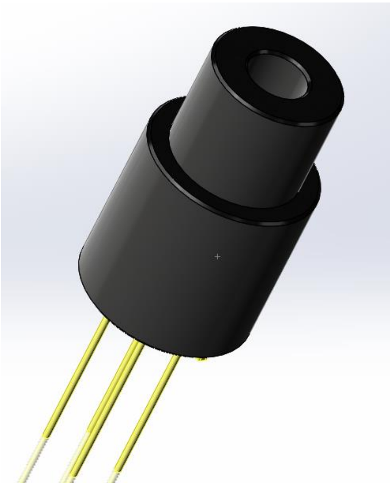


TSDHA405-5SL5

DIGITAL TEMPERATURE SENSOR

Product Description

The TSDHA405-5SL5 is a digital thermopile sensor in a TO5 package plus an additional external housing. The sensor includes an infrared sensor (thermopile) and a sensor signal conditioner.

The sensor can be connected to any microcontroller by an I^2C interface.

Features

- Small field of view
- I^2C Interface

Applications

- Body temperature measurement

ABSOLUTE MAXIMUM RATINGS

Absolute maximum ratings are limiting values of permitted operation and should never be exceeded under the worst possible conditions either initially or consequently. If exceeded by even the smallest amount, instantaneous catastrophic failure can occur. Even if the device continues to operate satisfactorily, its life may be considerably shortened.

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Supply voltage	V_{DD}	---	-0.3	---	+6.5	V
Storage temperature	T_{stor}	dry	-40	---	+85	°C
Voltage at supply and IO pins	V_{DD} V_{IO}	---	-0.3	---	V_{DD} +0.3	V
Current into supply and IO pins	I_{IN}	---	---	---	2	mA
ESD rating	ESD	Human Body Model	tbb	---	tbd	kV
Humidity	Hum	---	Non condensing			---

OPERATING CONDITIONS

If not otherwise noted, 3.3V supply voltage is applied, blocking capacitor of 1 - 10µF must be placed close to V_{DD} and Ground.

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Operating supply voltage	V_{DD}	--	2.6	3.3	5.5	V
Operating ambient temperature	T_{op}	Non-condensing	0	---	+50	°C
Operating object temperature	T_{Obj}		0		+50	°C
Resolution	RES		---	---	1.00	°C
Supply Current	I_{VDD}		---	800	1500	µA
		Sleep state, idle current	---	0.7	2	nA
Serial data clock I2C	F_{SCL}	---	---	400	---	kHz

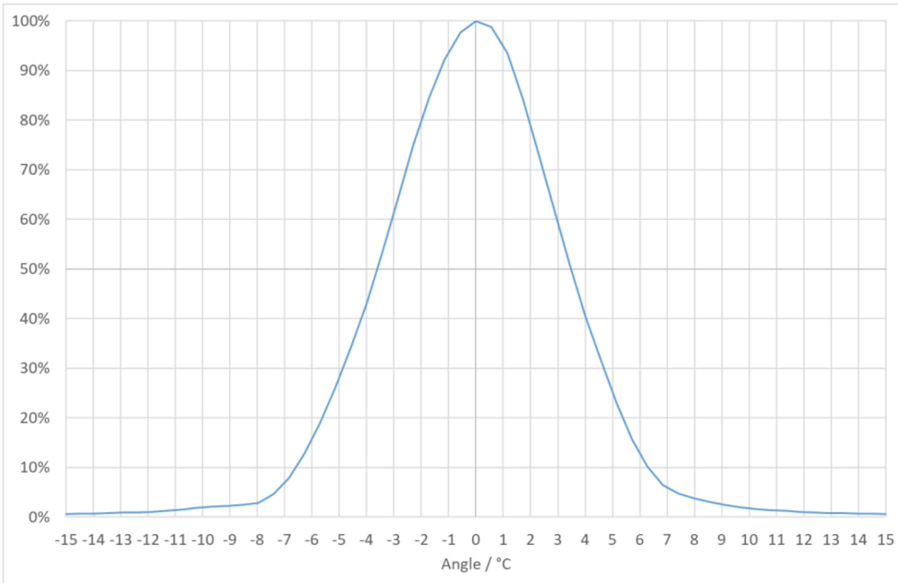
ACCURACY

If not otherwise noted, 3.3V supply voltage is applied, blocking capacitor of 1 - 10µF must be placed close to V_{DD} and Ground.

T_{sen} = sensor temperature, T_{obj} = object temperature

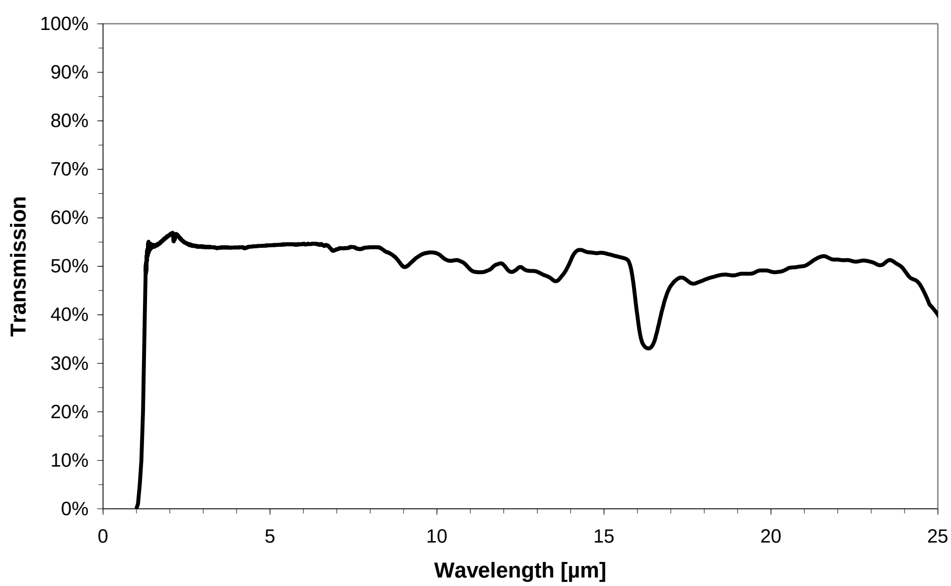
Parameter	Symbol	Sensor Temperature	Object Temperature	Max	Unit
Accuracy Primary Temperature	ACC_P	+15°C < T_{sen} < +35°C	+36°C < T_{obj} < +38°C	±0.5	°C
Accuracy Secondary Temperature	ACC_S	+0°C < T_{sen} < +50°C	+0°C < T_{obj} < +50°C	±0.7	°C

FIELD OF VIEW



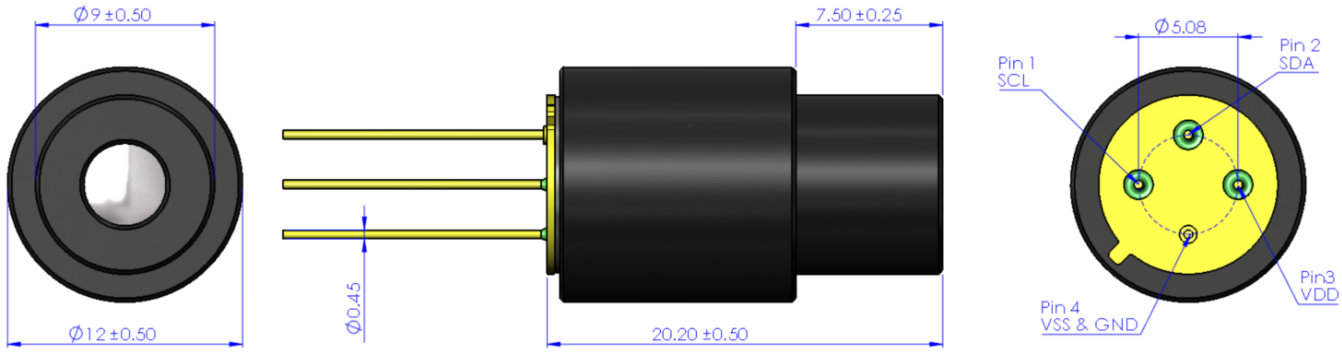
TRANSMISSION

Parameter	Property
Lens Material	Silicon
Transmission Range	≥1.1 μm



DIMENSIONS

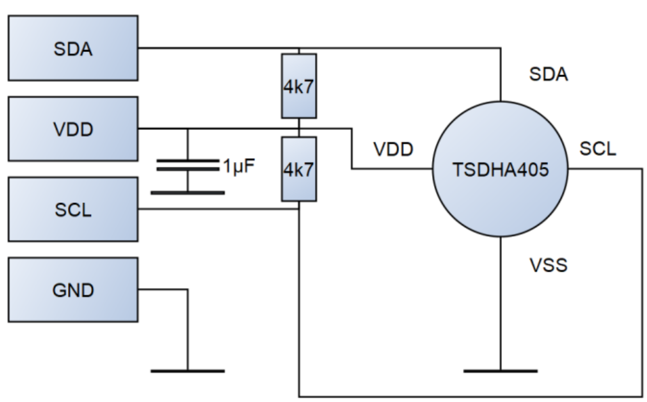
If not specified, all tolerances according DIN ISO 2768-m.



ELECTRICAL INTERFACE

Pin	Name	Type	Function
1	SCL	DI	I^2C Clock
2	SDA	DIO	I^2C Data
3	V_{DD}	Power	Supply Voltage
4	V_{SS}	Power	Ground

BASIC CONNECTION SCHEME



GENERAL INSTALLATION REQUIREMENTS

Due to the small field of view the TSDHA405-5SL5 is very sensitive against temperature changes in the environment. Therefore, the manufacturer has to take care to take the following points into consideration:

- Sudden change of ambient temperature and also touching the body of the sensor is not recommended during operation. This causes disturbance of the object temperature measurement. Typical recovery time is in the range of 30 seconds.
- The part should be shielded from forced convection (e.g. airstream) but not completely covered from natural convection to allow thermal equalization.

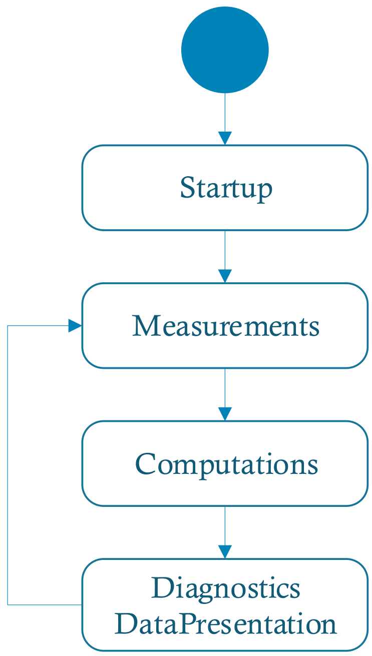
FUNCTIONAL DESCRIPTION OF THE SENSOR

The TSDHA405-5SL5 is a sensor for contactless temperature measurement using infrared radiation of the target object. The infrared radiation is focused by a silicon lens to the detector surface of a thermopile chip where it is transformed to a temperature. The thermopile chip generates a voltage signal depending on the temperature difference of the sensor housing and the detector surface temperature. A contact temperature sensor (NTC) measures the sensor housing temperature.

The TSDHA405-5SL5 uses a µC with integrated Sigma-Delta analog digital converter (ADC) and analog front end to convert the resistance of the NTC and thermopile voltage to digital values. Using these data, it calculates the target object temperature and provides both object and sensor (ambient) temperature via I²C.

I²C peripheral is implemented as a Slave Only device. Registers, buffers and flags implementation allows to behave asynchronously between communication protocol and main tasks. I²C master can read I²C buffer without main process interruption.

The following flow chart shows the general behavior:



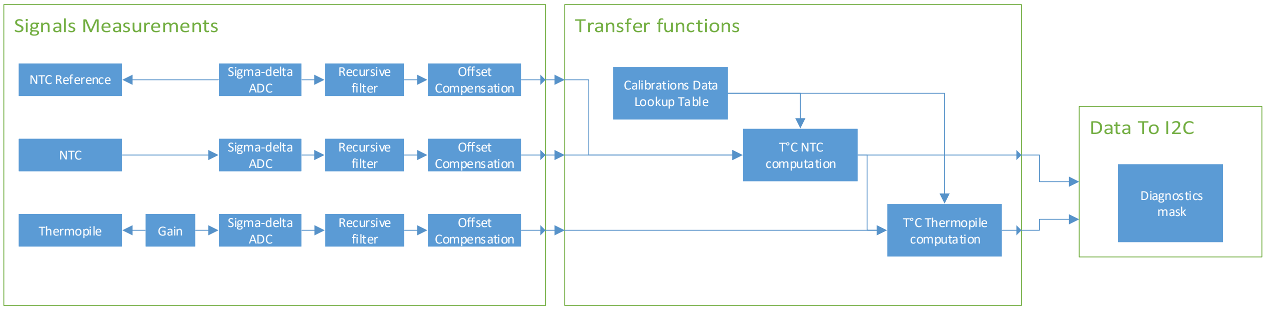
During startup the sensor checks if the data stored in the EEPROM are valid. If no the sensor will response with an error message. See chapter **Diagnostics** for details. When passing the validation, the data are loaded to work RAM. This includes routing of analog frontend, calibration parameters and the serial number. Since there is no read access to the EEPROM data during normal mode allowed this is necessary to read out the serial number during measurements.

The Sensor can be placed in a special state call “Calibration mode”. While in this mode, the sensor doesn’t perform any measurement nor computation. It is mainly used to read/write calibration data in EEPROM. Outside Calibration mode, read/write calibration command to the EEPROM are not allowed. Calibration mode can only be left by performing a power on reset.

After startup the sensor continuously measures the values of reference temperature sensor and thermopile voltage, calculates the corresponding temperatures and store the results in the dedicated output registers. Using I²C commands the user can readout these registers and also the RAM content without affecting the temperature calculation process.

DATA FLOW

The following flow chart shows the analog and digital signal flow during measurement operation.



The sensor temperature is calculated using the quotient of the NTC resistance and a fixed reference resistance network. The thermopile voltage is amplified using a low noise high gain amplifier before conversion. All analog signals are converted using the same ADC therefore a multiplexer is used to switch between the different signal inputs. This multiplexer is not shown in the chart.

DATA OUTPUT

The TSDHA405-5SL5 provides the measurement data in the following format:

- ADC values as 2 Byte signed integer
- Temperatures as 2 Byte signed integer representing tenth of °C:

  “3000” → 30.00°C

See more details for I2C communication in Chapter **I²C Interface Commands**.

DIAGNOSTICS

The TSDHA405-5SL5 uses the output that normally contend the temperature values to provide diagnostic data. The following table shows the different error codes:

Failures	NTC Code (xH) / Value(x°C) (Ambient temperature)	Thermopile Code (xH) / Value(x°C) (Object temperature)
EEPROM Check Fail	7788H / 306.00°C	7788H / 306.00°C
NTC Underflow	7594H / 301.00°C	- / -
NTC Overflow	75F8H / 302.00°C	- / -
TP Underflow	- / -	765CH / 303.00°C
TP Overflow	- / -	76C0H / 304.00°C

- / - : data is not impacted.

I²C ADRESS

The I²C address is user configurable. The standard I²C address is

I2C Address Hex	I2C Address Dec.
10	16

I²C INTERFACE COMMANDS

An I²C communication message starts with a start condition and it is ended by a stop condition.

Most commands consist of two bytes: the address byte and command byte.

TSDHA405-5SL5 is a slave, byte oriented, I²C device. Exchange is so limited by hardware.

- Write One I²C Input Data Register: Commands range is [0Ch-16h]

S	Slave Address	W	A	Command (ie: 10h)	A	Data	A	P

- Read One Output Data Register: Commands range is [00h-0Bh]

S	Slave Address	W	A	Command (ie: 07h)	A	P	S	Slave Address	R	A	Data	A	P

- Read Several Output Data Register: Commands range is [80h-8Bh]
  Commands are same as Command Read One Byte, added with 80h

S	Slave Address	W	A	Command (ie: 80h)	A	P					
			S	Slave Address	R	A	Data (ie: I2C_O0)	A	Data (ie: I2C_O1)	...	P

Note: S: Start; P: Stop; SlaveAddress: I²C Address = 10h; R: Write Lowest bit = 0; W: Read = 0; A: ACK

Through this protocol, master can access to the following registers:

Command (h)	Project Usage
00 [80]	Read NTC High byte [Start Read several Bytes until Stop, first byte is NTC High byte, Next Byte like command 01] 1)
01	Read NTC Low byte 1)
02 [82]	Read TP High byte [Start Read several Bytes until Stop, first byte is TP High byte, Next Byte like command 03] 1)
03	Read TP Low byte 1)
04	Read Sensor Format
07	Read Last Value (see command 11h, 12h and 13h)
10	Write Sensor Format, takes up until about 2sec, check with command 04h
11	Write RAM address to read
12	Write EEPROM address to read / write (only in Calibration Mode)
13	Write EEPROM data (only in Calibration Mode)
20	A write to this address occurs a Reset

1) to make sure that the High and Low byte of data are consistent, read word twice and check for equality

SENSOR FORMAT / STATE

Sensor Format commands (set = 10h, check = 04h) allow the master to change the value broadcast within NTC and TP slots.

Sensor Format	Sensor State	Description
00h	Measurement Mode Output temperature	Sensor behaves in a normal way. Data provided are temperatures and/or diagnostics mask.
FFh	Measurement Mode Output ADC values	Sensor behaves in a normal way. TP values are the ADC filtered values. NTC values are the result of the division with the NTC Reference.
A5h	Calibration Mode	Sensor stop its normal behavior and waits for command. Sensor changes his mode after Measurement process. This mode is used to safely read/write EEPROM content.
x	→ Measurement Mode Output temperature	Any wrong value will reset the format to normal (00h).

According to this, commands to EEPROM access (12h and 13h) will not be considered if the Sensor State is not in Calibration mode.

The state can be check by reading Sensor Format with command 04h.

Please note that changing Sensor State from calibration mode to Measurement Mode will not restore calibration data.

Sensor must have a power-

CHANGING EMISSIVITY

Emissivity of the TSDHA405-5SL5 is set to 100 % per default. That means that the infrared radiation of the surface to be measured is caused to 100 % from this surface. To adapt the sensor to the emissivity of the surface the user can edit it in the EEPROM.

The emissivity is defined as 2 Byte integer value where 0100h (256dec) is defined as 100%. To change the emissivity this value must be multiplied by the target emissivity and rounded:

*Example – set to 99% emissivity: 256 * 0.99 = 253.44 → 253 → 00FDh*

The following table show the registers to be modified:

EEPROM Address dec.	EEPROM Address hex.	Name	Default value
104	68	EMISSIVITY H	1
105	69	EMISSIVITY L	0

It's highly recommended not to change any other EEPROM content than the mentioned registers above. Otherwise checksum calculation will fail and the sensor will not work anymore.

SERIAL NUMBER

The serial number has 9 digits and is stored in the EEPROM. To read it out during normal operation it is transferred to the RAM during sensor startup.

Serial number has the following format: YYWW12345 – for example: 204200001

The following table shows the corresponding RAM content:

RAM Address dec.	RAM Address hex.	Name	Content hex.
252	0FC	Serial number HH	0C
253	0FD	Serial number H	2B
254	0FE	Serial number LL	D8
255	0FF	Serial number L	41

READ RAM (BANK 0)

At any time, the master can write a RAM address (Bank 0) with command 11h and read the value by command 07h.

Example: Read RAM address 95h, sensor address is 10h, RAM value is 32h.

S	10h	W	A	11h	A	95h	A	P	Set RAM address

S	10h	W	A	07h	A	P	S	10h	R	A	32h	A	P	Retrieve the value

READ EEPROM DATA

To be used, the sensor shall be placed in Calibration mode. Check when this mode is active with command 04h.

The master must write an EEPROM address with command 12h and read value with command 07h.

Set Sensor to Calibration Mode:

S	10h	W	A	10h	A	A5h	A	P	Command Set Sensor to Calibration Mode

S	10h	W	A	04h	A	P	S	10h	R	A	**A5h**	A	P	Read Sensor format while not A5h

Read EEPROM Byte (for 1 or more bytes):

S	10h	W	A	12h	A	05h	A	P	Write EEPROM address

S	10h	W	A	07h	A	P	S	10h	R	A	**xxh**	A	P	Retrieve the value

WRITE EEPROM DATA

To be used, the sensor shall be placed in Calibration mode. Check can be performed by reading command 04h.

To write a data at a specific EEPROM address, the master shall perform a Write EEPROM address first. Then the master writes the desired data with command 13h to launch the EEPROM writing process.

Afterward, master can perform a Read EEPROM data to check the written data.

Set Sensor to Calibration Mode:

S	10h	W	A	10h	A	A5h	A	P	Command Set Sensor to Calibration Mode

S	10h	W	A	04h	A	P	S	10h	R	A	**A5h**	A	P	Read Sensor format while not A5h

Write EEPROM Byte (for 1 or more bytes):

S	10h	W	A	12h	A	05h	A	P	Write EEPROM address
S	10h	W	A	13h	A	**32h**	A	P	Write EEPROM Data

Check Written EEPROM Byte (for 1 or more bytes):

S	10h	W	A	12h	A	05h	A	P	Write EEPROM address

S	10h	W	A	07h	A	P	S	10h	R	A	**32h**	A	P	Retrieve the value to check writing

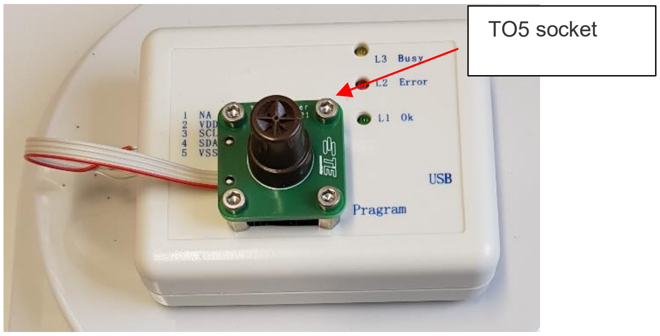
CHANGING I²C ADDRESS

For changing the I²C address a special equipment is needed. The following chapters describe the process in detail.

EQUIPMENT

The following equipment is needed to perform the change:

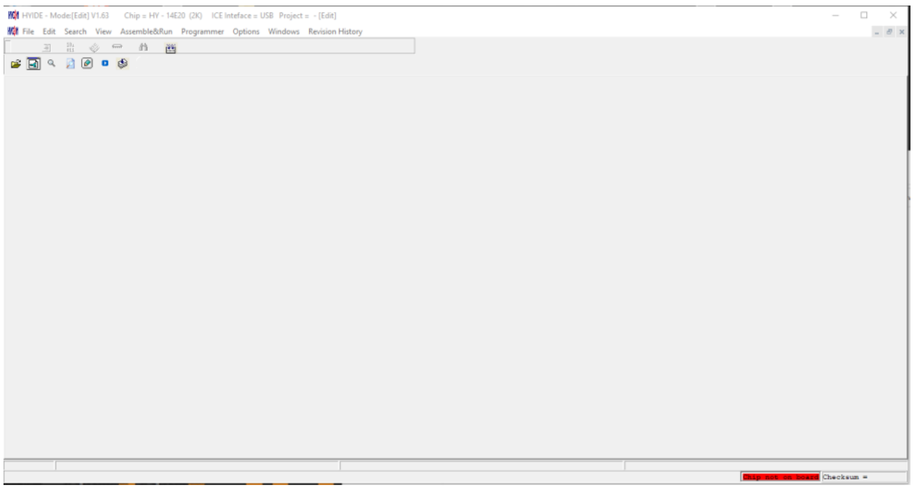
- USB box with TO5 socket with USB- and additional 4-wire cable



- Windows PC

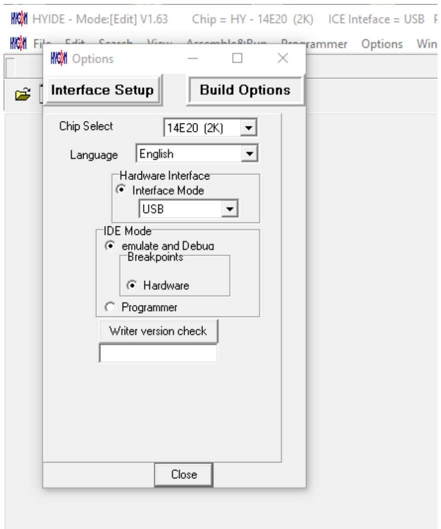
PREPARATION OF ENVIRONMENT

- Connect the USB box to a free USB port using a Mini-USB cable. The green LED must lit.
- Start the setup.exe located in folder \I2C_address_change\ on the flash drive.
- Accept the licence conditions and follow the instructions of the routine during installation.
- Uncheck all boxes at the end of installation except “Starting the software”.
- The software starts then automatically. Later you have to use the icon “HY14E IDE V1.6_beta3”. The following window appears:

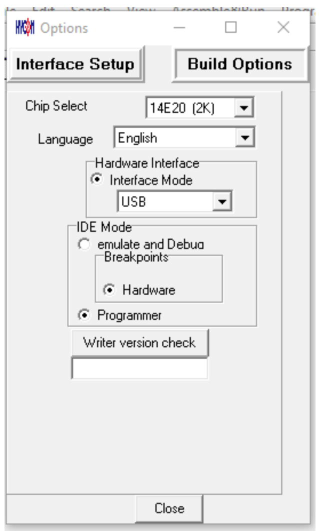


- In the lower right corner there may appear a status message that no chip is detected. This is ok since no device is plugged to the TO5 socket.

- Open the “Options” menu

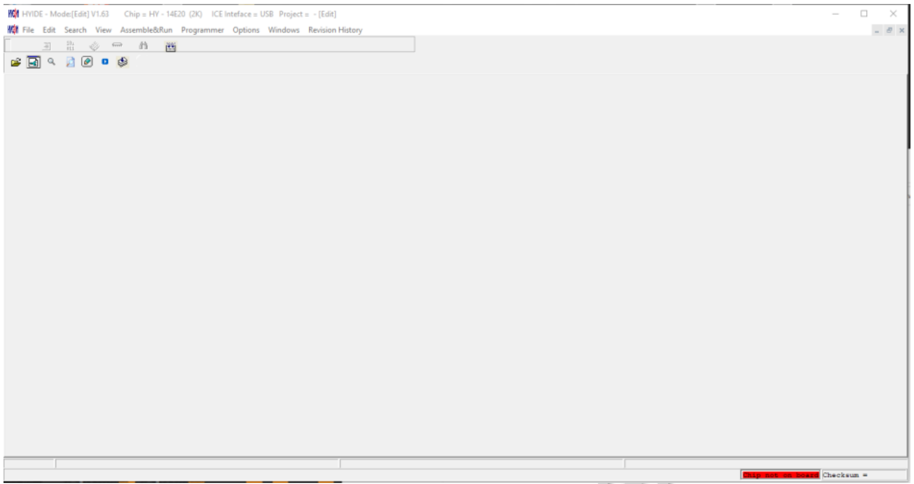


- Check “Programmer” in the lower middle of the dialog box and close the dialog. Now the “Programmer”-menu is accessable.

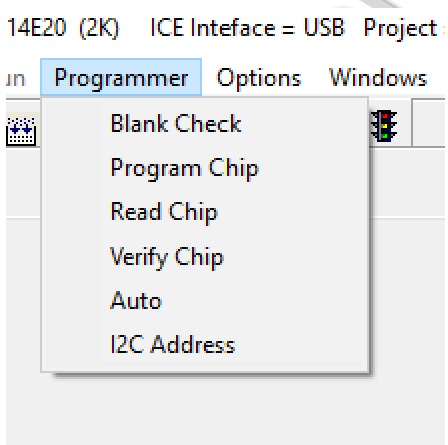


PERFORMING THE ADDRESS CHANGE

- Start the software if not already done. The following window appears:



- Select “I2C address” in the “Programmer” menu.

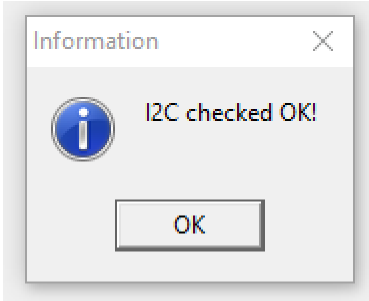


- The following window appears. If not, it's maybe minimized and only a title bar is shown. You have then to press the “restore” or “maximize” icon on the right side of the title bar.

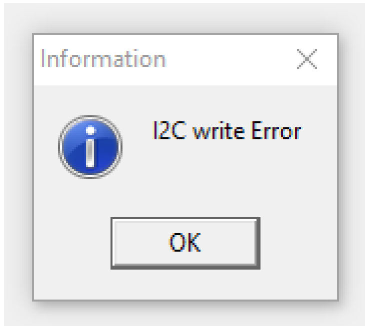
- Now place a device in the TO socket, the indicator must match to the small pin at the socket.
- Then press the “Read” button. The address of the device appears. It's shown as a hexadecimal number. If there is no device inserted “Read” returns always “FF” but no error message is shown!

- Now enter the new address and press “Write”. Please note that the software accepts all values between 0X00 and 0XFF. The standard I2C address range is only defined from 0X00 to 0X7F. The device may not work in your application if exceeding this range.

  If the following message appears everything is ok.



- If an error occurs the following message is shown.



- Then you must check if the part is connected correctly.

You can also detach the cable of the socket and use the 4-wire cable to connect the box directly to your I2C bus if the parts are already soldered to a PCBA. Both rows of pins of the connector have the same signal. Attention: Never remove the Jumper placed at Pin 1.