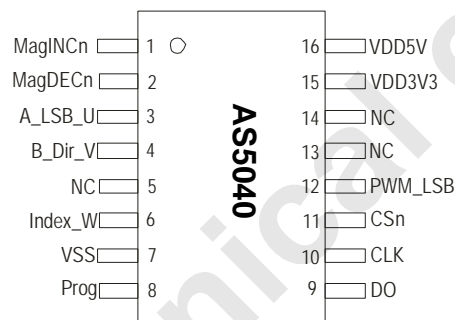


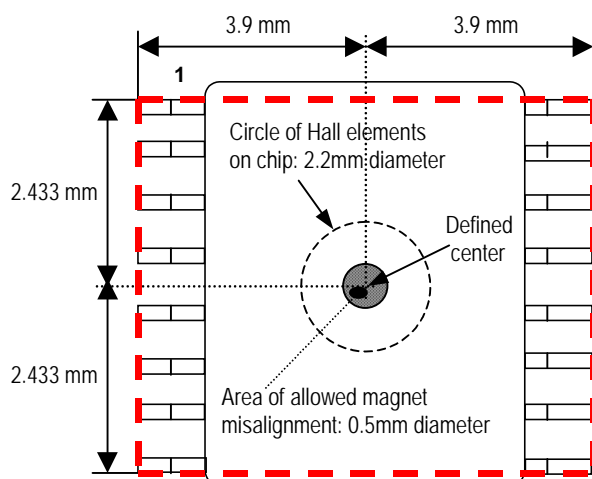
Figure 3: Pin configuration SSOP16

## 4 Pin Description

Pin	Symbol	Type	Description
1	MagINCn	DO_OD	Magnet Field Magnitude <b>INC</b> rease; active low, indicates a distance reduction between the magnet and the device surface.
2	MagDECn	DO_OD	Magnet Field Magnitude <b>DEC</b> rease; active low, indicates a distance increase between the device and the magnet.
3	A_LSB_U	DO	<i>Mode1</i> : Quadrature <b>A</b> channel <i>Mode2</i> : Least Significant Bit <i>Mode3</i> : <b>U</b> signal (phase1)
4	B_Dir_V	DO	<i>Mode1</i> : Quadrature <b>B</b> channel quarter period shift to channel A. <i>Mode2</i> : <b>D</b> irection of Rotation <i>Mode3</i> : <b>V</b> signal (phase2)
5	NC	-	must be left unconnected
6	Index_W	DO	<i>Mode1 and Mode2</i> : <b>I</b> ndex signal indicates the absolute zero position <i>Mode3</i> : <b>W</b> signal (phase3)
7	VSS	S	Negative Supply Voltage (GND)
8	Prog	DI_PD	<b>P</b> rogramming and Data Input for Mode configuration, incremental resolution setting, Zero-Position Programming and Daisy Chain mode configuration. Internal pull-down resistor (~74kΩ)
9	DO	DO_T	Data Output of Synchronous Serial Interface
10	CLK	DI, ST	Clock Input of Synchronous Serial Interface; Schmitt-Trigger input
11	CSn	DI_PU, ST	Chip Select, active low; Schmitt-Trigger input, internal pull-up resistor (~50kΩ)
12	PWM_LSB	DO	<b>P</b> ulse <b>W</b> idth <b>M</b> odulation of approx. 1kHz; <b>LSB</b> in <i>Mode3</i>
13	NC	-	must be left unconnected
14	NC	-	must be left unconnected
15	VDD3V3	S	3V-Regulator Output
16	VDD5V	S	Positive Supply Voltage 5 V

Table 1: Pin description

## 5 Principle of Operation



The AS5040 chip consists of a ring of hall elements, placed at the center of the IC at a circle diameter of 2.2mm (86.6mil).

The hall elements pick up the field of a magnet, placed atop this hall array circle. This information is digitized and fed into a digital signal processor (DSP), which calculates the angle of the magnet with a resolution of 0.35 degrees or 1024 positions per revolution (10bit) at a sampling rate of 100μs (10kHz).

The digital angle information is available in several formats: as serial 10-bit data stream, as pulse-width modulated (PWM) signal or as quadrature incremental signal

Figure 4: Tolerances of magnet placement

### 5.1 Magnet considerations

A magnet, having one north / one south pole in the horizontal axis is placed right above the ring of hall elements (see Figure 2). The magnet does not necessarily need to be circular, it can be rectangular as well, as long as the north and south pole are arranged horizontally over the center of the hall array ring.

The magnetic field strength along this ring should be in the range of  $\pm 45 \dots 75$  milliTesla (mT).

#### 5.1.1 Magnet size

The size of the magnet should be at least the size of the hall array ring (2.2mm). Smaller magnets are more critical in terms of misalignment due to the non-linear magnetic field distribution along the circumference of the magnet. The recommended magnet diameter is 4...6mm

#### 5.1.2 Magnet distance and material

To achieve the required field strength at a reasonable distance ( $\sim 0.5 \dots 5$ mm), it is recommended to use rare-earth magnets, such as Samarium-Cobalt (SmCo) or Neodyme-Iron-Boron (NdFeB) magnets.

#### 5.1.3 Magnet misalignment

In theory, the magnet misalignment is not critical for this type of angular measurement. In practice however, magnets are not perfectly linear. The magnetic field strength does not increase linearly with the radius. As you get towards the boundary of the magnet, the magnetic field comes to a maximum and then weakens as you move further away from the center. Therefore, a magnet should be chosen, that is still in the linear range at a  $< 3$ mm diameter.

#### 5.1.4 Non-linearity errors

A non-linear magnetic field results in a non-sinusoidal representation of the magnet, which in turn causes non-linearities in the calculated angle (calculated angle differs from actual angle).

With a perfectly centered magnet, the maximum error is  $< \pm 0.5$  degrees. This error is caused by internal mismatch and gain errors.

With the recommended 4mm magnet (Bomatec BMN-35H), the maximum error of  $< \pm 1.4$  degrees (including internal errors and temperature related errors) can be achieved while the magnet is off-center by a radius of  $< 0.25$ mm (see Figure 4).

## 6 AS5040 Adapter PCB Schematic:

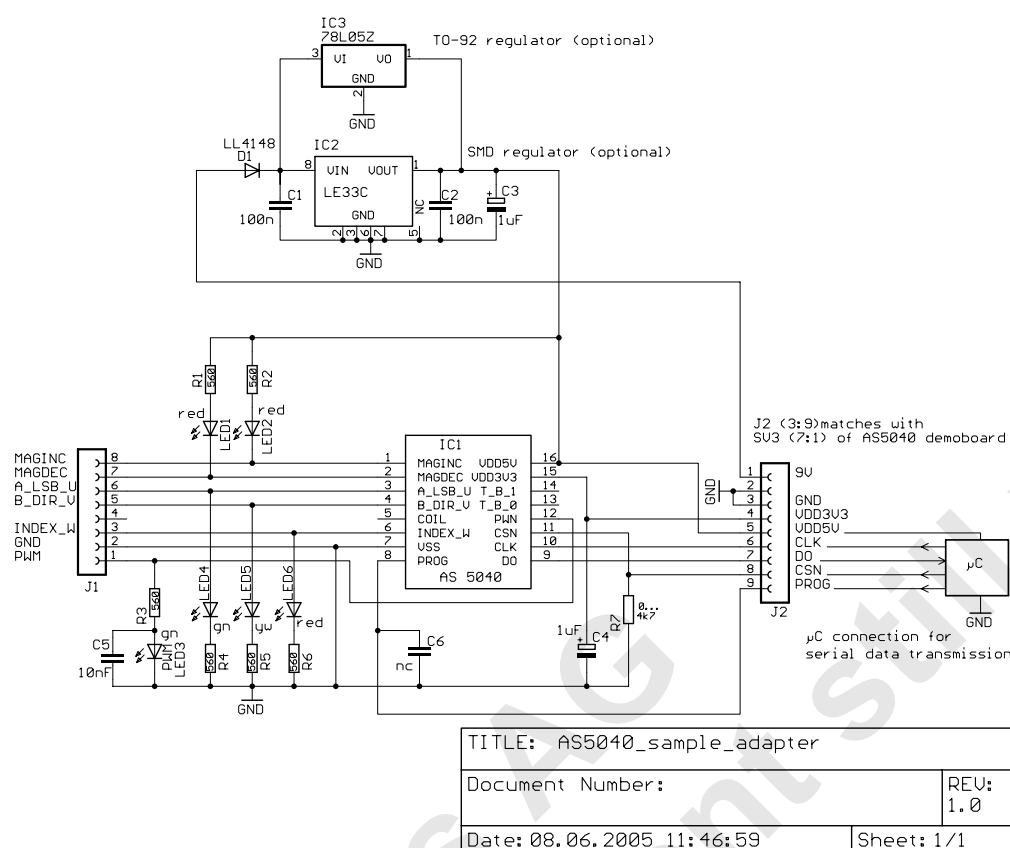


Figure 5: AS5040 Adapter PCB schematic

For normal operation, the only required external components are the buffer cap at VDD3V3 (C4) and the pull-down resistor for CSn (R7; 0Ω....4k7).

The PCB operates at several power supply levels:

### Power Supply options:

Supply voltage	apply at	ext. voltage regulator IC2 or IC3	digital I/O level	remark
3.0....3.6V	VDD5V and VDD3V3	not required *)	3.0....3.6V	short VDD5V and VDD3V3
4.5....5.5V	VDD5V	not required *)	4.5....5.5V	
7.5...20V	ext. voltage regulator (pin 1, J2)	3.3V type, e.g. LE33C (ST Micro)	3.3V	short VDD5V and VDD3V3
7.5...20V	ext. voltage regulator (pin 1, J2)	5.0V type e.g. 75L05	5.0V	PCB delivery status

\*) if already installed, external voltage regulator can be left installed.

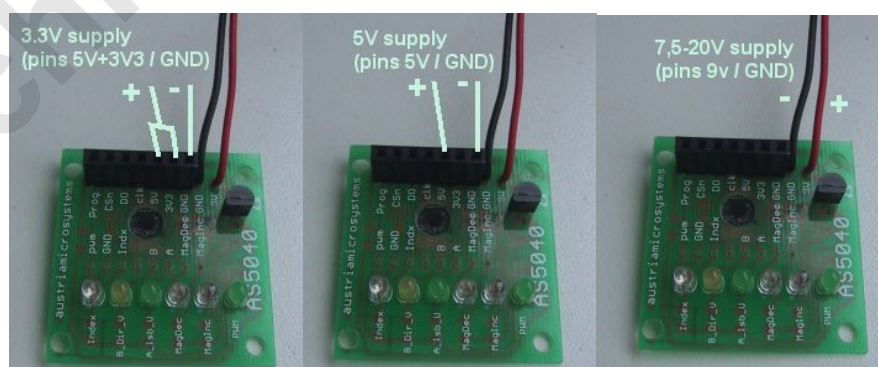


Figure 6: how to connect various power supply levels to the adapter PCB

**Output modes:**

a) PWM output:

no additional components are necessary. Once the power supply has been applied, the angle information is available at the PWM pin (pin1 of J1)

b) Incremental output:

no additional components are necessary. Once the power supply has been applied, the angle information is available at the incremental outputs: A,B and Index (pins 6, 5 and 3 of J1)

c) absolute angle information

To access the 10-bit absolute angle information, an external microcontroller must be connected as shown in Figure 5. Make sure that the controller is able to drive the CSn pin with the connected pulldown resistor (R7). If necessary, remove this resistor.

The clock rate can be as high as 1MHz. There is no minimum clock rate. Data can also be clocked manually. The digital I/O's of the AS5040 are buffered by VDD5V, therefore the digital I/O's of the controller should be at the same voltage level (see power supply options table).

d) Magnetic field strength status; Pushbutton function

no additional components are necessary. The two open-drain outputs MagInc and MagDec (pins 8 and 7 of J1) will turn on/off as the magnetic field (distance between magnet and chip surface) changes. When both outputs are on, the magnetic field is not within the recommended range (see datasheet).

**Programming (zapping) the Chip.**

For programming the AS5040, 3 digital signals are required: CSn, Prog and CLK (see datasheet). For permanent writing, VPROG must be elevated to 7.5V during the programming cycle.

For immediate programming, this PCB can be connected directly to the AS5040 demoboard (available separately), where all the programming timings are generated by the onboard microcontroller.

## AS5040 adapter PCB layout and component placement:

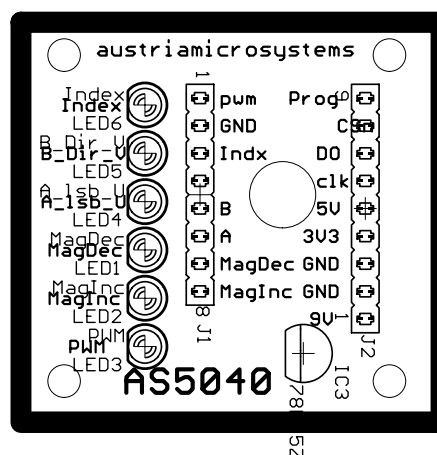
The PCB has several connection options. All required pins are accessible via the two 100mil- connectors J1 and J2.

These connectors are 600mil apart, which allows them to be soldered to a wide 16-pin DIL IC socket for easier access or ribbon cable connection.

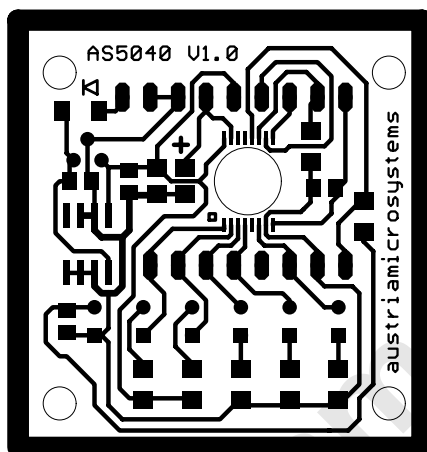
Furthermore, J2 (pins 3..9) fit to the AS5040 demoboard and allow this PCB to be used as external encoder.

The hole in the PCB underneath the chip allows centering of a 6mm diameter magnet.

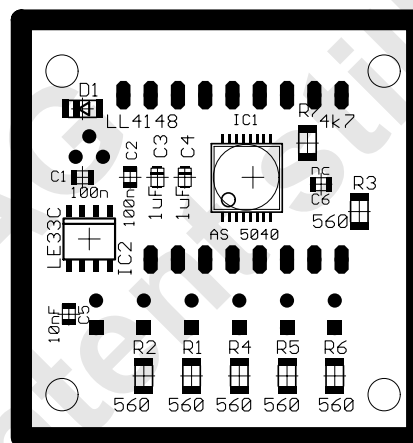
The 6 LEDs and voltage regulators are optional. Minimum required components are C4 (1 $\mu$ F) and R7 (0...4k7).



AS5040 adapter board: top view



Layout: Bottom View



Layout: Bottom Components

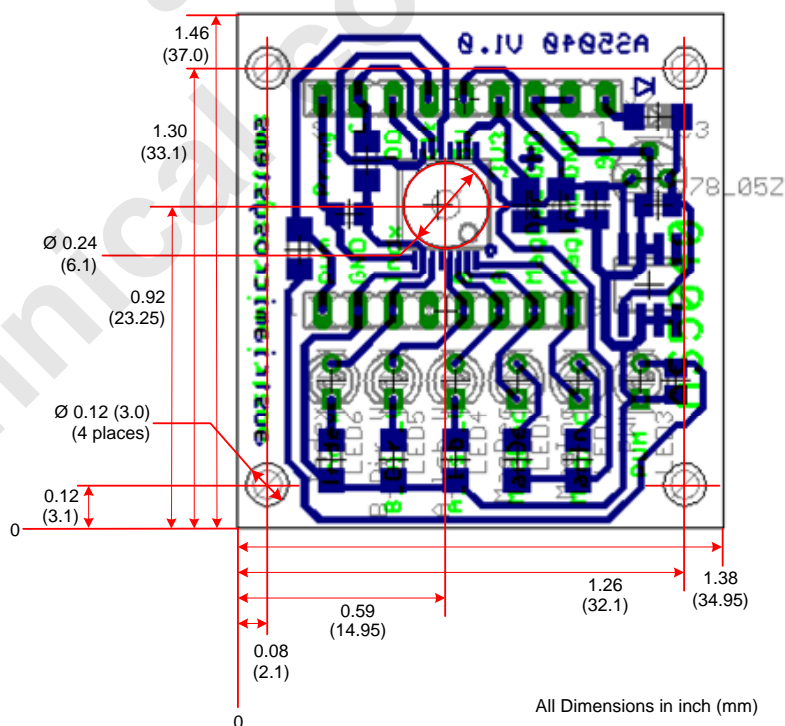


Figure 7: AS5040 / AS5035 Adapter board dimensions.



## 7 Supporting tools

austriamicrosystems provides the following tools for developments using the AS5040 rotary encoder IC:

AS5040 Demoboard (see Figure 8)

AS5040 Demoboard Operation Manual

AS5040 Demoboard Software

AS5040 Adapter PCB (see Figure 1)

These supporting tools are available at local distributors

[http://www.austriamicrosystems.com/06contactcenter/sales\\_start.htm](http://www.austriamicrosystems.com/06contactcenter/sales_start.htm)

or can be ordered online: [http://www.austriamicrosystems.com/03products/request\\_5040.htm](http://www.austriamicrosystems.com/03products/request_5040.htm)

## 8 AS5040 Demoboard

The AS5040 Demoboard is a complete rotary encoder system with built-in microcontroller, USB interface, 4-digit 7-segment display, incremental output LEDs, a LED displaying the PWM output and two magnet status LEDs.

It also supports external AS5040 applications, such as the AS5040 adapter PCB or in-system AS5040 customer applications that can be connected to the demoboard and displayed, modified and permanently programmed using the AS5040 Demoboard Software.

The AS5040 demoboard can be used in several ways:

### 8.1.1 as standalone unit supplied by a 9V-battery

Connect a 7,5V..12V supply to pins "GND" and "+9V" at the right side of the board. No other connections are required

### 8.1.2 as standalone unit supplied by an USB port

Connect the demoboard to a PC using a USB cable (included in demoboard shipment). The board is supplied by the 5V supply of the USB port. No other connections are required

### 8.1.3 as input device for the AS5040 demoboard software

This configuration uses the same hardware connection as 8.1.2, but additionally the AS5040 demoboard software is running. All indicators on the demoboard will be displayed on the PC screen as well.

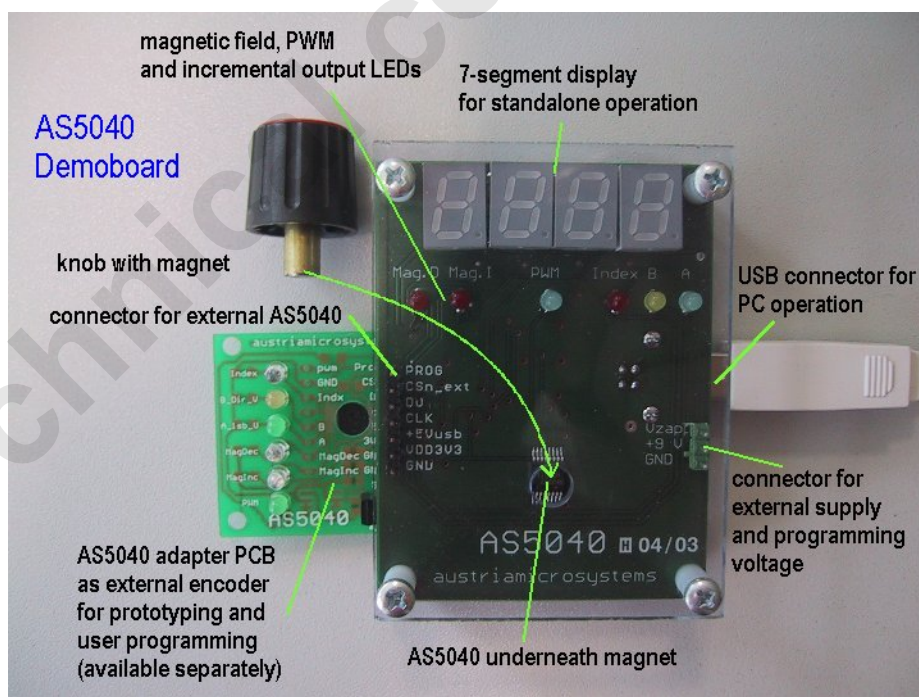


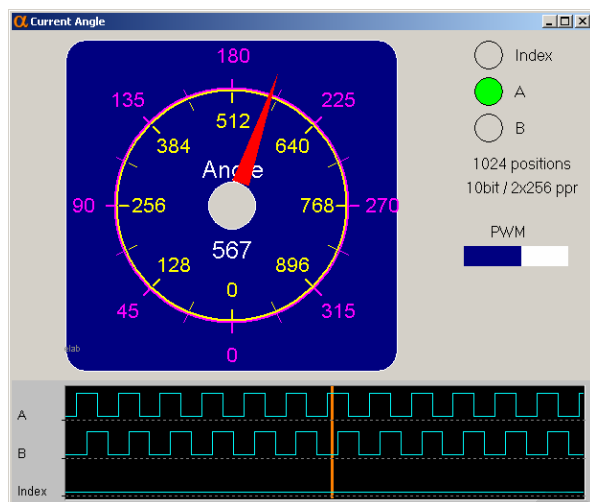
Figure 8: AS5040 demoboard and Adapter PCB

## 9 AS5040 Demoboard Software

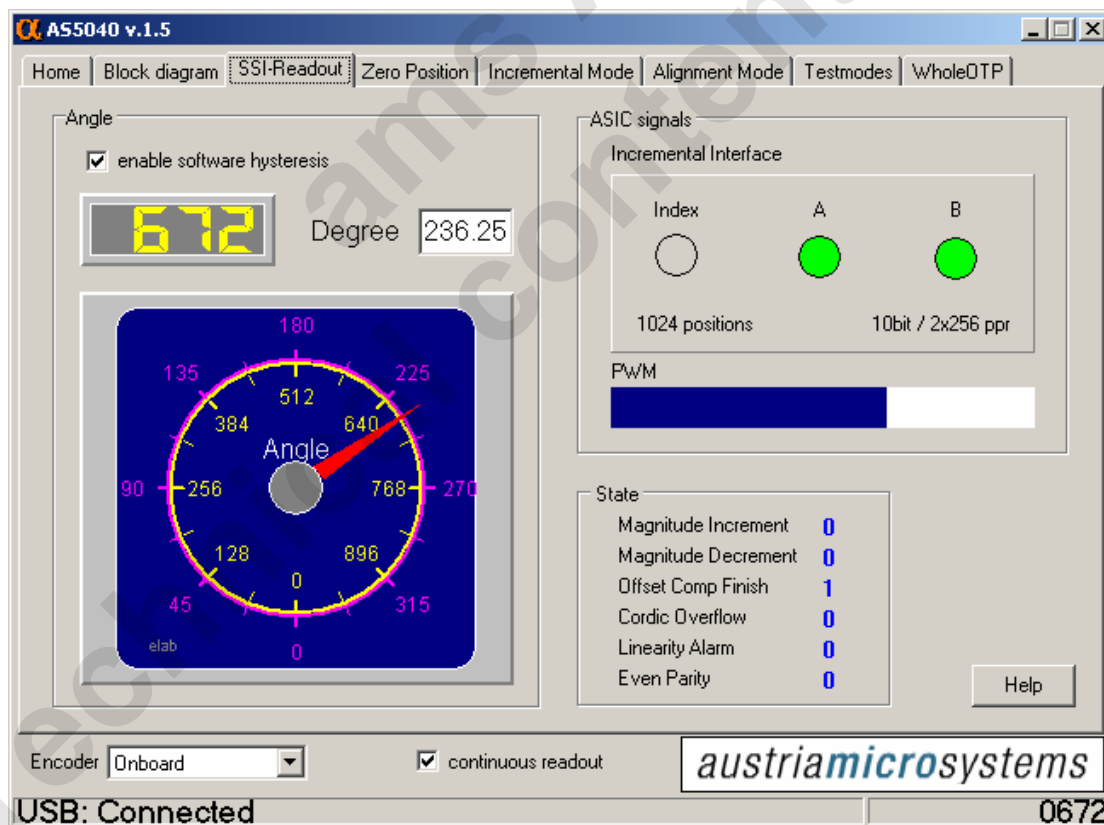
The AS5040 Demoboard Software can be downloaded for free from the Internet at:

<http://www.austriamicrosystems.com/04segments/industry/AS5040.htm>

It has several indicators and extra features, such as:



- Displaying the absolute angle as 10bit-word (0..1023), as absolute angle and as rotary dial
- Emulating the incremental output LEDs A, B and Index
- Displaying the incremental outputs as waveform in a sub-window
- Displaying the pulse-width-modulated (PWM) output as bar-graph
- Programming the incremental output mode (quadrature, single channel / direction, brushless DC motor commutation)
- Programming the resolution at 7,8,9 or 10 bits
- Programming the Index bit width at 1 or 3 bits
- Putting the AS5040 in Alignment mode
- Permanently programming (OTP) the incremental mode, resolution and Index bit width.
- Reversing the direction of rotation



Further information on the AS5040 Demoboard Software is available in the AS5040 Demoboard Operation Manual (see: 7 Supporting tools)

## 9.1 Connecting the AS5040 adapter PCB to the demoboard

The AS5040 Adapter PCB is intended as a standalone device that allows easy and quick testing of the AS5040 without the need of having to make your own PCB. It allows access to each IC pin via a standard 100mil pitch, 600mil Dual-In-Line connector, has LEDs on all digital outputs and comes with an onboard 5V linear voltage regulator (78L05) and a battery clip to supply the board from a 9V battery.

The 7-pin female connector is designed to fit directly onto the AS5040 Demoboard and use the Adapter PCB as external encoder (software setting: Encoder = external).

The demoboard however, runs at 3.3V supply voltage. The Adapter PCB is configured for 5V supply voltage. Connecting both boards without modifications will not harm any of the boards, but may lead to data transmission errors due to the different digital levels, especially when an extension cable is used between demoboard and Adapter PCB.



Figure 9: configuring the Adapter PCB for 3.3V operation

If you use the Adapter PCB as external encoder for the AS5040 demoboard with an extension cable or experience data transmission errors, it is recommended to configure the Adapter PCB for 3.3V supply voltage.

Perform the following modifications:

- disconnect the 5V supply between Demoboard and Adapter PCB: remove or cut off pin "+5VUSB" at the bottom of the AS5040 demoboard
- connect pins "3V3" and "5V" on the Adapter PCB. Ideally, connect the pins right at the bottom of the 7pin female connector with a piece of wire or solder joint.
- you may also remove the 78L05 voltage regulator from the Adapter PCB to prevent accidental damage of the IC when an input voltage is applied to the regulator (and the 5V output is fed to the VDD3V3 supply pin)

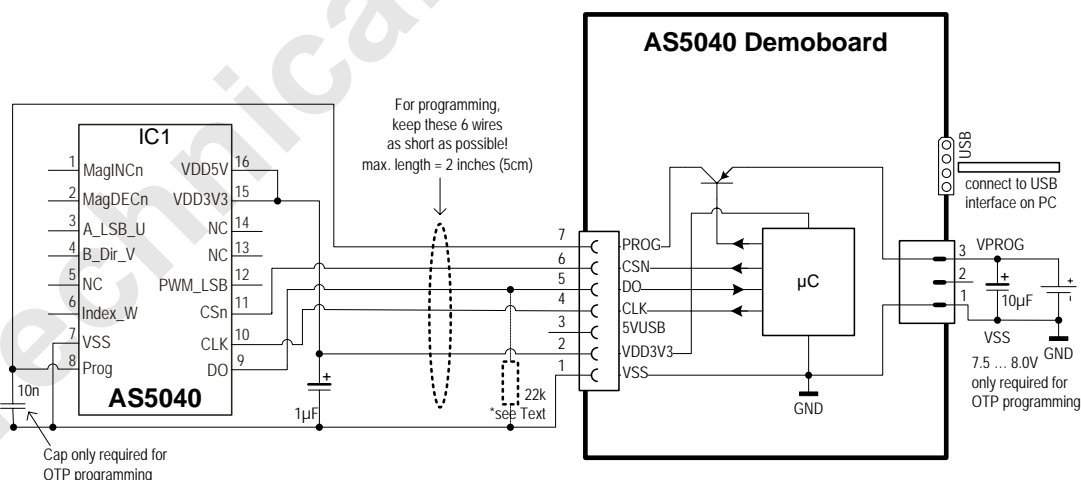


Figure 10: Connecting an external AS5040 application to the demoboard

*\* If longer cables are used, a pull-down resistor at the DO line of 22k - 56k Ohms is recommended to discharge the signal between data transmissions and no static voltage is built up.*

## 9.2 Reading the Adapter PCB with the AS5040 Demoboard Software:

Further information on the AS5040 Demoboard Software is available in the AS5040 Demoboard Operation Manual (see: 7 Supporting tools)

The AS5040 Adapter PCB can be read as "external encoder" in the same way as the internal encoder. Switching from internal to external encoder can be done on the bottom left corner of the demoboard software screen : Encoder = onboard / external. Additionally, when Encoder = external is selected, the buttons "Permanent write" and "Read" are enabled in the "Zero Position" and "Incremental Mode" screens to allow OTP programming of the external encoder

### Changing the incremental mode, Zero Position, etc.:

The programming options incremental mode, resolution, index bit width and zero position and ccw operation can be modified at any time during normal operation. Permanently programming these registers will set the default setting after power-up. Programmed settings can again be modified during normal operation but will be reset to default when the power supply is disconnected.

### OTP programming of the external AS5040 encoder:

To program the external AS5040 encoder, a programming voltage of 7.5 to 8V DC (130mA) must be applied to pins Vzapp and GND of the 3-pin connector at the right hand side of the demoboard. A 10 $\mu$ F buffer cap is recommended for this voltage (see Figure 10).

Programming is not recommended with long wires between demoboard and external encoder, as the inductance of the cable may generate high voltage spikes, that can cause wrong programming or even harm the IC. The maximum wire length between the demoboard connector and the PROG pin of the external encoder should be 50mm (2"). Additionally, a 10nF ceramic capacitor should be connected close to pin PROG and VSS.

An OTP (one time programming) cycle is automatically initiated, when button "Permanent write" is pressed. The default (non-programmed) logic state is "0", consequently the programmed logic state is "1". It is possible to write "1"s into the OTP register at subsequent programming cycles. However, a programmed "1" cannot be cleared any more after programming.

Note that the chip will not be programmed, as long as no programming voltage is applied to Vzapp, although the software will issue a warning message that the chip will be permanently programmed.



## 10 Applications

### 10.1 Replacing Optical Encoders

The following graphs show how to replace an optical encoder by the AS5040. It can be configured for 3.3V and 5V operation. Higher operating voltages can be handled with an external voltage regulator (e.g. > 7,5V with an external 78L05).

The maximum output voltage level on the A,B and Index pins corresponds to the voltage at pin VDD5V.

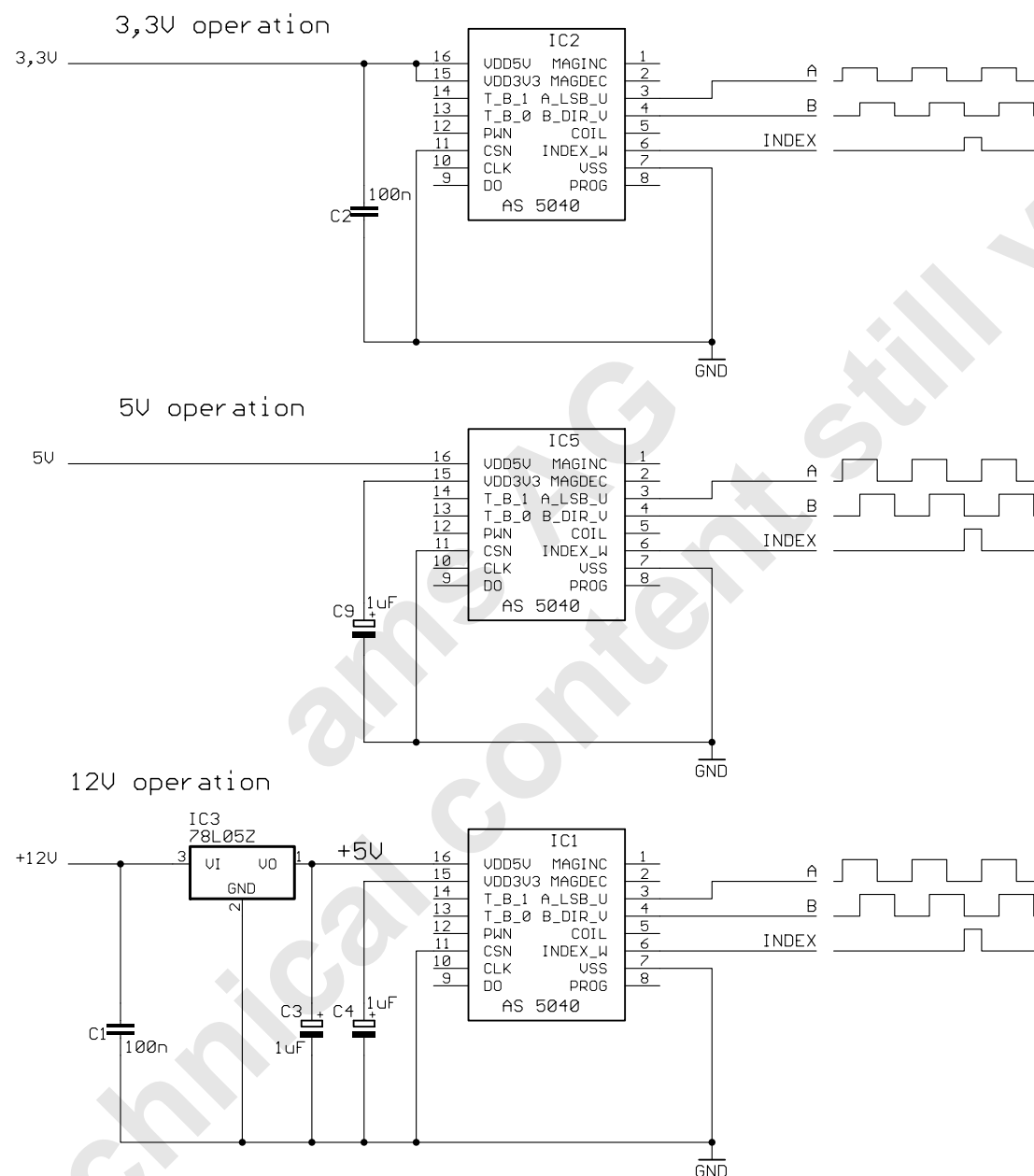


Figure 11: Incremental Outputs and power supply options

The incremental outputs A,B, Index can be used in the same way as the incremental outputs of an optical encoder. The maximum output current is 4mA for 5V output voltage and 2mA for 3.3V output voltage.

Per default, the AS5040 provides 256 pulses per revolution. Optionally, further resolutions can be programmed by OTP (one-time-programming):

Operating Mode	OTP Mode Register bit				Output A	Output B
	Md1	Md0	Div1	Div0		
0.0: Default	0	0	0	0	256ppr	256 ppr
1.0 Quad 10bit	0	1	0	0		
1.2 Quad 9 bit	0	1	0	1	128ppr	128ppr
1.4 Quad 8 bit	0	1	1	0	64ppr	64ppr
1.6 Quad 7 bit	0	1	1	1	32ppr	32ppr
2.0: LSB/Dir 10bit	1	0	0	0	512ppr	direction cw/ccw
2.2: LSB/Dir 9bit	1	0	0	1	256ppr	direction cw/ccw
2.4: LSB/Dir 8bit	1	0	1	0	128ppr	direction cw/ccw
2.6: LSB/Dir 7bit	1	0	1	1	64ppr	direction cw/ccw

Table 2: Incremental Programming mode options

Furthermore, the Index Pulse width can be programmed to 1LSB or 3LSB in the OTP register.

## 10.2 Generating the incremental pulses

Internally, the AS5040 always calculates absolute values. The incremental outputs are decoded from the absolute values as shown below:

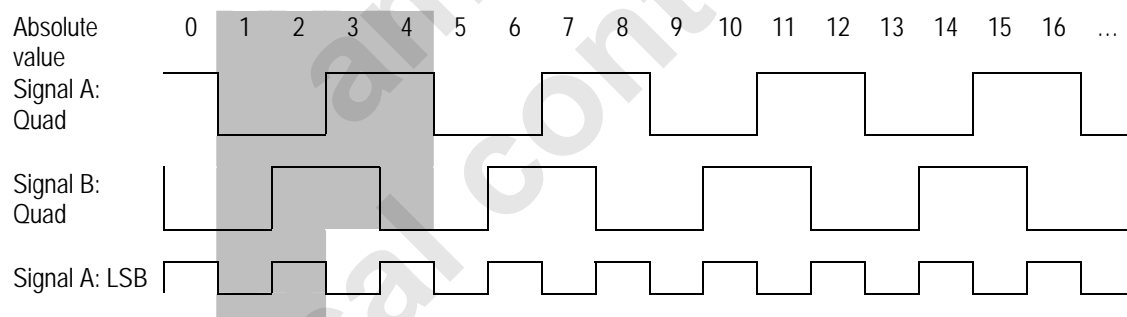


Table 3: Incremental signal generation

Four absolute values are required to generate one incremental pulse (see grey area in Table 3) and two absolute values are required to generate a single channel (LSB) pulse.

Consequently, the maximum number of incremental pulses in 10bit-mode is  $1024 / 4 = 256$  and the maximum number of single channel (LSB) pulses is  $1024 / 2 = 512$

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## 12 Revision History

Revision	Date	Description
A03	04. Jul. 2006	Figure 7: AS5040 / AS5035 Adapter board dimensions. added Update: GUI screen shots.
A02	12. Jan. 2006	Included Dimensions; Directly inserted all linked EPS
A01	Nov.12, 2004	add circuit diagram for OTP programming (Figure 10)

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