VeloTrack
Hardware & Software Manual

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1. Installation

1.1. Software Repository

All software packages are hosted in the following GitHub repository:

`https://github.com/jorenheit/velotrack`

Software mentioned in this document can be downloaded here, or alternatively one can clone into this repository using Git (details on using Git are outside the scope of this document).

1.2. Windows

The application itself can be installed simply by extracting the win32 ZIP-archive (or copying the contents of the win32 directory) to an arbitrary directory and running the `velotrack.exe` executable. Drivers need to be installed in order for the interface to communicate to the Arduino hardware inside the module. These drivers are included in the Arduino software, which can be downloaded from `www.arduino.cc`. This will require installing the Arduino IDE, which might or might not be desired (see also Section 3). Therefore, standalone drivers have been included in the ZIP-archive, which can be installed according to the instructions below.

Installing Standalone Drivers

1. When the module is first plugged in, Windows should inform about a new device, for which (most probably) no drivers have been found (Figure 1).

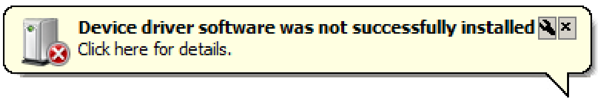


Figure 1: Unless the Arduino drivers have already been installed or present on the system, Windows will not be able to sucessfully install the driver software for the VeloTrack module.

2. To install these drivers, open the **Device Manager** (e.g. by running `devmgmt.msc` from the Start- or Run-menu, or navigating to it through Computer-Properties). An unknown device should be listed, as seen in Figure 2. Right-click this device and choose "Update Driver Software...".

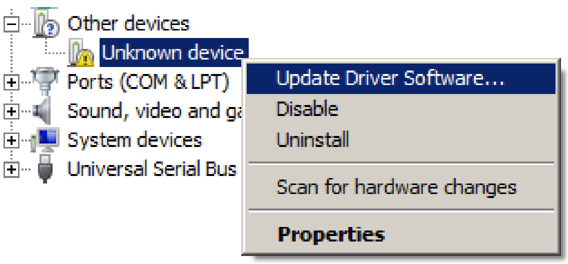


Figure 2: Right-click the unknown device listed in the Device Manager, and choose "Update Driver Software".

3. In the window that pops up, rather than choosing the default option which will search automatically for drivers, choose "**Browse my computer for driver software**". This will allow you to provide the drivers manually.

4. Enter the path to the *drivers* subdirectory, which is present in the folder where the VeloTrack ZIP-archive has been extracted (Figure 3), and click *Next*.

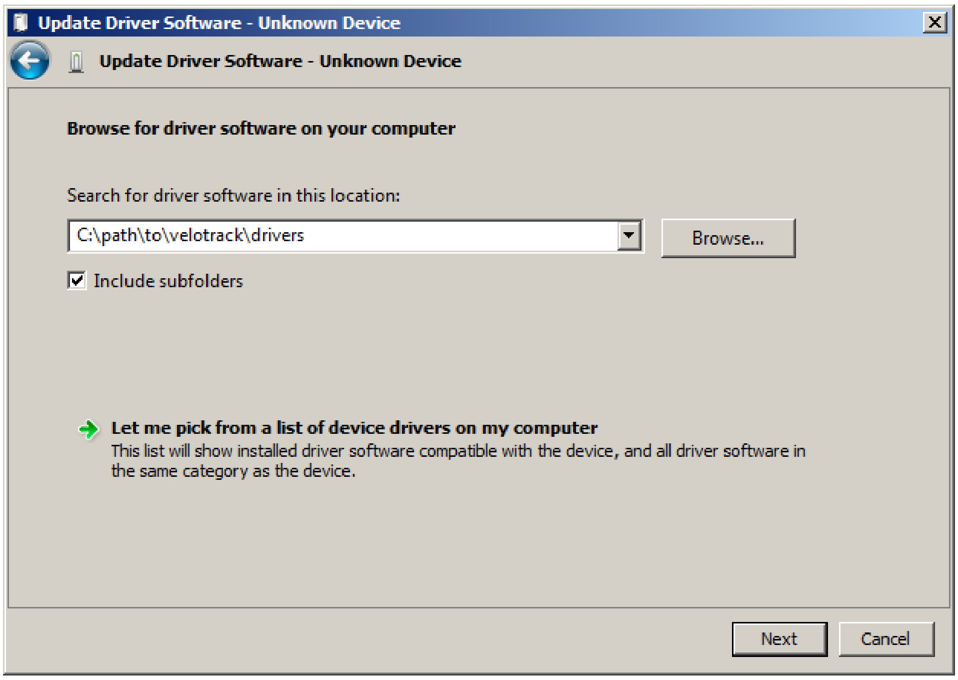


Figure 3: Enter the path to the *drivers* folder, which is a subdirectory of the velotrack folder.

5. The wizard will look for drivers in the specified folder and start installing them. A window will pop-up to verify that these drivers should be installed (Figure 4). Click *Install* to confirm.

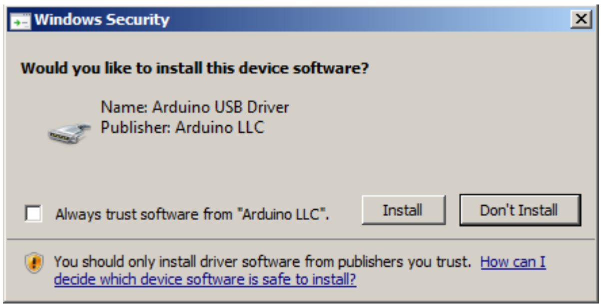


Figure 4: Confirm the driver installation.

6. After the installation has finished successfully, the Arduino is listed in the Device Manager, including the (virtual) COM-port it is connected to (e.g. `COM3`, Figure 5). It is advised to keep a (mental) note of this port, as it will be used later in the VeloTrack software.

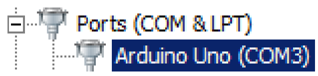


Figure 5: After installation, the Arduino is listed in the Device Manager.

1.3. Linux

There is both a 32-bit and 64-bit version of VeloTrack available for GNU/Linux systems as a precompiled binary. These can be installed simply by extracting the corresponding tarball and running the `velotrack.sh` shell-script. Running the executable (`velotrack`) directly will not work, unless the proper version of Qt5 is installed on the system. The wrapper-script will set up the shared-library path such that the dynamic libraries included in the `lib/` subdirectory will be loaded.

It's not necessary to install any drivers for the Arduino.

1.4. Compiling from Source

To compile VeloTrack on any system supported by the Qt framework, the project file `velotrack.pro` may be used. Loading this file in the Qt Creator IDE will allow you to compile the project, provided that the `QSerialPort` has been installed on the target system (e.g. on Debian/Ubuntu systems, this can be done by installing the `libqt5serialport5-dev` package, available from the repositories). Alternatively, from the commandline (assuming a Unix-like shell), run:

```
qmake -config release # this will produce a Makefile
make # compile and link the binary
./velotrack # run the program
```

2. Using the `VeloTrack` Interface

2.1. Overview

After opening the executable (`velotrack.exe` on Windows, `velotrack.sh` on Linux), you will be greeted by a splash screen (click to hide), and the main-window (Figure 6). The interface is quite minimal and contains the following elements:

1. *Port-selection list*: select the port to which the module is connected. This port-number corresponds to the one that was listed in the Device Manager (Figure 5).

2. *Connect/Disconnect*: A connection between the PC and the VeloTrack module at the selected port will be attempted when this button is clicked. When a connection is active, this button serves to terminate this connection.

3. *Scan*: Clicking this button will refresh the ports listed in the dropdown menu. When the USB cable is plugged in or unplugged, this will *not* be automatically detected. The scan-button can then be used to update the list.

4. *Start*: The big square button on the left, containing the green triangular symbol pointing to the right, is used to start a new measurement.

5. *Download*: The big square button on the right, containing the blue triangular sumbol pointing downward, is used to download measured data from the module to the computer. After downloading, you will be prompted to save the downloaded data to a file, securing its contents. Saving the content to disk can be delayed to, or redone at any later time by using the File - Save (Ctrl+S) action.

6. *auto-download*: When this box is checked (default), the data will be downloaded automatically when a measurement has been finished.

7. *Plot-area*: A large area of the window is dedicated to a graph-box, that shows a preview of the data after it has been downloaded to the computer. The data shown in this area always corresponds to the data currently present on the computer, which can be exported to disk using the File - Save (Ctrl+S) action.

8. *Status*: In a small region below the plot-area, the current status of the program is shown. Some errors will also be presented in this region.

2.2. Performing a Measurement

When the device has been connected using the *Connect* button, a succesful connection is indicated in the status-area ("Connected"). Also, while connecting, the red indication-LED will blink once. A measurement can be started now by clicking the *Start*-button; the yellow LED on the module lights up. The module has been configured to wait until

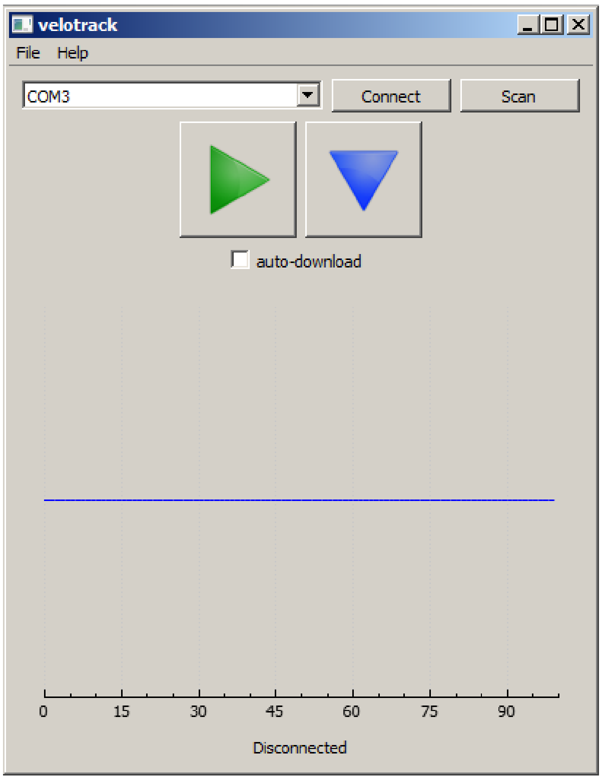


Figure 6: The VeloTrack main-window.

a certain displacement-threshold has been exceeded (this threshold can be reconfigured by reprogramming the module, as described in Section 3). As soon as the threshold is exceeded, the green light will turn on to indicate that the device is now measuring. The duration of the measurement is fixed and the light will turn off as soon as the measurement is finished.

When the measurement is finished, the data can be downloaded from the device. With the *auto-download* option checked, this will be done automatically; otherwise, hit the *Download*-button. After downloading, a dialog is prompted allowing you to save the data to a plaintext (`.txt`) file, and the results will be displayed in the graph-area. To save this data at a later time, click *Save* in the *File*-menu (or press `Ctrl+S`).

2.3. Warning

- Starting a measurement will erase the data already present in the buffer *of the module*. Make sure to download the data before starting a new measurement.
- Downloading the data will overwrite the data already present in the buffer *of the computer*. Make sure to save the data to a file before commencing a new download.

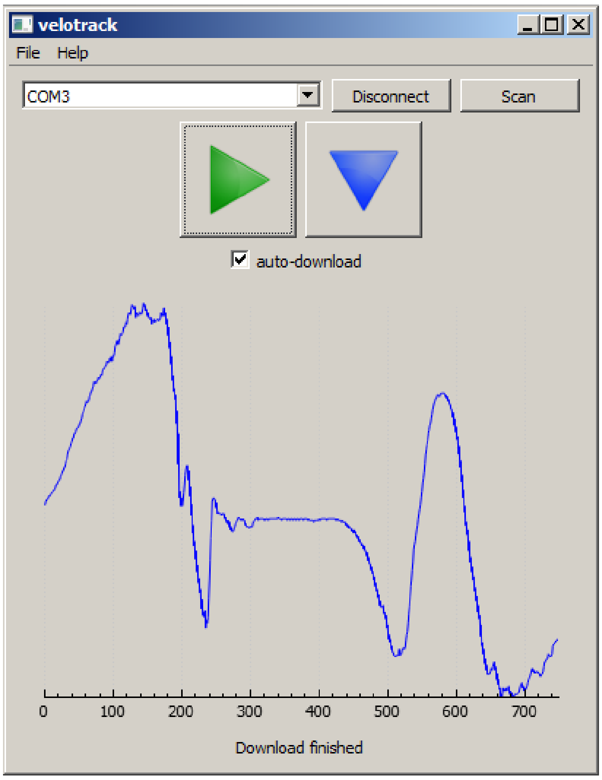


Figure 7: The VeloTrack main-window after a successful measurement and download.

3. Modifying the Firmware

Internally, the module contains an Arduino Mega 2560 development board. This can be reprogrammed through the USB-port, most easily using the official Arduino IDE (`www.arduino.cc`). However, after installing, a few additional steps have to be taken to enable C++11 support in the Arduino IDE (Integrated Development Environment), which is necessary to compile the firmware:

3.1. C++11 Compatibility

The compiler behind the Arduino IDE should be passed a flag that tells it to enable C++11 code. Only relatively new compilers support these features, so first make sure that version `>=1.5.7` of the Arduino IDE is installed. If so, locate the `platform.txt` file, which can probably be found at

```
{path to Arduino}/hardware/arduino/avr/platform.txt
```

In this file, edit the `compiler.cpp.flags` line by adding `--std=c++11` to it. For example (without the line-break):

```
compiler.cpp.flags=--std=c++11 -c -g -Os -w
                   -fno-exceptions -ffunction-sections -fdata-sections
```

After restarting the IDE, it should now be able to compile C++11 programs.

3.2. Changing Measurement Parameters

The firmware contains a set of 3 parameters that are most likely to be changed:

1. `RECORD_TIME` in milliseconds
2. `RECORD_INTERVAL` in microseconds
3. `RECORD_DELAY` in steps (see below)

These parameters are defined near the top of the `driver.ino` source-file, which can be found in the `src/driver` folder (not to be confused with the `velotrack/drivers` folder, which contains the Arduino drivers for Windows described in Section 1.2).

3.2.1. `RECORD_TIME` and `RECORD_INTERVAL`

`RECORD_TIME` defines the duration of a measurement in milliseconds. During this time, a measurement will be recorded every `RECORD_INTERVAL` microseconds. Therefore, the total number of measurements recorded is equal to:

$$N_{rec} = \frac{1000 \times \texttt{RECORD\_TIME}}{\texttt{RECORD\_INTERVAL}}$$

The value of N_{rec} is important due to the memory limitations of the Mega 2560 chip, which has 8kB of SRAM available to store measurements, minus the memory reserved for the remainder of the program. In the current implementation, this leaves $N_{buf}^{max} = 7964$ bytes for the measurement-buffer. This value could change when the firmware is modified. For an exact and current value of N_{buf}^{max}, set `RECORD_TIME` to 0 and compile the firmware (without uploading). The output will be along the lines of the following:

Global variables use 228 bytes (2%) of dynamic memory, leaving ***7,964 bytes*** *for local variables.*

The number of bytes left for local variables is the current value of N_{buf}^{max}.

At 2 bytes per record, a total in the order of 4000 measurements can be stored on the device.

$$N_{rec} \leq \frac{N_{buf}^{max}}{2} \approx 4000$$

The Arduino environment will warn when the program requires more memory than available.

3.2.2. `RECORD_DELAY`

`RECORD_DELAY` specifies the number of steps that has to be exceeded before the measurement is actually started. The datasheet of the HEDS-5701-A00 rotary encoder (Appendix A) specifies a total of 500 cycles per revolution of the disk. Every cycle consists of 4 detectable *steps* (changes of state), adding up to a total of 2000 steps per

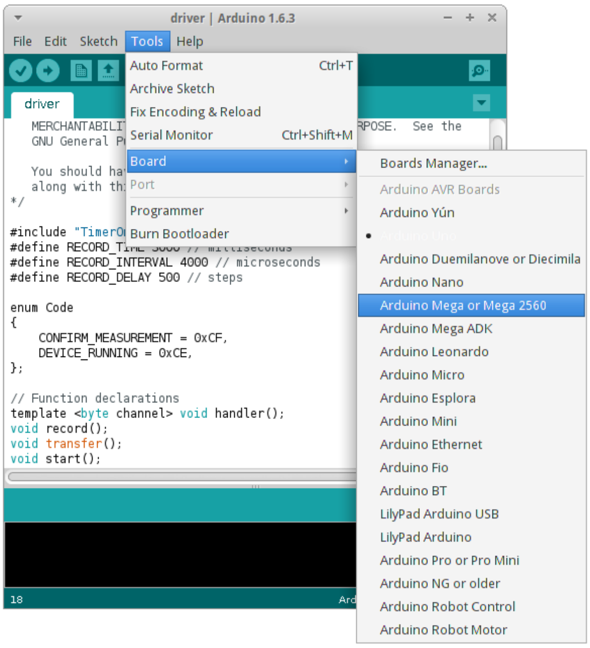


Figure 8: Before compiling and uploading the modified firmware, make sure the IDE knows for which type of Arduino it is intended by selecting "Arduino Mega or Mega 2560" in the Tools - Board menu.

Figure 9: Use the *Upload* button to compile and upload the new firmware to the module. The IDE will report about the memory usage in the black console area at the bottom of the window. Any messages warning you about stability-issues due to high memory percentages may be ignored.

revolution. The VeloTrack software has been calibrated with a conversion-constant to convert the number of steps to a distance in meters:

$$C = 7.45 \times 10^{-5} \, \frac{\text{m}}{\text{step}},$$

which can be used to calculate the threshold s in meters:

$$s = C * \texttt{RECORD\_DELAY}.$$

After changing these values accordingly, make sure the Arduino IDE is configured for the Arduino Mega 2560 board (Figure 8), and upload the modified firmware using the Upload-button (Figure 9). For more information on the internal workings of the module, see Section 4.

State	S1	S2	S3	S4
Channel A	1	1	0	0
Channel B	0	1	1	0

Table 1: The different states of the rotary encoder, as defined in the datasheet (Appendix A) and Figure 10.

$\rightarrow$	S1	S2	S3	S4
S1	0	$+1$	± 2	-1
S2	-1	0	$+1$	± 2
S3	± 2	-1	0	$+1$
S4	$+1$	± 2	-1	0

Table 2: Transition-table to map state-transitions to displacement. Ambiguous transitions (± 2) are ignored.

4. Internal Signal Processing

The rotary encoder emits two signals, on channels A and B respectively. Figure 10 (taken directly from the datasheet in Appendix A) shows these signals with respect to each other. The phase-difference between channel A and B allows for the detection of 4

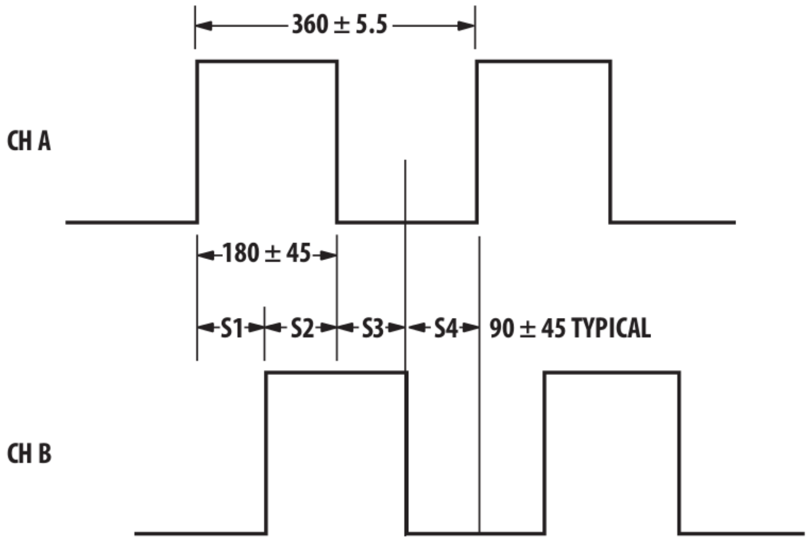


Figure 10: Signals from the rotary encoder

states, denoted S1-S4 in Figure 10 (Table 1). The direction of rotation can be deduced from the transition between states, as illustrated in Table 2. The transition-table is then used to determine positive and negative displacements. The firmware in the module (`driver.ino`) ignores ambiguous transitions (e.g. S1 to S3), i.e. in the table that is implemented in the firmware, these entries are set to 0. Whenever the microcontroller detects a change in either channel, the transition-table is consulted to determine which way the rotary encoder has moved and a counter is updated by adding the table-entry to it. Every `RECORD_INTERVAL` microseconds, the current value of the counter is stored to memory and reset to 0. It is the contents of this memory buffer that are transferred to, and displayed by the VeloTrack software.

The pin-layout of both the connection to the rotary encoder and the VeloTrack module is shown in Figure 11.

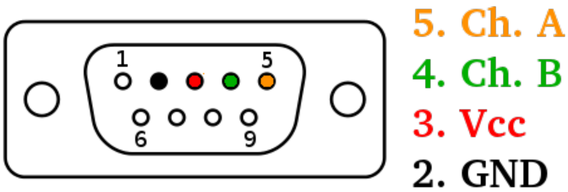


Figure 11: Pin-layout of the connector

5. Contact

For questions and support, please feel free to contact me at

jorenheit@gmail.com

A. HEDS-5700 Series Datasheet

The following pages contain the HEDS-5700 datasheet, referenced on several occasions in the text. It contains information about the signals emitted on both channels, as well as the pin-out. Note that this document contains generalized information on all devices in the 5700 series. The one contained in the enclosing box is of type 5701-A00.

Agilent Technologies

Panel Mount Optical Encoders

Technical Data

HEDS-5700 Series

Features

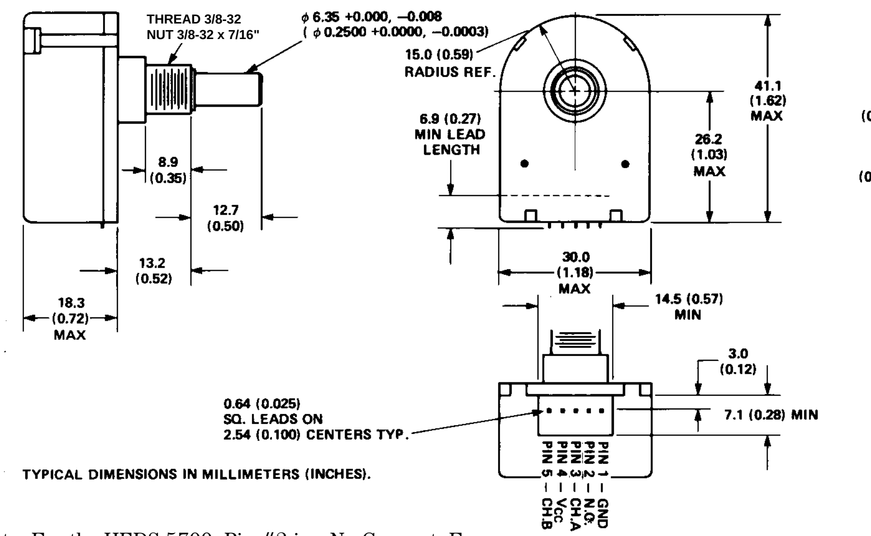
- **Two Channel Quadrature Output with Optional Index Pulse**
- **Available with or without Static Drag for Manual or Mechanized Operation**
- **High Resolution – Up to 512 CPR**
- **Long Rotational Life, >1 Million Revolutions**
- **-20 to 85°C Operating Temperature Range**
- **TTL Quadrature Output**
- **Single 5 V Supply**
- **Available with Color Coded Leads**

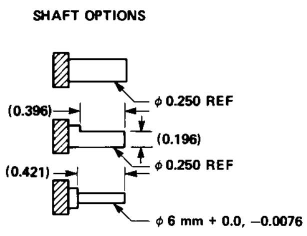
Description

The HEDS-5700 series is a family of low cost, high performance, optical incremental encoders with mounted shafts and bushings. The HEDS-5700 is available with tactile feedback for hand operated panel mount applications, or with a free spinning shaft for applications requiring a pre-assembled encoder for position sensing.

The encoder contains a collimated LED light source and special detector circuit which allows for high resolution, excellent encoding performance, long rotational life, and increased reliability. The unit outputs two digital waveforms which are 90 degrees out of phase to provide position and direction information. The HEDS-5740 Series provides a third Index Channel.

Package Dimensions





OPTIONAL WIRING COLOR CODE TABLE	
COLOR	OUTPUT
WHITE	A
BROWN	B
RED	V_{CC}
BLACK	GND
BLUE (THREE CHANNEL)	I

*Note: For the HEDS-5700, Pin #2 is a No Connect. For the HEDS-5740, Pin #2 is Channel I, the index output.

The HEDS-5700 is quickly and easily mounted to a front panel using the threaded bushing, or it can be directly coupled to a motor shaft (or gear train) for position sensing applications.

Applications

The HEDS-5700 with the static drag option is best suited for applications requiring digital information from a manually operated knob. Typical front panel applications include instruments, CAD/CAM systems, and audio/video control boards.

The HEDS-5700 without static drag (free spinning) is best suited for low speed, mechanized operations. Typical applications are copiers, X-Y tables, and assembly line equipment.

Note: Agilent Technologies encoders are not recommended for use in safety critical applications. Eg. ABS braking systems, power steering, life support systems and critical care medical equipment. Please contact sales representative if more clarification is needed.

Absolute Maximum Ratings

Parameter	Symbol	Min.	Max.	Units	Notes
Storage Temperature	T_s	-40	+85	°C	
Operating Temperature	T_a	-20	+85	°C	
Vibration			20	g	20 Hz - 2 kHz
Supply Voltage	V_{CC}	-0.5	7	V	
Output Voltage	V_O	-0.5	V_{CC}	V	
Output Current per Channel	I_O	-1	5	mA	
Shaft Load – Axial			1	lb	
– Radial			1	lb	

Recommended Operating Conditions

Parameter	Symbol	Min.	Max.	Units	Notes
Temperature	T	-20	+85	°C	Noncondensing Atmosphere
Supply Voltage	V_{CC}	4.5	5.5	V	Ripple <100 mV_{p-p}
Rotational Speed – Drag			300	RPM	
– Free Spinning			2000	RPM	

Electrical Characteristics Over Recommended Operating Range, Typical at 25°C

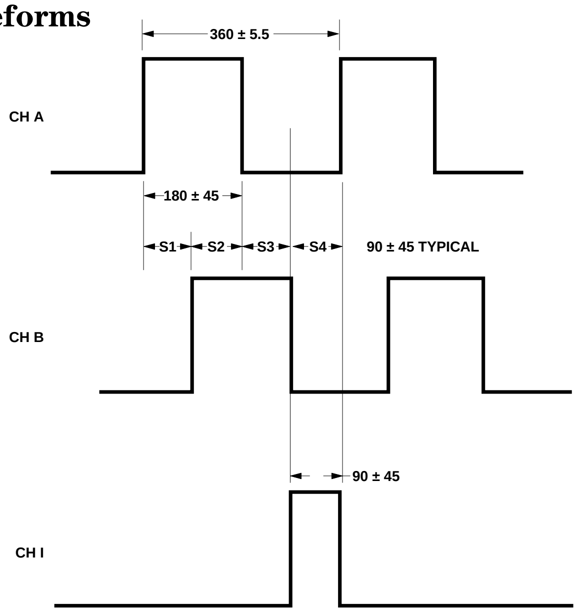
Parameter	Symbol	Min.	Typ.	Max.	Units	Notes
Supply Current	I_{CC}		17	40	mA	Two Channel
			57	85		Three Channel
High Level Output Voltage	V_{OH}	2.4			V	I_{OH} = -40 µA Max.
Low Level Output Voltage	V_{OL}			0.4	V	I_{OL} = 3.2 mA

Note: If more source current is required, use a 3.2 K pullup resistor on each output.

Mechanical Characteristics

Parameter		Min.	Typ.	Max.	Units	Notes
Starting Torque	– Static Drag		0.47		oz in	
	– Free Spinning			0.14	oz in	
Dynamic Drag	– Static Drag		1.1		oz in	100 RPM
	– Free Spinning		0.70		oz in	2000 RPM
Rotational Life	– Static Drag	1 x 10^6			Revolutions	1 lb Load
	– Free Spinning	12 x 10^6			Revolutions	4 oz Radial Load
Mounting Torque of Nut				13	lb in	

Output Waveforms



NOTE:
ALL VALUES ARE IN ELECTRICAL DEGREES, WHERE 360° e = 1 CYCLE OF RESOLUTION.
ERRORS ARE WORST CASE OVER ONE REVOLUTION.
CH B LEADS CH A FOR COUNTERCLOCKWISE ROTATION.
CH A LEADS CH B FOR CLOCKWISE ROTATION.

Ordering Information

HEDS-57□□–□□□

Outputs
0 - 2 Channel
4 - 3 Channel

Mechanical Configuration
0 - Pins
1 - 6" Coded Leads

Resolutions (Cycles Per Revolution)
HEDS-570X 2 Channel
K - 96 CPR
C - 100 CPR
F - 256 CPR
G - 360 CPR
A - 500 CPR
I - 512 CPR
HEDS-574X Three Channel*
A - 500 CPR

Drag Option
0 - Free Spinning
1 - Static Drag

Shaft Configuration
0 - 1/4" dia. with no flat
1 - 6 mm dia. with no flat
2 - 1/4" dia. with flat

*Please contact factory for other resolutions.

Agilent Technologies

		00	01	02	10	11	12
HEDS-5700#	A		*	*	*		
	C		*	*	*	*	
	F	*				*	*
	G	*					
	I	*	*	*	*		*
	K		*		*		
HEDS-5701#	A	*		*			*
	C				*		
	F	*	*		*	*	
	G	*					
	H		*				*
	I			*			
HEDS-5740#	A			*			

www.agilent.com/semiconductors

For product information and a complete list of distributors, please go to our web site.

For technical assistance call:

Americas/Canada: +1 (800) 235-0312 or (408) 654-8675

Europe: +49 (0) 6441 92460

China: 10800 650 0017

Hong Kong: (+65) 271 2451

India, Australia, New Zealand: (+65) 271 2394

Japan: (+81 3) 3335-8152(Domestic/International), or 0120-61-1280(Domestic Only)

Korea: (+65) 271 2194

Malaysia, Singapore: (+65) 271 2054

Taiwan: (+65) 271 2654

Data subject to change.

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