Kjærulf Pedersen a/s

Inclinometer type: KPM 100

Sheet no.

Application:

- Orientation measurements

Properties:

- Roll output of ±180°
- Pitch output of ±90°
- Yaw output of ±180°
- Accelerations in three directions
- Angular velocity in three directions
- Magnetic felt strength in three directions
- Modbus communication
- Alarms
- Bootloader

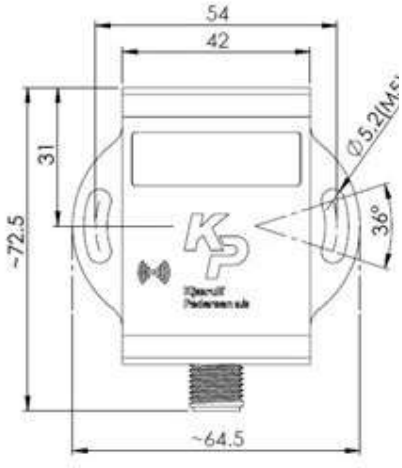
	7700001	7700-E010817V1

ELECTRICAL SPECIFICATIONS:

Supply:
10-28 VDC.

Output:
Modbus RTU RS485 protocol.

Connection: M12
Others on request depending on quantity



FUNCTIONALITY.

The sensor is built for measuring orientation.
The main components of the sensor are an accelerometer, a gyroscope, a magnetometer, and a DSP processor for inclinometer calculations.
Data output is the orientation in degrees.

ENVIRONMENTAL:

Temperatures:
Temperature on electronics: -40°C to 80°C.

EMC:
Emission: Domestic, EN 61000-6-3
Immunity: Industrial, EN 61000-6-2

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User guide KPM100

This is the user guide for the KPM100. It contains all information needed to connect and use the sensor. It is assumed that the user is familiar with the Modbus protocol.

Any questions not answered by this document can be forwarded to abs@kp-as.com.

Contents

Revisions

Rev A	Initial release
Rev B	Added more detail to the hardware setup
Rev C	Updated for firmware version v1.2
Rev D	Updated for firmware version v1.4
Rev E	Updated for firmware version v1.5

Sensor parameters

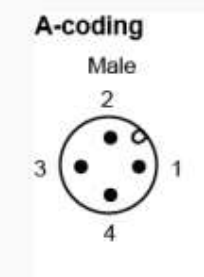
Parameters	Value
Supply voltage	10-28Vdc
Temperature range:	
Operational	-40-80°C.
Storage	-50-80°C.
Output:	
Roll	±180°
Pitch	±90°*
Yaw	±180°
Angular velocity	[Deg/s]
Acceleration	[g]
Magnetic field strength	[Gauss]
Features:	
Alarms	
Bootloader	
Communication:	
Connection	Male M12
Protocol	Modbus RTU RS485

*Se section “The pitch’s ±90° limit”.

Hardware setup

M12 connection

Communication with the KPM100 is done through an A-coded M12 connection.



M12 connector pin-out:

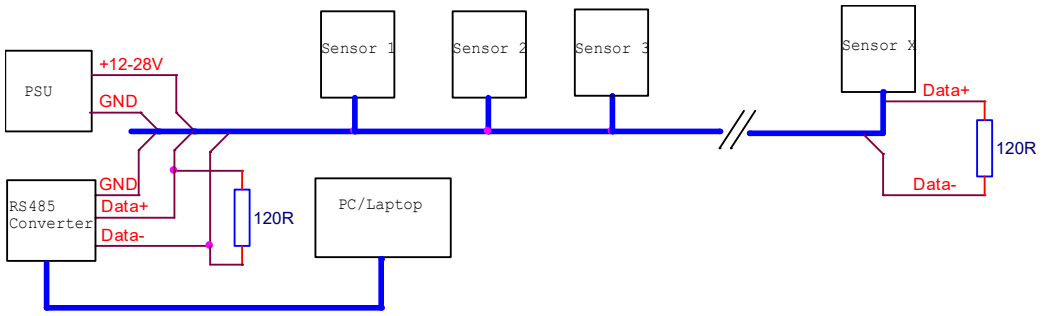
- Pin 1: Operating voltage
- Pin 2: RS485A
- Pin 3: 0V
- Pin 4: RS485B

Connection the KPM100 to the PC software

The requirements for using the KPM100 with the PC-software are:

1. A KPM100.
2. A power supply. The sensor can be sourced from 10V to 28V.
3. A M12 cable.
4. A RS485 to serial converter. This converts the differential signal to a more traditional serial signal. There are many options, but an example could be USB-RS485-WE-1800-BT.
5. A PC with KPM100-GUI software and a COM or USB port depended on the RS485 to serial converter.
6. 120Ω termination resistors.

An overview over the connections can be seen below. For the best result use shielded twisted pair cables and use a termination at the farthest ends of the bus connection. It is not recommended to set up the RS485 bus as a star connection, instead use a daisy chain.



Mounting orientation

The KPM100 can mounted in any orientation. However, gimbal locking occurs at +90° and -90° pitch so these orientations should be avoided.

Roll, pitch and yaw definitions

The KPM100's axis can be seen on the figure below.

The KPM100 output assumes the rotation order: $R_x R_y R_z$ where R_x, R_y, R_z are the rotation matrices around the x-axis, y-axis and z-axis respectively.

The KPM100 measures orientation relative to gravity and magnetic north.

The pitch's ±90° limit

The sensor limits the pitch value to ±90° to ensure that every orientation has only one corresponding set of values. This does not mean that the sensor cannot exceed 90°. For example, if KPM100 is turned 135° in the pitch direction the expected output would be:

$$[0° \text{ roll} \quad 135° \text{ pitch} \quad 0° \text{ yaw}]$$

However, the sensor outputs:

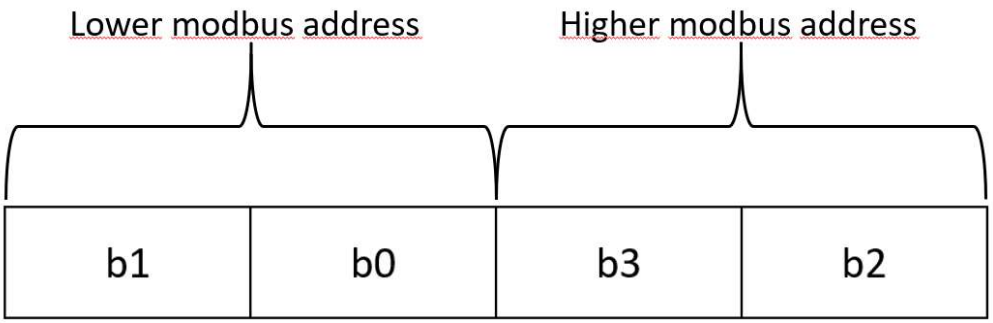
$$[180° \text{ roll} \quad 45° \text{ pitch} \quad 180° \text{ yaw}]$$

Both are the same orientation. However, the sensor only outputs the latter.

Floating-point values in the modbus interface

Some values in the modbus interface are floating-point values. Floating-point values are 32bit while the modbus interface is 16bit. Therefore, each floating-point value takes up two modbus addresses.

They are stored in the following format:

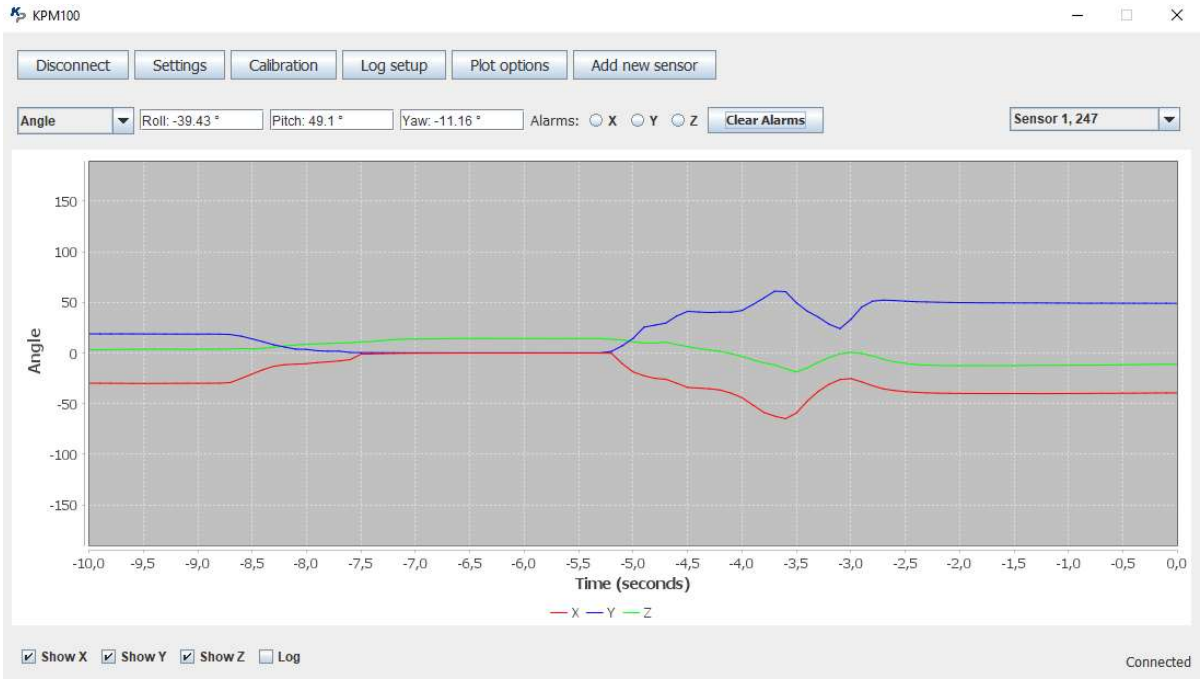


Where bn is a byte and b0 is the least significant byte.

KPM100 GUI

To simplify the setup of the KPM100 the KPM100 GUI is recommended. The GUI has the following features:

- Display sensor output graphically.
- Easy settings and alarms setup.
- Logging feature
- Greatly simplifies the magnetometer calibration process.


KPM100
Disconnect
Settings
Calibration
Log setup
Plot options
Add new sensor
Angle
Roll: -39.43 °
Pitch: 49.1 °
Yaw: -11.16 °
Alarms: X Y Z
Clear Alarms
Sensor 1, 247
Angle
150
100
50
0
-50
-100
-150
-10,0 -9,5 -9,0 -8,5 -8,0 -7,5 -7,0 -6,5 -6,0 -5,5 -5,0 -4,5 -4,0 -3,5 -3,0 -2,5 -2,0 -1,5 -1,0 -0,5 0,0
Time (seconds)
X Y Z
Show X
Show Y
Show Z
Log
Connected

Magnetometer calibration

To get a valid yaw output it is necessary to calibrate the internal magnetometer. It is highly recommended to use the KPM100 GUI to perform this calibration. When using the GUI do the following:

1. Start up the GUI and connect to the relevant sensor.
2. Open the calibration window.
3. Press the “Start calibration”-button.
4. Rotate the sensor such that its roll and pitch changes significantly from other samples. The actual roll and pitch values are irrelevant, they just need to be different from other samples.
5. When enough samples have been taken press the “End Sampling”-button.
6. Optionally input the magnetic field strength of your location. Alternatively leave it be, and the software will estimate it. This value has no effect on the yaw measurement.
7. Press the “calculate”-button.
8. In the bottom panel press the “upload”-button to upload.

Bootloader

The KPM100 is equipped with an EZBL- bootloader that allows the firmware, in the sensor, to be updated via the Modbus communication cables.

The firmware is encoded in the bl2 file type. The master must upload a valid bl2 firmware file according to the standard EZBL framework hand-shake definition from Microchip.

When the KPM100 starts up it is in bootloader-mode for 2 seconds. In this mode it looks for a bl2 formatted file containing the new firmware update. The bootloader recognizes a bl2 file by the file’s unique hash code. If the hash is detected within the 2 seconds, the sensor remains in the bootloader until a valid file has been received. If no hash is detected within the 2 seconds, and a valid application exists, the application is started.

If an ongoing bl2-file upload is aborted the bootloader will remain active, but the old application in the sensor is deleted. A restart will in this cause the sensor to start and remain in bootloader-mode, until new valid firmware is successfully uploaded.

New firmware can also be uploaded by the KP-flasher, a java program created to simplify the uploading process. Contact abs@kp-as.com for more information about the KP-flasher.

Modbus interface

The communication protocol is a Modbus RTU RS485 protocol. Only three commands are accepted:

- FC3 – Read the holding registers
- FC4 – Read the input registers
- FC16 – Write multiple holding registers

Modbus holding registers

These registers are used to change the KPM100's settings. The Modbus address of each setting can be seen in the table below.

Alias	Address decimal	Address hex	Default value
Modbus address	0	0x00	247
Baud rate	1	0x01	1152
Parity	2	0x02	0
Calibrate gyroscope	3	0x03	0
Calibrate accelerometer	4	0x04	0
Enable anti-aliasing	5	0x05	0
Anti-aliasing Fc	6	0x06	50
G-range	7	0x07	2
Degrees Per Second (DPS)	8	0x08	500
Magnetometer-range	9	0x09	49
Clear Alarm	10	0x0A	0
Read only disable	11	0x0B	0
Restart	12	0x0C	0
Roll alarm low limit	20	0x14	-90
Roll alarm high limit	21	0x15	90
Pitch alarm low limit	22	0x16	-90
Pitch alarm high limit	23	0x17	90
Yaw alarm low limit	24	0x18	-90
Yaw alarm high limit	25	0x19	90
Roll DPS alarm low limit	26	0x1A	-450
Roll DPS alarm high limit	27	0x1B	450
Pitch DPS alarm low limit	28	0x1C	-450
Pitch DPS alarm high limit	29	0x1D	450
Yaw DPS alarm low limit	30	0x1E	-450
Yaw DPS alarm high limit	31	0x1F	450
Magnetometer soft-ion matrix	50-67	0x32-0x43	-
Magnetometer offset values	68-73	0x44-49	0

Additional settings can be found in a read-only part of holding registers. These contain the temperature compensation values and some utility commands used during the factory calibration. Writing these values are not recommended.

Alias	Address decimal	Address hex	Default value
Accelerometer temp compensation values	80-115	0x50-0x73	-
Firmware version number	130-131	0x82-0x83	1.4
Save temp compensation	132	0x84	0
Other temp compensation values	133-136	0x85-0x88	-
Reset EEPROM	137	0x89	0
Hardware ID	138	0x8A	108
Gyroscope temp compensation values	140-175	0x8C-0xAF	-
Magnetometer temp compensation values	176-193	0xB0-0xC1	-

Modbus holding descriptions

Modbus address

This is the Modbus address of the KPM100. Any value between 1 – 247 can be chosen.

Baud rate

This address controls the baud rate. Four different values can be chosen:

- 96: 9600 baud
- 192: 19200 baud
- 576: 57600 baud
- 1152: 115200 baud (default)
- 2304 230400 baud

Parity rate

This address controls the parity bit. Three different values can be chosen

- 0: Even parity (default)
- 1: Odd parity
- 2: None parity

Calibrate gyroscope

This register controls the gyroscope calibration. It is important that the sensor is not moved during the calibration. The calibration last for approximately 1 second.

- When writing 1 to this register, the calibration routine for the gyroscope is started.
- When writing 0 to this register the gyroscope calibration values are deleted.

Calibrate accelerometer

This register controls the accelerometer calibration. When calibrating it is important that the sensor is places such that only the z-axis (see section “Z-axis” below) is affected by gravity. The sensor should not be moved during the calibration. The calibration last for approximately 1 second.

- When writing 1 to this register, the calibration routine for the accelerometer is started.
- When writing 0 to this register the accelerometer calibration values are deleted.

Enable anti-aliasing

This register enables the anti-aliasing feature. The cutoff frequency is controlled by the “Anti-aliasing Fc” Modbus address.

- When writing 1 to this register, the anti-aliasing filter is enabled.
- When writing 0 to this register, the anti-aliasing filter is disabled (default).

Anti-aliasing Fc

This register controls the cutoff frequency of the anti-aliasing filter. The value is multiplied by 10, such that a value of 50 corresponds to a cutoff frequency of 5Hz. To enable the anti-aliasing filter, write 1 the “Enable anti-aliasing”-address.

G-range

This register controls the range of the accelerometer. It can take 4 different values:

- 2: ± 2 g (default)
- 4: ± 4 g
- 8: ± 8 g
- 16: ± 16 g

Note! Changing this value deletes the accelerometer calibration values.

Degrees Per Second

This register controls the Degrees Per Second range (DPS) of the gyroscope. It can take 3 different values:

- 245: ± 245 °/s
- 500: ± 500 °/s (default)
- 2000: ± 2000 °/s

Note! Changing this value deletes the gyroscope calibration values.

Magnetometer range

This register controls the magnetometer range. It is a hardcoded value of: ± 49.152 Gauss (default)

Read only disable

This register controls access to the read-only part of the Modbus registers.

- When writing 1 to this register enables writes to the read-only registers.
- When writing 0 to this register disables writes to the read-only registers (default).

Writing the read-only registers is not recommended.

Alarm low limit

These registers control the lower alarm limit. When either a roll, pitch or yaw measurement is below these limits an alarm is raised (se section “Alarms”). The addresses are:

- 0x14: Roll low alarm limit.
- 0x16: Pitch low alarm limit.
- 0x18: Yaw low alarm limit.

Note that the pitch's range is ± 90 so any pitch alarm outside this range will never be triggered.

Alarm high limit

These registers control the higher alarm limit. When either a roll, pitch or yaw measurement is above these limits an alarm is raised (se section "Alarms"). The addresses are:

- 0x15: Roll high alarm limit.
- 0x17: Pitch high alarm limit.
- 0x19: Yaw high alarm limit.

Note that the pitch's range is ± 90 so any pitch alarm outside this range will never be triggered.

DPS alarm low limit

These registers control the DPS lower alarm limit. When either a roll, pitch or yaw DPS (degree per second) is below these limits an alarm is raised (se section "Alarms"). The addresses are:

- 0x1A: Roll low alarm limit.
- 0x1C: Pitch low alarm limit.
- 0x1D: Yaw low alarm limit.

DPS alarm high limit

These registers control the DPS lower alarm limit. When either a roll, pitch or yaw DPS (degree per second) is above these limits an alarm is raised (se section "Alarms"). The addresses are:

- 0x1B: Roll high alarm limit.
- 0x1D: Pitch high alarm limit.
- 0x1F: Yaw high alarm limit.

Clear Alarm

When writing 1 to this register the clears the alarms (se section "Alarms"). No other values are accepted.

Restart

Writing 1 to this register restarts the sensor. No other values are accepted.

Magnetometer offset values and Magnetometer soft-ion matrix

The addresses contain the magnetometer calibration values. They are stored as floats.

It is recommended that the KPM100 GUI is used to calibrate.

Firmware version number

These two registers contain the version number of the firmware. They are read only.

Reset EEPROM

Writing 1 to this register will reset the sensors EEPROM. All settings and temperature compensation values will be deleted. The register is read only. If unsure, don't use this register.

Temperature compensation values

The temperature compensation values are stored in the following register sections.

- Accelerometer temp compensation values.
- Save temp compensation values.
- Other temp compensation values.
- Gyroscope temp compensation values.
- Magnetometer temp compensation values.

They are read only. **If in doubt do not touch.**

Modbus input registers

The input registers contain the inclinometer data and are read-only registers. Each address can be seen below.

Alias	Data type	Address decimal	Address hex
Roll	Int 16bit	0	0x00
Pitch	Int 16bit	1	0x01
Yaw	Int 16bit	2	0x02
Accelerometer X	Int 16bit	3	0x03
Accelerometer Y	Int 16bit	4	0x04
Accelerometer Z	Int 16bit	5	0x05
Angular velocity X	Int 16bit	6	0x06
Angular velocity Y	Int 16bit	7	0x07
Angular velocity Z	Int 16bit	8	0x08
Magnetic field strength X	Int 16bit	9	0x09
Magnetic field strength Y	Int 16bit	10	0x0A
Magnetic field strength Z	Int 16bit	11	0x0B
Roll alarm	Int 16bit	12	0x0C
Pitch alarm	Int 16bit	13	0x0D
Yaw alarm	Int 16bit	14	0x0E
Roll DPS alarm	Int 16bit	15	0x0F
Pitch DPS alarm	Int 16bit	16	0x10
Yaw DPS alarm	Int 16bit	17	0x11
Roll	Float	21-22	0x15-0x16
Pitch	Float	23-24	0x17-0x18
Yaw	Float	25-26	0x19-0x1A
Accelerometer X	Float	27-28	0x1B-0x1C
Accelerometer Y	Float	29-30	0x1D-0x1E
Accelerometer Z	Float	31-32	0x1F-0x20
Angular velocity X	Float	33-34	0x21-0x22
Angular velocity Y	Float	35-36	0x23-0x24
Angular velocity Z	Float	37-38	0x25-0x26
Magnetic field strength X	Float	39-40	0x27-0x28
Magnetic field strength Y	Float	41-42	0x29-0x2A
Magnetic field strength Z	Float	43-44	0x2B-0x2C
Temperature	Float	45-46	0x2D-0x2E
Roll 360	Float	47-48	0x2F-0x30
Pitch 360	Float	49-50	0x31—0x32
Yaw 360	Float	51-52	0x33-0x34
Gyro default frame X	Float	53-54	0x35-0x36
Gyro default frame Y	Float	55-56	0x37-0x38
Gyro default frame Z	Float	57-58	0x39-0x3A

Roll, pitch and yaw (int)

These registers contain the orientation. These are calculated by mixing the accelerometer and gyroscope measurements. The registers are:

- 0x00: Roll (±180°)
- 0x01: Pitch (±90°)
- 0x02: Yaw (±180°)

Note, these values are multiplied by 100.

Accelerations

These registers contain the data measured by the accelerometer. The addresses are:

- 0x03: The x-axis
- 0x04: The y-axis
- 0x05: The z-axis

The accelerations are measured in g. Note that the values are scaled by 100.

Angular velocity

These registers contain the angular velocity measured by the gyroscope. These values are in the same frame of reference as the accelerometer and magnetometer.

The addresses are:

- 0x06: Angular velocity around the x-axis
- 0x07: Angular velocity around the y-axis
- 0x08: Angular velocity around the z-axis

The angular velocities are measured in °/s. Note that the values are scaled by 100.

Magnetic field strength

These registers contain the magnetic field strength measured by the magnetometer. The addresses are

- 0x00: Angular velocity around the x-axis
- 0x0A: Angular velocity around the y-axis
- 0x0B: Angular velocity around the z-axis

The magnetic field strengths are measured in gauss. Note that the values are scaled by 10.

Alarms

These registers contain the alarms. When the angels are out of the area defined by the alarm limits in the holding addresses an alarm is raised. The alarms can be cleared by writing 1 to the “Clear alarm” register (holding address 0x0A). Note that the alarm is raised until cleared.

The addresses are:

- 0x0C: Roll alarm
- 0x0D: Pitch alarm
- 0x0E: Yaw alarm

DPS alarms

These registers contain the DPS (degree per second) alarms. When the change of roll, pitch or yaw exceeds the DPS alarm limits an alarm is raised.

The addresses are:

- 0x0F: Roll alarm
- 0x10: Pitch alarm
- 0x11: Yaw alarm

Input float registers

These registers contain the same as their 16bit counterparts. However, they are not scaled, and they follow the format in section “Floating-point values in the modbus interface”.

Roll, pitch and yaw 360

These registers contain the same information as the roll, pitch and yaw registers (0x15-1A). However, here the range are 0° to 360°. Note that the pitch is in the range: 0° to 90° and 270° to 360°.

Gyro default frame

These registers contain the gyroscope values in their default frame of reference.