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Operating manual

NPS-2100-20

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14.0 The NPS2100-20

This User Guide is an Extract from the *System2000* User's guide - which is available upon request.

The NPS2100-20 is a NanoSensor™, high voltage amplifier and control electronics combined as a single channel stand alone module, powered by external ±15V, 130V and −30V dc supplies.

The NPS2100-20 can be used to provide closed loop position control of translators, X-Y stages, mirror steering mechanisms etc. Alternatively it can be used open loop as a piezo controller and NanoSensor™.

The NanoSensor™ is a non-contact capacitive displacement measuring device, producing an analogue output voltage proportional to the sensor spacing. It measures the change in capacitance of a parallel plate capacitor formed by attaching one plate to the item whose displacement is to be monitored and the other to a reference surface.

The capacitor plates, Target and Probe, may be the discrete sensors detailed in section 13 of the manual or built in sensors as with the S300 type device.

The NanoSensor™ is factory calibrated for scale factor and linearity, and has a nominal 5kHz bandwidth.

The NanoSensor™ can be configured either for -S for short range or -L for long range. These correspond to a sensor capacitance of 10pF and 2pF respectively. Depending upon the area of the chosen sensor, the capacitance corresponds to a nominal sensor gap G. For example the NS20 sensors with a -S configuration corresponds to a nominal gap G of 100μm.

With the NanoSensor™ scale factor set to 0.1G/V the analogue output of the NanoSensor™ swings from +5 volts through zero to -5 volts as the sensor gap changes from 150% through 100% to 50% of the nominal gap G.

The NanoSensor™ has gain adjustment switches which allow the sensor output scale factor to be set in the range ±0.1G/V to ±0.01G/V.

Both bandwidth, configuration (-S or -L) and gain are selectable using internal switches accessible through the side panel.

Table 14.1. NPS2100-20 Module Specifications.

Parameter	NPS2100-20	Notes
Size	218x77x34mm	
Power Supplies	±15 @ 120mA 120V-130V @ 30mA -32V to -27V @ 30mA	Maximum current consumption in normal operation
NanoSensor Analogue Output	0±5V	Greater range is available at reduced performance
NanoSensor Scale Factor	±0.1to ±0.01GV^{-1}	G is the nominal gap. The scale factor is switch selectable through the side panel.
NanoSensor Noise Level (-S, -L)	0.15ppmHz$^{-½}$ rms (-L) 0.03ppmHz$^{-½}$ rms (-S)	ppm refers to parts per million in the nominal gap
NanoSensor Thermal Drift	5 ppmK^{-1}	ppm refers to parts per million in the nominal gap
NanoSensor Warm-up time	10 mins	
NanoSensor Warm-up drift	80 ppm	ppm refers to parts per million in the nominal gap
NanoSensor PS Rejection	10ppmV^{-1}	ppm refers to parts per million in the nominal gap
NanoSensor Linearity Error	< 0.2%	Linearity error depends upon sensor installation
NanoSensor Bandwidth	50, 500, 5000±10% Hz	The bandwidth is switch selectable through the side panel.
HV amplifier output swing	-20 to +120V	
HV amplifier bandwidth	5kHz	Typical - Dependant upon the actuator
HV amplifier analogue input gain	6V/V	Open loop operation only
HV amplifier digital input gain	7.3mV/V	Open loop operation only
HV amplifier noise level	0.2mV rms	Typical
HV amplifier current limit	50mA	
Closed loop bandwidth	User settable	See section 14.5
Closed loop slew rate	User settable	See section 14.5
Analogue input range	±10V	
Digital input D/A Resolution	14 Bits	

The high voltage amplifier is intended to be used for driving piezo-electric (MTP) translators. In closed loop operation the input to the high voltage amplifier is set by the control electronics. In open loop operation the user has direct control of the amplifier via ±10V analogue and/or 14 Bit digital inputs.

The control electronics allows the user to optimise the NPS2100-20 closed loop response. Closed loop operation gives vast improvements in stability and linearity over open loop operation.

14.1 Specifications

Table 14.1 shows the performance of the NPS2100-20. Table 14.2 shows the resultant NanoSensor™ performance with NSxx sensors.

Table 14.2 Performance with NSxx Range of Sensors

Sensor	Active Area mm^2	Module	Nominal Gap µm	Thermal Drift nmK^{-1} (Note1)	Noise Factor $nmHz^{-½}$
NS20,40, 60	113.1	-S	100	0.5	0.003
		-L	500	2.5	0.075
NS30	50.26	-S	44.44	0.22	0.001
		-L	222	1.11	0.033
NS50,70	22.62	(This sensor cannot be used with -S)			
		-L	100	0.5	0.015

Notes:

1 This is the electronic module drift contribution only. Thermal expansion of the sensor and the device on which it is mounted must also be taken into account. See chapter 11 for sensors details.

14.2 Unpacking and Handling

The NPS2100-20 is a robust unit and requires no special handling precautions other than normally followed with electronic equipment. Static discharge to any of the connectors may cause damage, so ensure that all personnel handling the unit are adequately grounded.

If Probe and Target sensor electrodes were provided with the NPS2100-20 then take care when unpacking them. The electrodes are strongly constructed but can be damaged by scratching of the surface or undue force on the leads. Do not allow the electrode surfaces to become contaminated, this could cause short circuits between the electrodes when installed or short circuits between the active central part of the electrode and the guard-ring. If contamination is suspected clean with a lint-free cloth moistened with alcohol, DO NOT USE ACETONE OR OTHER STRONG SOLVENTS.

14.3 Installation

14.3.1 System Contents

The NPS2100-20 consists of the following items.

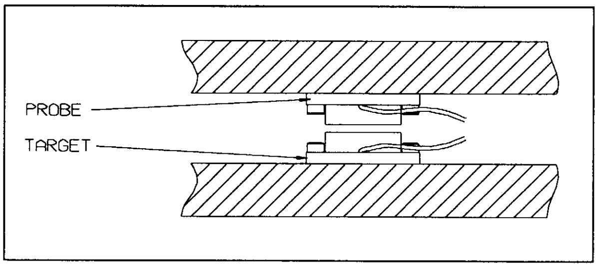
Q'tity	Description Part Number
1	Electronics module NPS2100-20
1	NPS2100-20 User's Guide

Depending upon the application the NPS2100-20 will be shipped with pre-configured nano mechanisms such as an X-Y stage, S300 or micro-rotator; or with sensors and an MTP translator.

If provided, the Target and Probe sensors must be installed opposite each other as shown in Fig.14.1. See Chapter 11, Sensors, for full installation details of the standard range of sensor electrodes.

Section 12 of the manual gives mechanical mounting and installation details for translators.

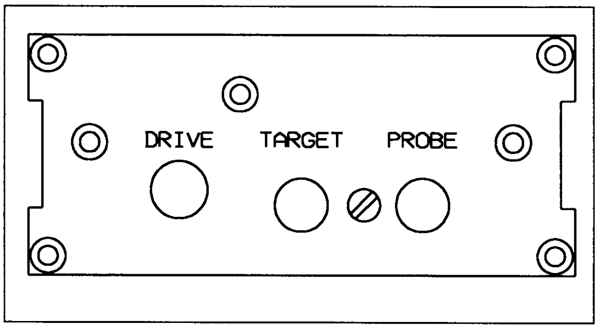
Fig.14.1 Sensor Installation



14.3.2 Connecting the Sensor and Translator Electrodes

Connect the probe electrode to the socket labelled PROBE and the target electrode to the socket labelled TARGET, and the translator to the socket labelled DRIVE see Fig. 14.2. Incorrect connection will not cause damage but performance will be reduced.

Fig.14.2.Sensor & translator Connections



14.3.3 NPS2100-20 Interface Connector

Interface to the NPS2100-20 is via a 37 way D-type connector. ALL power supplies, analogue input, NanoSensor™ output, 14 Bit digital input and OVERLOAD status signal are via this connector. For pin designation, see Table 14.3.

WARNING! INCORRECT CONNECTION MAY DAMAGE THE UNIT. CHECK ALL CONNECTIONS BEFORE APPLYING POWER.

Notes (for Table 14.3)

1/ Digital ground (28), ±15V RTN (3), and HV RTN (22) should all be connected together.

-32V to -27V RTN MUST be connected to HV RTN.

2/ The 37-way D-Type backshell should be connected to earth.

3/ The analogue input is a ±10V differential input

4/ The NanoSensor output is a ±5V single ended output

5/ Do not connect to any of the other pins.

6/ Do NOT connect to pins 5, 6, 7, 9, 10, 11, 20, 21 & 27

Table 14.3. 37-way D-Type connections

Function	Pin	Signal
± 15V Power	1	+15V
± 15V Power	2	-15V
± 15V Power	3	±15V RTN
+HV Power	4	120 to 130V
HV Power	22	120 to 130V & -32 to -27V RTN
-HV Power	23	-32 to -27V
Analogue input	8	+ve analogue input
Analogue input	26	-ve analogue input
Nanosensor output	24	+ve sensor output
Nanosensor output	25	sensor output RTN
Digital interface	12	D13 (MSB)
Digital interface	13	D12
Digital interface	14	D11
Digital interface	15	D10
Digital interface	16	D9
Digital interface	17	D8
Digital interface	18	D7
Digital interface	36	D6
Digital interface	35	D5
Digital interface	34	D4
Digital interface	33	D3
Digital interface	32	D2
Digital interface	31	D1
Digital interface	30	D0 (LSB)
Digital interface	19	WR D to A control
Digital interface	37	CS D to A control
Digital interface	29	OVERLOAD status output
Digital interface	28	Digital ground
Factory test points	5,6,7,9,10, 11,20,21,27	DO NOT CONNECT

14.4 Interfacing with the NPS2100-20

14.4.1 Using the NanoSensor output

The NanoSensor output is a voltage representing the Translator expansion in closed loop operation, or sensor displacement in open loop operation.

Section 14.5.1 shows how to select the NanoSensor nominal gap. Section 14.5.3 shows how to set the NanoSensor gain. Knowing the nominal gap and gain it is straightforward to determine the Translator expansion or sensor displacement from the sensor output

Example: Nominal gap =100μm. Gain = 0.04G/V.

Closed loop +1V on the NanoSensor output represents a Translator **expansion** of 0.04 x 100μm = 4μm .

14.4.2 Using the Analogue Input

The analogue input is a differential input in the range ±10V. It is suggested that the -ve analogue input is connected to the ±15V RTN signal.

In open loop operation the analogue input directly controls the high voltage amplifier as follows:

Analogue input	Translator voltage	Comments
-10V	-20V	Minimum extension
0V	50V	
+10V	120V	Maximum extension

Closed loop the analogue input controls Translator expansion. The analogue input scale factor is simply half the NanoSensor scale factor. (See section 14.5.3)

Example: NanoSensor scale factor = 4μm/V

Closed loop the analogue input scale factor will be 2μm/V. An analogue input of say -5V would cause the Translator to **contract** by 10μm.

14.4.3 Using the Digital input

A 14 Bit Digital input is available equivalent to the ±10V analogue input range. Open loop the digital input directly controls the high voltage amplifier as follows:

Digital input	Translator voltage	Comments
0000Hex	-20V	Minimum extension
2000Hex	50V	
3FFFHex	120V	Maximum extension

Closed loop the digital input controls the Translator expansion. ±5V on the NanoSensor output is equivalent to the full 14 Bit digital input. Each LSB of the digital input is equivalent to 6.1mV on the NanoSensor output.

Example: NanoSensor scale factor =10μm/V

Closed loop ±5V on the NanoSensor output is 100μm. The digital input scale factor will be 6.1nm/LSB.

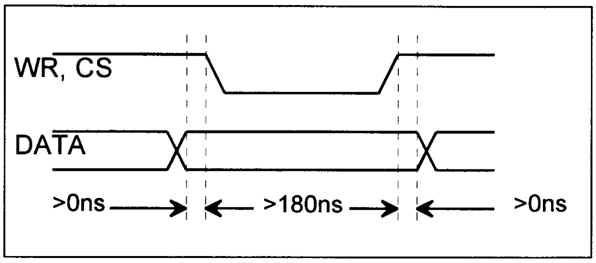
14.4.4 Writing to the Digital Input

To write to the digital input follow these steps:

1/ Write the data to the 14 input lines D13 to D0. D13 is the most significant bit.

2/ Take the CS and WR control lines low (0). This allows the data into the converter and sets its output the desired level.

3/ Take the CS and WR control lines high (1). This latches the data. Any further changes on the data lines will not affect the converter output.

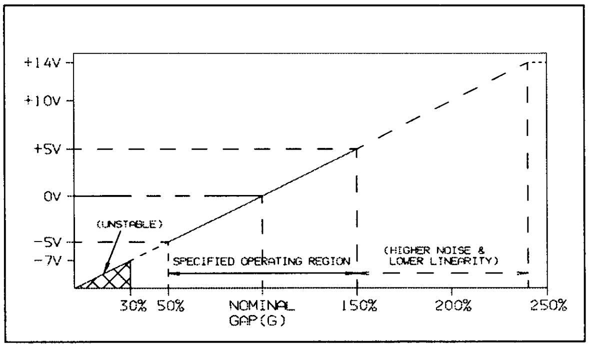


14.5 Configuring the NPS2100-20 operation

14.5.1 Choosing the Nominal Gap and Scale Factor

For correct operation the nominal gap is numerically equal to the displacement range to be measured, Table 14.2 shows the nominal gaps available with the standard NSxx range of sensors with the sensor gain set to 0.1G/V. Operation outside the specified ±5V output voltage range is possible with reduced performance as illustrated in Fig.14.4. Once the gap G is chosen then the scale factor is automatically 1V for 0.1G with the x1 gain setting.

Fig.14.4 Output Voltage Range



Example:

It is required to measure displacements of 0±50μm i.e. a full range of 100μm. Reference to Table 14.2 shows that NS20,40 or 60 sensors with a -S module would be suitable (see the section 11 on NS Sensors for the difference between these sensor pairs). The scale factor would be 1V=10µm on the 0.1G/V gain setting. The NanoSensor would operate to specification with outputs between -5V and +5V, however if the gap went up to 200µm the output would go to +10V. This would still be a good measure of the gap but specified performance is not guaranteed. If the gap went down to 30µm the output would be -7V. Below this, stable operation of the NanoSensor cannot be guaranteed and the output may not reflect the actual gap.

14.5.2 NanoSensor Bandwidth Adjustment and -S, -L Configuration Setting

The bandwidth of the NanoSensor is factory set to 5kHz. The configuration (-S, -L) and bandwidth can be adjusted using the 4-way dual in line switch on the side panel (see Fig.14.5) as follows:

Bandwidth Switch Setting				Bandwidth	Comments
A	B	C	D		
on	off	off	---	5kHz	Factory set
off	on	off	---	500Hz	
off	off	on	---	50Hz	
---	---	---	on	-L	
---	---	---	off	-S	

14.5.3 NanoSensor Gain adjustment

The gain of the NPS2100-20 is factory set to 0.1G/V where G is the nominal gap. This can be adjusted in the range 0.1G/V to 0.01G/V by switches on the side panel (See figure 14.5) as follows:

Gain Switch Setting				Gain	Comments
A	B	C	D		
on	off	off	off	0.1G/V	Factory Setting
off	on	on	on	0.05 G/V	
off	on	on	off	0.04 G/V	
off	on	off	on	0.0333 G/V	
off	off	on	on	0.0267 G/V	
off	on	off	off	0.0233 G/V	
off	off	on	off	0.0167 G/V	
off	off	off	on	0.01G/V	

14.5.4 NanoSensor Phase adjustment

The NanoSensor output can be inverted using one of the switches on the side panel. Open loop this changes the sign of the NanoSensor gain. Closed loop it changes the phase of the control loop. This ensures that the closed loop system will be stable regardless of the configuration. Do not set switch C and D on at the same time.

Phase & Open/Closed loop Switch Setting				Gain	Comments
A	B	C	D		
---	---	off	on	-1	Loop phase reversal
---	---	on	off	1	

1.5.5 Selecting Open or Closed loop operation

Open or closed loop operation is selected by a switch on the side panel (See figure 14.5) as follows.:

Phase & Open/Closed loop Switch Setting				Operation	Comments
A	B	C	D		
off	on	---	---	Open loop	
on	off	---	---	Closed loop	

In the closed loop operating mode the analogue and digital inputs drive the High Voltage amplifier directly. In the closed loop operating mode the input to the High Voltage amplifier input is set by the control electronics. Do not set switch A and B on at the same time.

14.6 Using the NPS2100-20 for Closed Loop Position Control.

14.6.1 Theory Of Operation

The NanoSensor output is proportional to the distance between the sensor heads. This is compared to a demand voltage which is the sum of the analogue and digital inputs. The difference between demand and NanoSensor is an error signal. The control electronics uses the error signal to produce an input to the high voltage amplifier. The high voltage output controls the expansion of the Translator, which in turn controls the gap between the sensor heads. Thus the inputs control the distance between the Probe and Target sensors.

14.6.2 Connections

Connect the Nano mechanism or Translator and sensors as described in sections 14.3. Connect the interface cable to the supplies.

14.6.3 Setting the sensor nominal gap

For Translator and sensor configurations the sensor gap must be set to its nominal value. Set the operating mode to open loop (section 14.5.4) with no digital or analogue input. Apply power to the NPS2100-20 and monitor the NanoSensor output on an oscilloscope or voltmeter. Adjust the displacement between the sensors until the voltage is 0V±200mV.

For translator mounting kits, S300, X-Y stages & microrotators the Target & Probe sensor gap is factory set and cannot be adjusted.

14.6.4 Setting the dc offset adjustment

For factory configured nano mechanisms the NPS2100-20 has a dc offset adjustment facility. Monitor the NanoSensor output open loop. Use a small flat bladed screw driver to turn the DC offset adjustment potentiometer to set the NanoSensor output to 0V±20mV. See figure 14.5

14.6.5 Setting the NanoSensor gain

Whilst monitoring the NanoSensor output open loop apply +10V to the analogue input. Increase the NanoSensor gain starting at 0.1G/V towards 0.01G/V as shown in section 14.5.3 until the NanoSensor output is as big as possible but under 5V in magnitude.

If the NanoSensor output is negative change the sign of the NanoSensor output using the ±1 gain switch as shown in section 14.5.4.

14.6.6 Closing the Loop and Setting the Frequency Response

Change the open/closed loop switch to closed as described in section 14.5.5 Connect the NanoSensor output to an oscilloscope. Apply a 20Hz, 100mV pk-pk square wave to the analogue input . Turn the bandwidth adjustment potentiometer (See figure 14.5) slowly clockwise whilst looking at the rise and fall times of the NanoSensor waveform. When the rise and fall times are as fast as possible without overshoot the frequency response is at its fastest setting.

14.6.7 Setting the Closed Loop Slew Rate

Apply a 10V pk-pk, 10Hz square wave to the analogue input. Turn the slew rate adjustment potentiometer (See fig 14.5) slowly anti-clockwise whilst looking at the rise and fall times of the NanoSensor waveform. When the rise and fall times are as fast as possible without introducing distortion the slew rate is at its optimum setting.

14.7 Using the NPS2100-20 for Open Loop Position Control and Position Sensing.

The NPS2100-20 can be used open loop for controlling the translator and position monitoring. These functions can be completely independent.

14.8 Open and Closed loop Noise

The NPS2100-20 both senses displacement and positions the Translator. The measurement noise and translator noise are different.

14.8.1 NanoSensor Noise

The NanoSensor noise is largely independent of configuration but depends upon the NanoSensor bandwidth setting (See 14.5.2). The NanoSensor noise for various standard NSxx sensors is given in table 14.2

Example:

NS60 sensors, -S configuration, 5kHz NanoSensor BW.

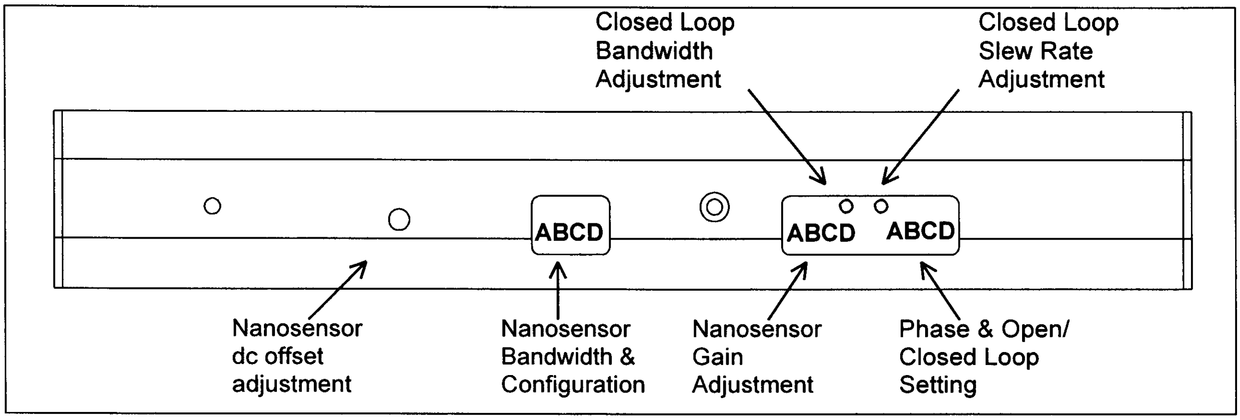
From table 14.2 the NanoSensor noise with NS60 sensors, -S configuration is 0.003nmHz$^{-½}$. The square root of the 5kHz bandwidth is 70.7 therefore the NanoSensor noise will be 0.21nm rms.

14.8.2 Translator Noise - Open Loop

The Translator noise is dependent upon the configuration, open or closed loop, and upon the closed loop bandwidth.

Open loop the Translator noise is determined by the high voltage amplifier noise which is given in table 14.1

Fig.14.5. NPS2100 Side View



as 0.2mV rms. The 120V high voltage amplifier swing corresponds to the full range of the Translator therefore the Translator noise open loop is 1.6ppm rms of the Translator range.

Example: MTP45 Translator open loop.

The Translator noise will be 45μm x 0.0002/120 = 0.075nm rms.

14.8.3 Translator Noise - Closed Loop

Closed loop the Translator noise is determined by the NanoSensor noise, the NanoSensor bandwidth the closed loop bandwidth and high voltage amplifier noise.

The Translator noise is given by

$[((BWcl / BWns)^{-½} \times Nns)^2 + Nt^2]^{-½}$

where BWcl is the closed loop bandwidth, BWns is the NanoSensor bandwidth, Nns is the NanoSensor noise as determined in 14.8.1, Nt is the Translator noise due to the high vlotage amplifier as determined in 14.8.2.

Example 1:

NS60 sensors, -S configuration, 5kHz NanoSensor BW. MTP45 Translator with a closed loop bandwidth of 50Hz.

As shown in 14.8.1 the NanoSensor noise will be 0.21nm rms. The square root of the ratio of the closed loop bandwidth to the NanoSensor bandwidth is 0.1. This calculation gives 0.021nm rms.

This is added as the root of the sum of the squares (rss) to the high voltage amplifier noise which, from section 14.8.2, is 0.075nm rms.

The rss is $(0.021^2 + 0.075^2)^{-½} = 0.078$nm rms

Example 2:

NS60 sensors, -L configuration, 5kHz NanoSensor BW. MTP45 Translator with a closed loop bandwidth of 500Hz.

Noise due to the high voltage amplifier = 0.075nm rms. Noise due to the NanoSensor = $0.075 \times 5000^{-½} \times (500/5000)^{-½} = 1.68$nm rms.

The Translator noise will be $(0.075^2 + 1.68^2)^{-½} = 1.68$nm rms.

Note that in closed loop operation the NanoSensor noise will be higher than the noise on the Translator. The noise on the Translator is limited to the closed loop bandwidth wheras the NanoSensor noise is at the Nanosensor bandwidth, nominally 5kHz.

Typically pk-pk noise is 5 times the rms figure.

The Queensgate Guarantee

The Queensgate guarantee is simple, clear and dependable. We guarantee to you that our products meet their advertised specifications and we will cover all parts and labour for repairs for a period of at least one year from the date of purchase. Repairs are relatively rare as our products are designed to be robust *(we don't like repairs either)*. When repairs are needed, we try to make sure that your down time is kept to the absolute minimum.

If a problem occurs the following steps should be taken:

Notify the local agent, distributor or Queensgate Instruments, giving full details of the difficulty. It is especially important to include the model, type, serial number and date of purchase.

On receipt of this information our engineering staff will send further service instructions to isolate or cure the problem.

If field repair is not possible then shipping procedures including an RA number (Return Authorisation) will be forwarded to you.

Once you have the shipping procedure and RA number send the instrument back to Queensgate, carriage and insurance prepaid, and we will repair it as quickly as we can.

If it is out of the Warranty Period we will prepare an estimate for the work to be carried out prior to starting the repair.

This is Queensgate's investment in support, service and guarantees. Our customers are the most important part of our business.

Electromagnetic Compatibility

CE

The NPS2100-20 Nanopositioning Control System conforms with the protection requirements of Council Directive 89/336/EEC, relating to Electromagnetic Compatibility, (emissions) by the application of the following EMC Standard:

BS EN 50081-1 1992 Emissions Standard, Residential, commercial and light industrial (Class B level).

The NPS2100-20 system relies for its operation on the detection of very small signals from its capacitance bridge. As such, exposure to interference fields as defined in BS EN 50082-1 1992 Immunity Standard, Residential, commercial and light industrial may cause spurious voltage fluctuations on the Nanosensor output, and in the case of closed loop systems, spurious voltages may be applied to the piezo translator causing undesired motion.

Immunity can be improved by use of extra shielding around the Probe and Target cables. Please consult Queensgate Instruments for advice on the use of NPS2100-20 in high interference field environments.