TEXYS 16 rue Edouard Branly F 58640 Varennes-Vauzelles
www.texys.fr info@texys.fr ☎33 (0) 3 86 21 27 18 fax 33 (0) 3 86 21 24 49

STRAIN GAUGE AMPLIFIER XN4
OPERATING MANUAL

1. Description

- ✓ XN4 is a PCB analog strain gauge amplifier, with high resolution and high speed, with offset and gain adjusted by microcontroller.
- ✓ XN4 is fully EMI-RFI protected.
- ✓ Thanks to its small size, XN4 may be bonded close to the gauges, which will reduce noise on the signal.
- ✓ When the amplifier is wired to the strain gauge bridge, the user may, with a single V_{PROG} signal (no use of a computer):
  - o Adjust the offset
  - o Adjust the gain by applying an effort on the part
  - o Start a self-learning process for temperature compensation of the offset.
  - o Adjust temperature gain compensation depending on part and gauge materials
  - o Check the gauge bridge state
- ✓ This amplifier simplifies strain gauging because it doesn't need zeroing, nor temperature compensation for offset or sensitivity. Just bond 1, 2 or 4 gauges on the part, wire them to the amplifier and it will do the job!
- ✓ This amplifier allows the strain gauging agent or the final user to quickly calibrate several parts with the same value.
- ✓ XN4 has a communication port to a computer (with the Texense USB Connect 1-Wire) with new possibilities:
  - o Keyboard entry for offset, gain and the gain sensitivity compensation factor.
  - o Digital output at 100Hz (0 to 5000mV with 10 bits resolution)

2. Specifications

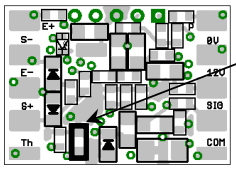
Supply voltage:	5V to 16V
Supply current:	3.5mA (18mA total current with a 350 ohms full bridge) For a 120ohms full bridge, a special XN4-P is available (see §7)
Bridge supply voltage:	5V (internal)
Bridge gauge impedance:	120 to 1000 ohms
Bandwidth:	Cut off frequency: default 90Hz (1 pole filter), adjustable up to 9 kHz (capacitor) For higher frequency, contact Texys
Offset:	Adjustable from 0.5V to 2.5V using analog setting V_{PROG}. Adjustable from 0V to 5V using digital setting with Texense USB Connect 1-Wire. Factory default value: 2.5V Temperature compensation by self-learning process, in oven. Max initial recommended bridge unbalance: Bridge resistance / Max Unbalance (Excitation 5V) 350 / +/- 2mV 120 ohms / +/- 1.5mV 1000 ohms / +/- 3.5mV If more, the offset tuning will not be independent of the gain.
Gain:	From 70 to 1250 (factory default value: 200) by steps of 0.4% approximately. Temperature compensation set by a single resistor R_{METAL} depending on part and gauge material or by entering a PPM value with Texense USB Connect 1-Wire.
Analog output signal:	0 to 5V Offset drift with temperature : < 10mV
Digital output:	Ascii data (10 bits resolution) at 100Hz with Tx/Rx signal and Texense USB Connect 1-Wire
Operating Temperature:	-40° to 125°C
Dimensions:	13 x 10 x 3.3 mm

3. Bandwidth

The cut-off frequency Fc is set by the bandwidth capacitor: $C = \frac{1}{2\pi Fc \times 18000}$

Examples:

Cut off Frequency	Capacitor value
40Hz	220nF (1)
90Hz (default value)	100nF (1)
190Hz	47nF (1)
9kHz (2)	1nF (1)

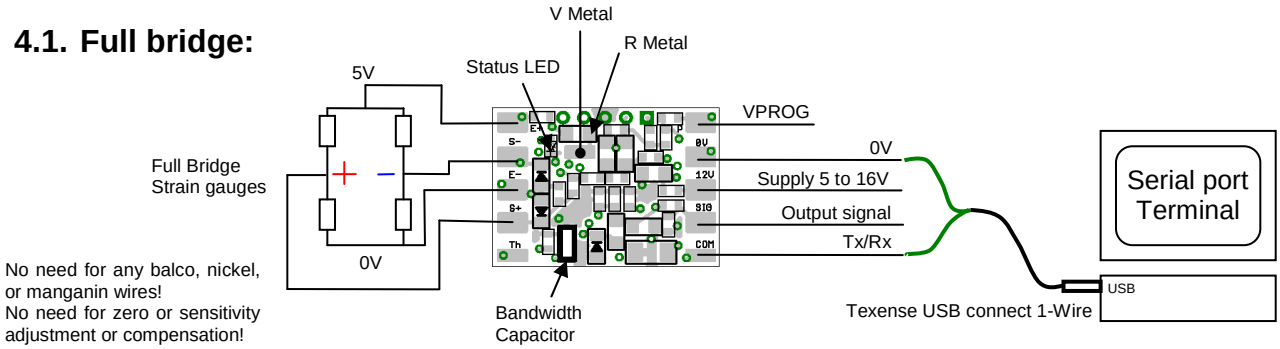


Bandwidth Capacitor

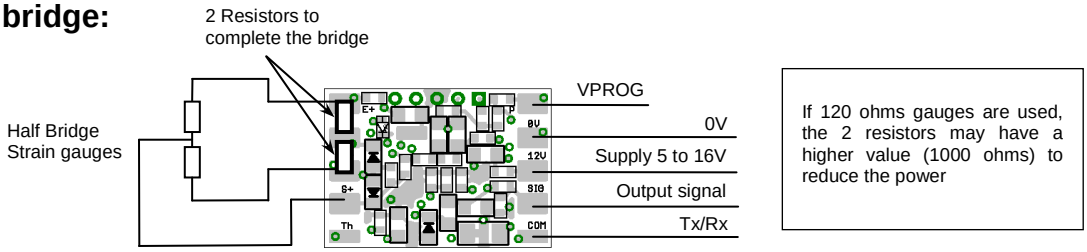
Note 1: Use 0603 X7R capacitors only.
Note 2: For higher cut off frequency, contact Texys.

4. Wirings

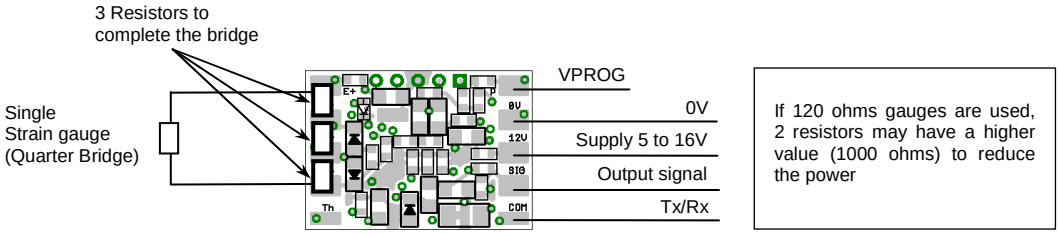
4.1. Full bridge:



4.2. Half bridge:



4.3. Quarter bridge:

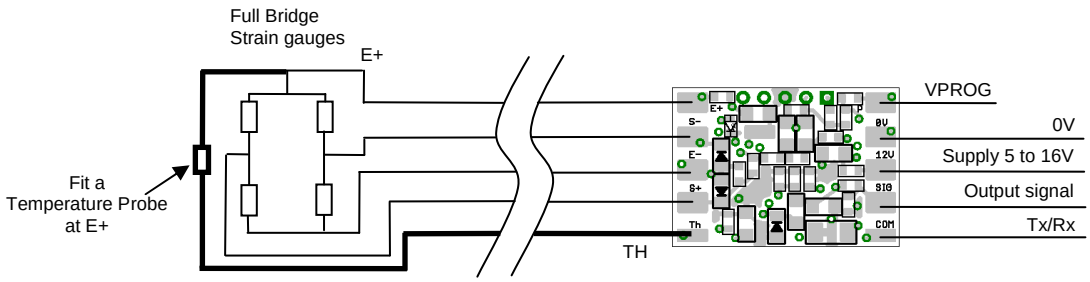


4.4. 120Ω strain gauges:

For 120Ω strain gauges, choose XN4-P amplifier. See §7.

5. External temperature probe for remote applications

When XN4 is used in a remote application (in line amplifier for example), an external temperature probe must be fitted on the strain gauged part in order to achieve good gain and offset compensation. There is an internal probe on the bottom side of XN4. When a valid probe is connected to the TH pad, the internal probe is ignored.
Connect the temperature probe beside the gauges between E+ and the TH pad, see figure below:



Temperature probe must be a 15kΩ NTC Thermistor (15kΩ at 25°C, Beta = 4000).
Here are some examples:

- Through-Hole: AVX ND03N00153J 3.5mm (Farnell ref 1672367, Newark ref 33P7738)
- SMT 0402: Vishay BC Components - NTCS0402E3153FHT (Farnell ref 1761139, Newark ref 34R4323)

6. Temperature measurement

Measuring the ambient temperature is not calibrated because temperature only serves as an index for the temperature compensation.

► You can choose to use internal or external probe temperature (see §5).

► If internal XN4 probe is used, place the XN4 very close to the gauge. The internal heating of the XN4 will affect the probe measurement. Depending on gauge resistance and supply voltage.
For example with a 350Ω gauge and 12V power supply → the measured temperature is **7°C higher**.
If you want to avoid measuring the heating circuit, you can choose to use an external probe temperature (see §5).

7. XN4-P amplifier

For 120 ohms strain gauges, use the XN4-P for a better power dissipation up to 480 mW. See §5 and §6.
Dimensions are 17 x 10 x 4 mm.

8. Operation Modes

- For the analog settings, the handlings are described with the **Texense Switch Box** (see §10.2).
- For the digital settings, the handlings are described with the **Texense USB Connect 1-Wire** (see §10.3).

8.1. Normal Mode

Status led blinks shortly every second.

8.2. Offset Setting

8.2.1. Offset Analog Setting

Offset is adjustable from 0.5V to 2.5V. For analog setting, you can use the Texense Switch Box (see §10.2).

- Set V_{PROG} at the desired offset voltage, between 0.5V to 2.5V.
  - Press and hold OFFSET button.
  - Turn the offset potentiometer to set V_{PROG} at the desired signal voltage,
  - Release OFFSET button.
- Check that no force is applied on the part.
- Press and hold OFFSET button.
- Press and release RESET button.
- Release OFFSET button.

The status LED is off during offset setting.
After a few seconds, the output signal voltage matches V_{PROG}.
The amplifier gets back to normal mode and status led blinks shortly every second.
Offset without strain gauge connected (XN4 alone): the offset setting is performed with +/- 20mV accuracy.

8.2.2. Offset Digital Setting

Offset is adjustable from 0V to 5V. For digital setting, use Texense USB Connect 1-Wire (see §10.3).

- Press ‘o’ on the keyboard
- Enter the offset in mV (from 0 to 5000)

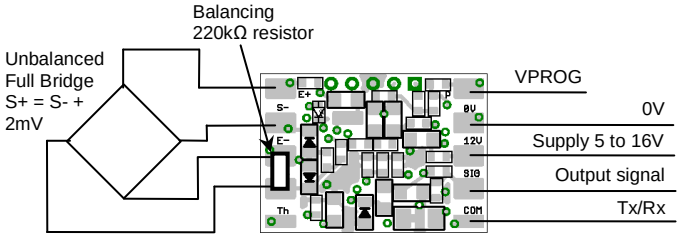
Offset without strain gauge connected (XN4 alone): the offset setting is performed with +/- 20mV accuracy.

8.2.3. Problem during offset setting

If the strain gauge bridge is too unbalanced, or too noisy, after 10 sec, the XN4 returns to normal mode with a non accurate offset setting (+/- 20mV).

- **Noise:** if the signal is noisy, capacitors on the supply voltage and between S+ and S- may help.
  If braided cables are used, the braid may be tied to 0V.
- **Bridge unbalanced:** if the voltage between S+ and S- is too high, it is preferable to reduce it with a single “balancing” resistor.
  If S+ > S-, fit a resistor between S+ and E-,
  if S+ < S-, fit a resistor between S- and E-.

  Eg with a 350 ohms full bridge:
  If voltage between S+ and S- = 2mV,
  fit a 220kΩ resistor between S+ and E-
  as shown in figure:



8.3. Gain Setting

8.3.1. Gain Analog Setting (calibration)

It will adjust the amplifier gain to achieve the desired voltage (between 2.6V and 4.5V) for the desired force.
For analog setting, you can use the Texense Switch Box (see §10.2).

- Set V_{PROG} at the desired voltage, between 2.6V to 4.5V.
  - Press and hold GAIN/THRESHOLDS button.
  - Turn the gain potentiometer to set V_{PROG} at the desired signal voltage.
  - Release GAIN/THRESHOLDS button.
- Apply desired force on the part.
- Press and hold GAIN/THRESHOLDS button.
- Press and release Reset button.
- Release GAIN/THRESHOLDS button.

The status LED blinks quickly during calibration.
After a few seconds, when the gain is set, the output signal voltage matches V_{PROG}.
The amplifier gets back to normal mode and status led blinks shortly every second.

Problem during calibration

If the desired signal value doesn't match V_{PROG}, it is because the gain has reached its maximum. The strain gauge bridge sensitivity is too low because the part may be too thick. Set V_{PROG} to a lower value and try a new calibration.

8.3.2. Gain Digital Setting

Gain is adjustable from 70 to 1250.
For digital setting, use Texense USB Connect 1-Wire (see §10.3).

- Press 'g' on the keyboard
- Enter the gain in tenth (from 700 to 12500)

Every single value is not available and the XN4 will display the actual gain value (closest to the requirement)

8.4. Check the bridge raw signal (if temperature < 60°C)

Be careful when you launch the check mode, temperature must be < 60°C. Otherwise the Self-learning process is started, and you loose the compensation table (see §8.5).
The check mode set the amplifier to default settings (offset = 2.5V, gain = 200) to check the bridge with no compensation. That mode is used to check the bridge unbalanced which may have been hidden by successive offset settings.
Example: if the output signal is 2.7V and without effort, that means (2.7-2.5)/200 = 1mV bridge unbalance.

8.4.1. entering check mode by analog command

For analog command, you can use the Texense Switch Box (see §10.2).

- Press and hold CHECK/COMPENS button.
- Press and release Reset button.
- Release CHECK/COMPENS button.

The status LED is normally ON and put off shortly every second (reverse of normal mode).
No compensation is achieved.
To return to normal function, reboot the device (Press and release Reset button).

8.4.2. entering check mode by digital command

For digital command, use Texense USB Connect 1-Wire (see §10.3).

- Press 'v' on the keyboard, and confirm.

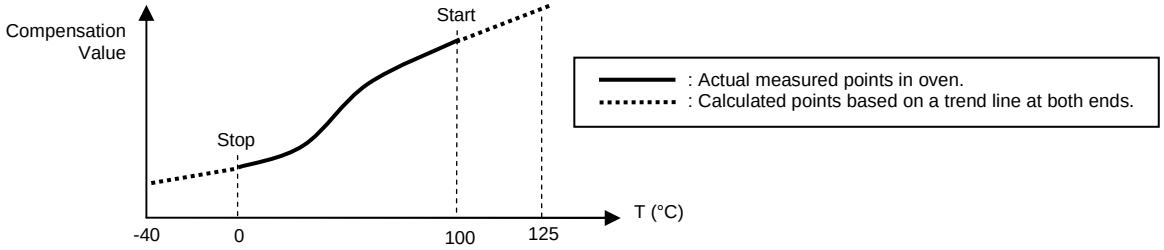
The status LED is normally ON and put off shortly every second (reverse of normal mode).
No compensation is achieved.
To return to normal function, reboot the device (reset supply power, or press '!').

8.5. Self-learning process for temperature compensation of the offset

This mode is a self-learning process that will write a compensation table into the controller memory.
To launch the Self-learning process, temperature must be > 60°C.

- Put the part in a oven in a rest position (no force).
- Warm up the oven to the desired temperature (> 60°C, max 125°C).
- Stop the heating of the oven or program a cooling down profile: **Not quicker than 1° per minute.**
- Start Learning Mode (Analog or Digital launch, see below)
- The self-learning ends when the timeout delay is reached, or when you stop the process. (see §8.5.3).

Example graph if the compensation begins in an oven at 100°C and stops at 0°C



8.5.1. Analog command

To launch the Self-learning process, temperature must be > 60°C (otherwise the check mode is launched).
For analog launch, you can use the Texense Switch Box (see §10.2).

- Press and hold CHECK/COMPENS button.
- Press and release Reset button.
- Release CHECK/COMPENS button.
- The status LED toggles slowly every second.
- Let oven temperature decrease.

As it does, the controller records (for each 1.5°C) the necessary value to compensate the offset.
The process will stop when the timeout delay is elapsed. Be sure that the desired lower temperature can be reached within this time. The amplifier gets back to normal function and status led blinks shortly every second.
It is not recommended to stop the process by switching off the power, as a write may be in progress (see §8.5.3)
When analog command is used, you should wait the timeout delay (default: 5 hours).

8.5.2. Digital command

For digital launch, use Texense USB Connect 1-Wire (see §10.3).

- Press 'c' on the keyboard, and confirm to start the process.

The status LED toggles slowly every second.

- Let oven temperature decrease.

As it does, the controller records (for each 1.5°C) the necessary value to compensate the offset.
The process will stop when the timeout delay is elapsed. Be sure that the desired lower temperature can be reached within this time. The amplifier gets back to normal function and status led blinks shortly every second.
It is not recommended to stop the process by switching off the power, as a write may be in progress (see §8.5.3)
However, you can stop the process by using the reboot command: press '!'.
See §10.3.4 to check the recorded compensation table shape.

8.5.3. Stopping the process

Ensure that the self-learning process is not being stopped by a power reset. Otherwise there may be problem writing into the compensation table.

- ❖ When analog command is used: you should wait the timeout delay (default: 5 hours).
- ❖ When digital command is used: you can wait until the timeout delay is elapsed
  or you can use the reboot command: press '!'

8.5.4. Timeout delay setting

The timeout is used to stop the process. The default value is 5 hours.
For handling, use Texense USB Connect 1-Wire (see §10.3).

- Press 't' on the keyboard
- Enter the number of hours for the duration of the process (from 2 to 12 hours).

9. Gain compensation versus temperature

As Elastic modulus of the strain gauged part and the gage factor of the strain gauge itself change with temperature, it is necessary to correct the amplifier gain with temperature.

The compensation value may be adjusted by user, either by analog setting or digital setting (see §9.1).

The following values are given as an example for standard gauges and materials:

As the gain step is about 0.4%, low ppm values will not generate gain changes (100ppm will get the gain change from 1 step every 40°C)

For use as remote amplifier with fully compensated strain gauges, R_{METAL} should be 11.5kΩ, or the ppm value must be set to 0 in order to avoid any additional thermal compensation within the amplifier.

Material of strain gauged part	Gain variation	ppm / °C	Changing gain every
Steel (default)	-0.033 %/°C	- 330	11.2°C
Titanium	-0.050 %/°C	- 500	7.4°C
Aluminum	-0.059 %/°C	- 590	6.3°C
No compensation	*0*	*0*	-

9.1. Analog/Digital setting

The ppm value can be entered either by analog setting or digital setting.
The ppm value is selected through the flag ppm_dig:

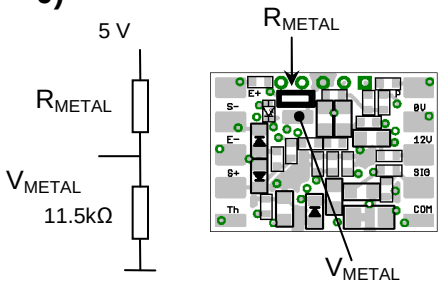
- ppm_dig = 0 → ppm = value resulting from Vmetal voltage. See §9.2
- ppm_dig = 1 → ppm = digital value from "ppm" parameter. See §9.3
- Default setting is "analog" (ppm_dig = 0).

A digital setting will switch the flag ppm_dig to "digital" (ppm_dig = 1). To force the setting back to "analog":

- Press 'u' on the keyboard
- Enter '0' (→ ppm_dig = 0). See §10.3 for handling.

9.2. Analog setting with the R_{METAL} Resistor (if ppm_dig = 0)

By default, the flag ppm_dig = 0. So the ppm value resulting from Vmetal.
For analog setting, you can use the Texense Switch Box (see §10.2).



- The gain drift is given by the voltage V_{METAL} (gain drift 'D' in %/°C):

$$D = \frac{(Vmetal - 2V5)}{20} \quad \longrightarrow \quad Vmetal = 20D + 2V5$$

- The resistor R_{METAL} is part of a resistor bridge with an 11.5kΩ pull down resistor:

$$Vmetal = 5V \times \frac{11k5}{Rmetal + 11k5} \quad \longrightarrow \quad Rmetal = \frac{5 \times 11k5}{Vmetal} - 11k5$$

Table for Constantan Strain gauges:

Material of strain gauged part	Gain variation	V_{METAL}	R_{METAL}
Steel (default)	-0.033 %/°C	1.84 V	20kΩ (default)
Titanium	-0.050 %/°C	1.50 V	27kΩ
Aluminum	-0.059 %/°C	1.32 V	33kΩ
No compensation	*0*	*2.50 V*	*11.5kΩ*

Any other compensation may be achieved by changing R_{METAL}:
Example: -0.04%/°C → V_{METAL} = 20x(-0.04)+2.5 = 1.7V
R_{METAL} = 5x11.5k/1.7-11.5k = 22324 → R_{METAL} = 22kΩ

9.3. Digital setting with the Tx/Rx wire and Texense USB Connect 1-Wire

The digital setting allows setting the compensation between -1000ppm/°C and +1000ppm/°C.
See §10.3 for handling.

- Press 'p' on the keyboard.
- Enter the gain compensation in ppm/°C (from -1000 to +1000).

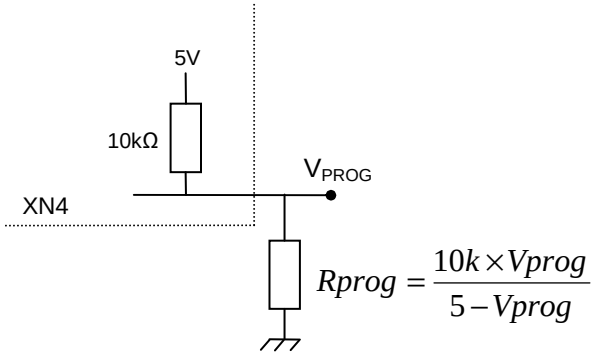
A digital setting will switch the flag ppm_dig to "digital" (ppm_dig = 1, see §10.3.2).

10. Controlling the XN4

XN4 is controlled either through V_{PROG} (analog setting) or through Tx/Rx signal (digital setting).

10.1. V_{PROG} (analog setting)

As shown on the diagram, a single resistor R_{PROG} is needed to set V_{PROG}:



$$Rprog = \frac{10k \times Vprog}{5 - Vprog}$$

The Texense Switch box has potentiometers for easier setting. See §10.2

10.2. Texense Switch Box (analog setting)

Texense Switch Box

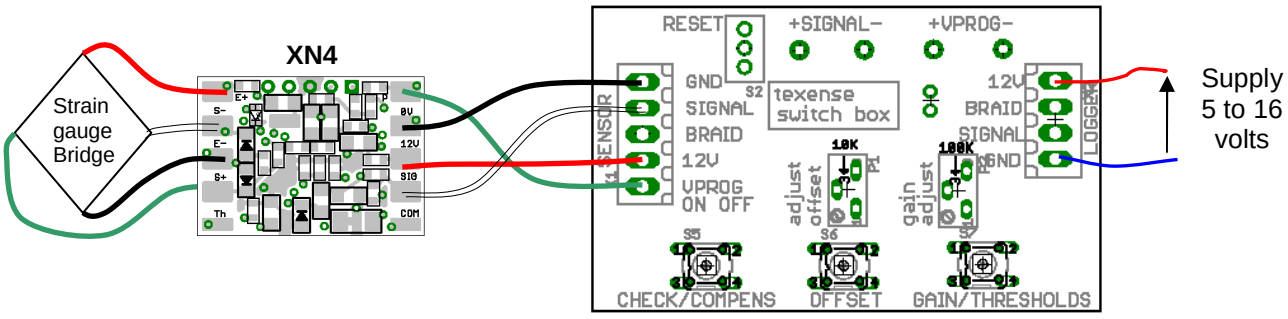
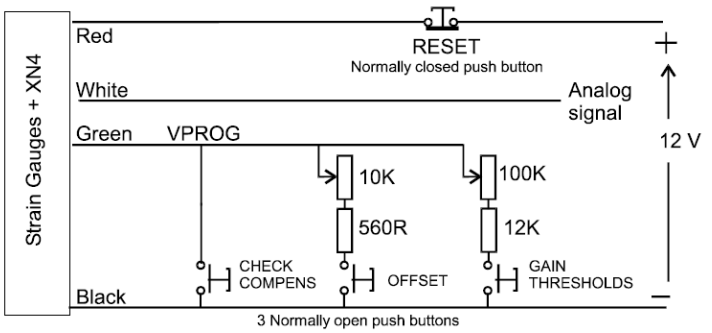


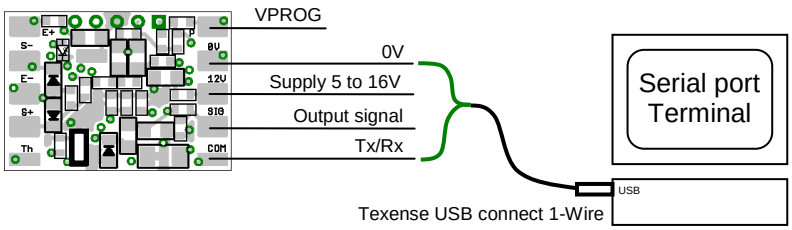
Diagram of the Texense switch box



Switches are not necessary, just provide that the V_{PROG} voltage is set at the desired value when powering up the XN4:

- V_{PROG} = 0 for Check (or Compensation if Temperature > 60°C)
- 0.5V < V_{PROG} < 2.5V for Offset mode
- 2.5V < V_{PROG} < 4.5V for Gain mode
- V_{PROG} > 4.5 for normal operation

10.3. Tx/Rx wire and Texense USB Connect 1-Wire (digital setting)



Use HyperTerminal or available software for serial link management.
Settings of the serial port:

- 38400 bauds
- 8 bits
- No parity
- 1 bit stop
- No flow control

10.3.1. Header

At power up, the XN4 displays a header (with current parameter values and a list of commands).
To display the header, at any time, in normal mode:

- Press ‘h’ on the keyboard

```
XN4 V0.96  SN00000000          1023 000 002 255 128 000 058 5 040 0 254 095 Texys use only

        command   value     min    max
offset     'o'      2500       0   5000       Offset setting in mV
gain       'g'      4995     700  12500       Gain setting in tenth
ppm        'p'      -335   -1000   1000       ppm setting in ppm/°C
ppm_dig    'u'         0       0      1       flag to choose the ppm setting (DIG or ANA)
out_dig    'd'         0       0      1       flag to enable digital output
timeout    't'         5       2     12       Time setting for self-learning process (compens)
compens    'c' (5hours max)                   Start of a self-learning process
table      'x'                                Displays the compensation table
erase      'e'                                Reset the compensation table.
check      'v'                                Enter in Check mode
header     'h'                                Displays this header
reset      '!'                                Reboot the XN4 (not reset parameter)

It states whether parameter has been set through analog (ANA) or digital (DIG):
Offset (ANA) : 2500mV             Actual offset in mV
Gain   (DIG) : 4995/10 @TA= 25dC  Actual gain in tenth, and temperature of the gain setting
PPM    (ANA) : -340               Actual ppm en ppm/°C

Vmetal       : 1828mV             Vmetal in mV
Thermistor   : external           Temperature measurement external or internal
```

10.3.2. Commands

Key	function	handling	Comments	See §
o	Offset setting in mV	Value (mV) + enter	Default: 2500 mV	8.2.2
g	Gain setting in tenth	Value in tenth + enter	Default: 2000 (=200.0)	8.3.2
p	ppm setting in ppm/°C	Value (ppm) + enter	This operation will set ‘u’ to 1	9.3
u	flag to choose the ppm setting (DIG or ANA)	1 (digital) or 0 (analog) + enter	Default: Analog with R_{METAL}	9.1
d	flag to enable digital output	1 (enable) or 0 (disable) + enter	Default: disabled	10.3.3
t	Time setting for self-learning process (compens)	Value (hours) + enter	Default: 5 hours	8.5.3
c	Start of a self-learning process	‘y’ to confirm, or any key for cancel	Temperature must be > 60°C	8.5.2
x	Displays the compensation table			10.3.4
e	Reset the compensation table.	‘y’ to confirm, or any key for cancel		10.3.5
v	Enter in Check mode	‘y’ to confirm, or any key for cancel	Offset = 2V5, Gain = 200.0	8.4.2
h	Displays the header		Displayed at power up	10.3.1
!	Reboot the XN4 (not reset parameter)		Used to stop self-learning process	

10.3.3. Digital output at 100Hz (*out_dig* command ‘d’)

XN4 can send the amplifier output in mV (0 to 5000mV), ±10mV accuracy, 4 digits ascii data + LF Return;

- Press ‘d’ on the keyboard
- Enter ‘1’ to enable the digital output (‘0’ to disable)

Example with 920mV:

```
...
0920
0920
0920
0920
0920
...
...
...
```

10.3.4. Compensation table (*table* command ‘x’)

View the compensation table after a temperature offset compensation process:

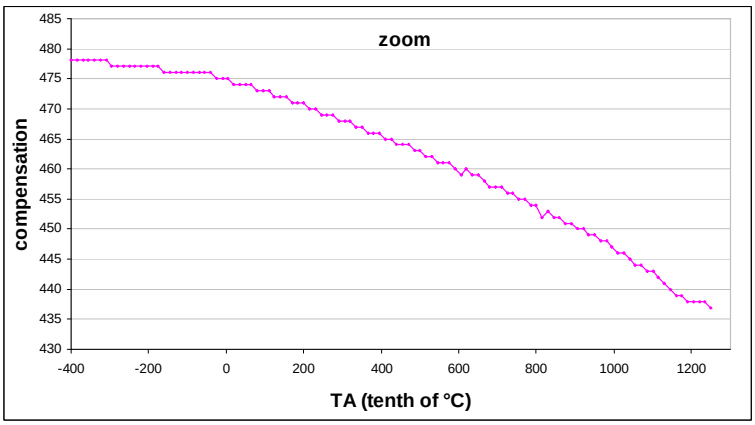
- Press ‘x’ on the keyboard

The XN4 outputs 2 columns with temperature (tenth of °C) and compensation value (10 bits, 0 to 1023).

Example:

```
...
110 473
125 472
140 472
155 472
170 471
185 471
200 471
215 470
230 470
245 469
260 469
275 469
290 468
305 468
320 468
335 467
350 467
...
```

These data may be copied into a graph to check the compensation trend:



10.3.5. Resetting the compensation table (*erase* command ‘e’)

The compensation table can be reset (to middle value 512).

- Press ‘e’ on the keyboard, and confirm.

After a table reset, an offset setting has to be done.