# PLUG-IN TOOLS

kleindiek nanotechnik

# Plug-in Tools Handbook

kleindiek nanotechnik

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Contact support@nanotechnik.com with questions or for further information

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# Contents

# General

## Safety

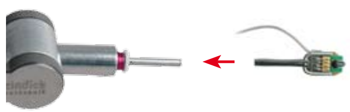
Power supply units should never be disassembled – they may contain high-tension circuits that can cause severe electric shock and damage the unit. For repairs, please speak to your local distributor or contact us directly. Avoid touching the connector pins. Only use the power supply provided and check that the input voltage is correct if it is not a switching power supply.

## Handling

These systems consist of precision instruments. Please use caution when handling all components. Do not apply strong pressure or vibration to any of the components as this can cause damage to the finely tuned internal parts. Dirty environments should be avoided – fine turnings, metal dust or glass fibres can get inside the instruments and cause operation failure. Avoid bending or damaging the cables.

## Tip extensions

Depending on your mounting solution, the manipulator may be anywhere from very close to the sample to a considerable distance away. In some cases, your plug-in tool will be able to bridge the remaining gap and comfortably reach the sample. However, if the gap is too large, you can use one of the various tip extension pieces to extend the length of the manipulator. Tip extensions have a 2 mm Ø opening at the front and are not to be confused with tip holders, which have a 0.5 mm Ø hole. To use a tip extension, simply slide it into the front of the manipulator and then insert the plug-in tool.





## Slot extension

If your manipulator mounting solution does not allow for enough space between the sample and the manipulator for you to install the plug-in tool, then use the slot extension piece provided to set the manipulator back by the required distance.

## Specifications

For detailed technical specifications of the components included with your system, please refer to the inspection checklist in your documentation folder.

## Consumables

If you wish to order additional consumables for your system, please speak to your local distributor or contact us directly for pricing and delivery information.

# LCMK-EM Low-current measurement kit

## Main components

LCMK tip holder

Feed cable

Triax adaptor cable

Terminal block adaptor

Triax to BNC adaptor

Triax to triax adaptor

## Installation

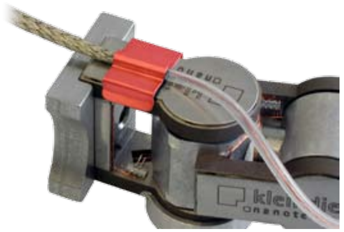
Follow the *Vacuum flange & feedthrough* instructions in the *Micromanipulator Installation Handbook* in order to install the flanges required for the LCMK feedthroughs.

Plug the remaining end of the feed cable into your Source Measurement Unit (SMU). Use the adaptor cables and plugs if necessary. For high-voltage applications, we recommend that the triax adaptor cable is plugged into the feed cable.




Ground the LCMK tip holder in order to keep magnetic pickup as low as possible. If you are using one manipulator, join the **Tip** and **Shield** ports at the back of the NanoControl using the grounding cable provided. If you are using multiple manipulators, attach a BNC terminator to each of the respective BNC outputs of the splitter box. If you are using the Safe Tip Approach (STA) set the respective switches to GND.

Slide the LCMK tip holder into the front of the manipulator.



Attach the cable clip to the top of the manipulator.

Insert a probe tip into a standard tip holder (see *Probe tips* in the *Micromanipulator Installation Handbook*). Insert the standard tip holder into the LCMK tip holder.

## Operation

The Low-Current Measurement Kit (LCMK) is a plug-in tool for your manipulator to allow current measurements down to 1 pA. The LCMK consists of vacuum-compatible triax cable, a dedicated vacuum feedthrough and a triax feed cable in order to reduce leakage current and amplifier input capacity to a minimum. The triax feed cable is designed to be connected directly to a Source Measurement Unit (SMU) to keep the series resistance as low as possible.

The inner conductor, the guard and the shield signals are fed through the vacuum feedthrough. All three signals are electrically isolated from the flange. The shield is connected to the housing of the triax input plug on the SMU and is fed through to the cable clip on the manipulator. The guard ends at (but is not connected to) the LCMK tip holder. The inner signal conductor is connected to the front end of the LCMK tip holder but is electrically isolated from the rest of the tip holder. If short circuits between the shield of the vacuum cable and the interior of the SEM are not desired, then the vacuum cable should be arranged in such a way as to avoid contact when the microscope stage or the manipulator moves. Cable ties and cable holders are included with your manipulator system to assist you with this. Connecting the shield of the vacuum cable to the microscope's ground potential may sometimes be useful for reducing magnetic pickup, but may result in ground loops. This is microscope specific and should be tested individually.

## Application

All cables should be handled carefully to avoid damage. The LCMK tip holder should never be touched when a voltage from a SMU or any other source is being applied. This especially applies to high-voltage applications where a voltage of up to 210 V may be present in the inner conductor or the guard. Touching the LCMK tip holder or a damaged cable can cause severe electric shock. For repairs, please speak to your local distribution partner or contact us directly. Apply voltages higher than 210 V at your own risk.

For a detailed explanation on how to contact objects of interest using the manipulator and further application-specific information, please read the *Micromanipulator Application Handbook*.



**Important notes on high-voltage applications**

- The voltage must only be applied to the inner conductor (red plug of the triax adaptor). The shield (black plug) must be properly grounded. The guard (blue plug) must be left open if the voltage exceeds 210 V.
- The LCMK is certified up to a voltage of 1250 V applied between the inner conductor and the shield for a duration of one hour. However, the warranty on this product does not cover voltages greater than 500 V.
- Voltages larger than 200 V should not be applied during venting or pumping as they may cause damage to the SEM. Only apply voltages in a vacuum of $10^{-4}$ mbar or lower.

# MGS2-EM Microgripper

## Main components

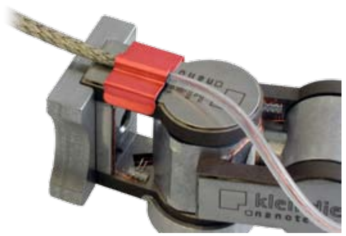
Microgripper

Y-cable

## Installation

Slide the gripper into the hole at the front of the manipulator. Note that the gripper is very fragile. Take extreme caution when handling it, even when it is still in its packaging.

Attach the cable clip to the top of the manipulator.



Ensure that the fine position for channel D is set to zero for all your NanoControls.

| | | | |
|---|---|---|---|
| A | 0 | f32 | 3 |
| B | 0 | f32 | |
| C | 0 | f64 | P |
| D | 0 | f08 | 1 |



Plug the green connector on the gripper into one of the numbered slots on the splitter board. Take note of the numbers of the plugs that you used for the manipulator and for the gripper (for example MM3A = 1, MGS = 3).


Attach the Y-cable to the ports on the splitter box with the same numbers as the slots that you used on the splitter board.

You can also bypass the splitter board and box by plugging the Y-cable into the **Out** port of the NanoControl and attaching both the gripper and the manipulator to the Y-cable using the SMC to DSUB adaptors provided.

## Operation

The gripper is piezo-electric and is driven by a voltage between 0 and 80 V. An increase in voltage causes the gripper to close. Using the Y-cable, the gripper is connected to the D channel of the NanoControl that is driving the manipulator to which the gripper is fitted. At zero voltage, the gripper arms may be open or closed, depending on the temperature and humidity of the environment and on the vacuum level.

### Adjusting the NanoControl settings

The gripper can only be controlled in fine mode (f01 to f64). Thus, you need to adjust the NanoControl settings of channel D so that it is always in fine mode. The lower the speed setting, the finer the movement of the gripper will be.

Press the **menu** button to open the menu and scroll to **17 Speed**. The current speed is shown in the upper right-hand corner of the display. Use the up/down buttons on the left to change speed.

```
17 Speed         5

   A    B    C    D
c08  c08  c32  f32
```

Use the fourth knob to set the following fine mode values for the different speeds of channel D:

- 1: f01
- 2: f04
- 3: f08
- 4: f16
- 5: f32
- 6: f64

In order to operate the gripper with the Joypad, you need to assign one of the Joypad axes to channel D. The Joypad axis numbers are shown in *Axis mapping* in the *Micromanipulator Operation Handbook*.

Scroll to **04 Joypad Mapping**. Turn the third knob (axis 3) to set its value to **D**. Test the new settings using the Joypad.

```
04 Joypad
   Mapping
   1    2    3    4
   C    A    D    B
```

To save the changes to the current profile, press and hold the menu button until the NanoControl beeps.

**Using the NanoControl**

The gripper can be controlled using the D channel knob of the NanoControl (default setting is knob number 4).




**Using the Joypad**

The gripper can be controlled using the Joypad axis that you assigned earlier.

**Using the Cube**

The Cube is designed to drive only three NanoControl channels. If you are using the Cube in conjunction with the gripper, we recommend that you control it using the NanoControl or Joypad.

## Application

Always ensure that the fine position for channel D is set to zero before you insert or remove the gripper from the splitter board. If it is not, the gripper may be damaged by sudden and unpredictable movements.

Please note that the gripper is very fragile. The gripper tips cannot be repaired once damaged – a new unit must be ordered. Take extreme caution when handling or operating the gripper. When contacting objects of interest with the gripper, do not attempt to touch the sample surface when the manipulator is in speed 4, 5 or 6.

When moving the manipulator at high speeds, it is possible that vibrations from the coarse steps may cause an object that you have picked up to fall out of the gripper. If you experience this, select a lower speed when moving the manipulator or use the microscope stage to move to the target region.

For a detailed explanation on how to approach sample surfaces using the manipulator, please read the *Micromanipulator Application Handbook*.

# ROTIP-EM Rotational tip


RoTip controller

RoTip

RoTip cable

## Installation

Connect the power supply unit to the power mains using the multiple socket outlet provided. In order to avoid ground loops, it must be connected to a power supply socket on your microscope. Connect the power supply to the **Power** port.


If your system contains *one* or *two* RoTips, connect the **Out** port to a splitter box port labelled **RC** using the 15-pin cable provided.

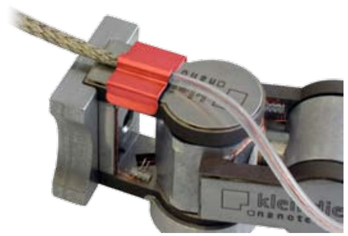

If your system contains *three* or *four* RoTips, plug the dedicated feed cable (HDSUB15 plug on one end, round 19-pin feedthrough plug on the other end) into the **Out** port.




Plug the green connector on the RoTip cable to one of the numbered slots on the splitter board. If your system contains *three* or *four* RoTips, then there will be a dedicated splitter board for them.

You can also bypass the splitter board and box by connecting the RoTip directly to the **Out** port on the controller by using the SMC to DSUB adaptor provided. Only one RoTip can be connected at a time and it is assigned to channel A (knob one).

Slide the RoTip into the front of the manipulator.



Attach the clip on the RoTip cable to the top of the manipulator and plug in the RoTip.

Probe tips, other plug-in tools or your samples can be inserted into the front of the RoTip. Do not turn the rotational axis by hand. The motor does not contain a slipping clutch and applying force in either direction may damage it. Take special care when inserting and removing items.

## Operation

The RoTip is a micromotor which can rotate at three different speeds. It has a fixed number of steps per revolution, so it is possible to determine how many degrees have been moved with each step. This is shown on the display of the RoTip controller. By simply selecting a speed and turning the knobs on the RoTip controller, it is possible to rotate any tool or object that is inserted into the RoTip. The controller is capable of driving four individual RoTips.

Each knob on the RoTip controller can be used to control one RoTip.


Press and hold the **menu** button for two seconds in order to reset the current positions of all RoTips to zero.

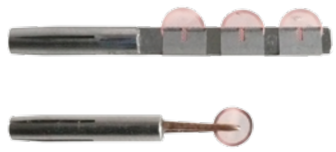

The two sets of buttons on the left and right of the display are used to change between the speeds "slow", "med" and "fast".


The letters A, B, C, and D in the first column of the display represent the four output channels and correspond to the knobs **1 to 4**. The numbers in the second column show the current position of each RoTip. The fourth column shows the current speed setting.

```
A -90.0 deg  fast
B  20.2 deg
C 275.8 deg
D   0.0 deg
```



## Application



Use the TEM grid holder or TEM grid tweezer to comfortably position and rotate TEM grids when preparing your TEM samples in SEM or FIB.

For a detailed explanation on how to perform specific tasks with the manipulator and RoTip, please read the *Micromanipulator Application Handbook*.

# FMS-EM Force measurement system

## Main components


FMS controller


Force measurement tips (FMTs)

FMT holder

Calibration spring

## Installation

Connect the power supply unit to the power mains using the multiple socket outlet provided. In order to avoid ground loops, it must be connected to a power supply socket on your microscope. Connect the power supply to the **Input** port.


Connect your analysis instrument to the **Output** port. The centre pin of the BNC output is connected to the voltage output of the bridge amplifier. The housing of the BNC output is connected to the internal ground of the controller.



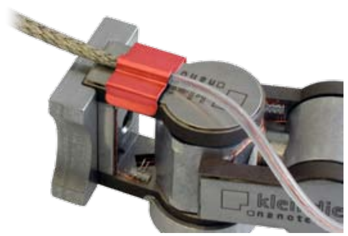



Connect the **Tip** port to the splitter box using the 9-pin cable provided.

Plug the green connector on the FMT holder into the slot labelled **FMS** on the splitter board.

You can also bypass the splitter board and box by plugging the FMT holder directly into the **Tip** port on the controller by using the SMC to DSUB adaptor provided.

Slide the FMT holder into the front of the manipulator.

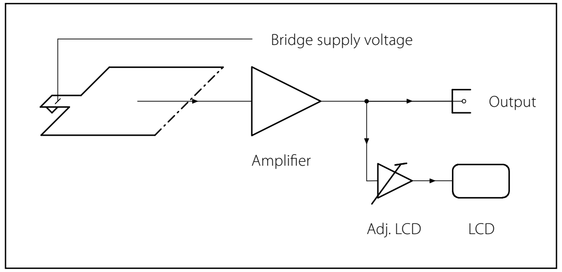


Attach the cable clip to the top of the manipulator.

Use the pliers provided to grip the FMT as close to the top as possible. Gently slide the FMT into the FMT holder. Note that FMTs are very fragile. Take extreme caution when handling them, even when they are still in their packaging.

## Operation

The FMS consists of a cantilever, a resistor bridge, an amplifier, an analogue output, a loudspeaker and a display. The resistor bridge is integrated into the cantilever (FMT) and the other components are integrated into the FMS controller. The FMT is covered with piezo-resistive material. When it is brought into contact with a sample (and is thus bent), this material generates an electrical signal. The material is one of the components of the resistor bridge, so that the resistance of the bridge changes when the cantilever is bent. By applying a voltage to the bridge, the change in resistance can be converted into a change in voltage.




The voltage changes at the resistor bridge are amplified and the amplified signal is output by the FMS controller in three different ways:

- Through the BNC plug on the rear of the FMS controller (maximum output voltage range is ± 10 V).
- On the display on the front of the FMS controller (a variable voltage divider can be used to adjust the displayed values between forces and voltages).
- Through the loudspeaker in the FMS controller (the volume can be adjusted using the regulator).

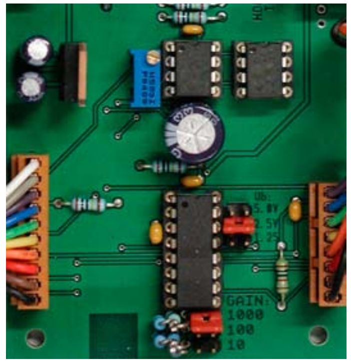
The output voltage at the BNC plug is dependent on:

- The sensitivity of the cantilever.
- The bridge supply voltage.
- The gain of the amplifier.



### Changing the gain or bridge supply voltage

The resistor bridge voltage is set to 2.5 V as a default. This provides the optimum signal-to-noise ratio for our FMTs. Changing the voltage may be necessary if force sensors from other manufacturers are used. The amplifier after the resistor bridge is set to a gain of 100 as a default. Note that the output of the amplifier is limited to ± 10 V. If you need to measure larger forces, the gain should be decreased.




The following jumpers can be set inside the FMS controller:

- **Gain**: options are 1000, 100 and 10. The default is 100.
- **Ub**: the bridge supply voltage can be set to 1.25 V, 2.5 V or 5 V. The default is 2.5 V.
- **Case to ground**: Connects the housing of the controller to ground. This can be changed to try to reduce noise or other interference. The default is that the case is connected to ground.

### Moving the decimal point on the display

On the rear of the display (inside the controller) is a jumper with three positions that can be used to set the position of the decimal point on the display. It does not affect the figures on the display and can be changed freely to suit your preference. Remove the jumper if you do not need the decimal point at all.

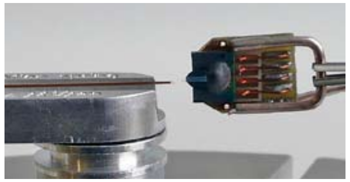
## Application


Switch on the loudspeaker by turning the volume knob. The loudspeaker offers a highly sensitive method of checking whether the FMT has made contact with the sample surface. If the volume is too high, coupling from the speaker output back to the FMT may occur. Decrease the volume until the feedback disappears. If you wish to check if the FMS is working, gently blow onto the rear side of the FMT. You should hear a sound from the loudspeaker.

The FMS requires calibration before you can begin using it, especially if you have inserted a new FMT. We recommend that you recalibrate before each experiment. Calibration needs to be performed in your SEM. Each spring has its own unique spring constant, which is engraved into its housing. Write down the spring constant for your calibration spring as you will need it later.

Stick the calibration spring onto a stub. Twist the FMT holder in the manipulator so that the FMT is vertically oriented.

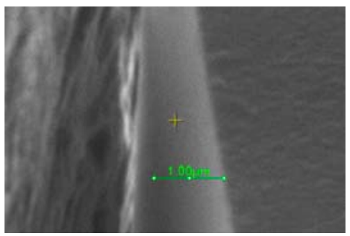
Vertically align the FMT with the calibration spring. Position the rear side of the FMT (the side without the sharp tip) next to, but not touching, the calibration spring. Do not use the front side of the FMT because you may damage the tip.



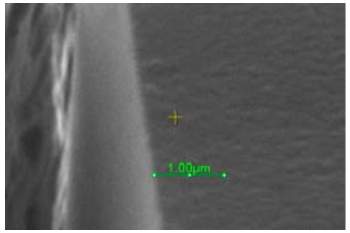
Set **LCD-Adj.** to 10. Turn the **Coarse** and **Fine** regulators to zero the display (this sets the bridge voltage to zero).


Pump the system and switch on the electron beam. Use the manipulator to carefully move the FMT toward the calibration spring using speed 4 and then speed 3. The spring constant for your calibration spring is only valid at the very end of the spring, so align the very end of the FMT with the very end of the spring to ensure an accurate calibration. Touch the spring very gently with the FMT.

Focus on the edge of the FMT. Mark 1.0 µm on the screen.






Move the FMT using speed 2 until the calibration spring has been bent to the 1.0 µm mark.

Force = spring constant × distance

Force = 9.90 µN/µm × 1.0 µm

Force = 9.90 µN

Assuming that the calibration spring has a spring constant of 9.90 µN/µm, you can calculate the force you have just applied as shown. Turn **LCD-Adj.** to set this value on the display. The system is now calibrated and the display will show values corresponding to the force applied instead of merely displaying the bridge voltage output.

Electron irradiation of the piezo-resistive areas of the FMT may cause a change in offset and sensitivity over time. Avoid exposing anything but the tip of the FMT to the electron beam or use a low beam current.

Using the FMS to analyse objects of interest is similar to the procedure described for calibration. For a detailed explanation on how to contact objects of interest using the manipulator, please read the *Micromanipulator Application Handbook.*

**Using the system without calibrating**

You can use the tables below for sensitivity calculations when using the FMS without first performing a calibration. However please note that there is a large margin of error when working like this (approximately 40%).

FMT-120

| Gain | LCD-Adj. | LCD ± 2000 | Output |
|---|---|---|---|
| 10 | 0.20 | ± 2000 µN | 5 mV/µN |
| 10 | 2.00 | ± 200.0 µN | 5 mV/µN |
| 100 | 2.00 | ± 20.00 µN | 50 mV/µN |
| 1000 | 2.00 | ± 2.000 µN | 500 mV/µN |

FMT-400

| Gain | LCD-Adj. | LCD ± 2000 | Output |
|---|---|---|---|
| 10 | 1.00 | ± 200.0 µN | 10 mV/µN |
| 100 | 1.00 | ± 20.00 µN | 100 mV/µN |
| 1000 | 1.00 | ± 2.000 µN | 1000 mV/µN |
| 1000 | 10.00 | ± 200.0 µN | 1000 mV/µN |

# MIS-EM Microinjection system

## Main components


MIS controller

Microvalve

Microvalve holder

Feedthroughs
(liquid and electrical)

Micropipette

## Installation

Connect the power supply unit to the power mains using the multiple socket outlet provided. In order to avoid ground loops, it must be connected to a power supply socket on your microscope. Connect the power supply to the **power input** port. Plug the feed cable for the electrical feedthrough into the **valve** port.

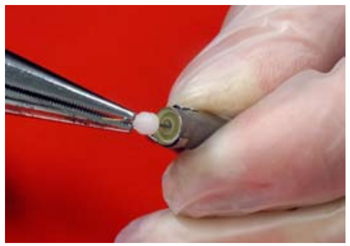

Follow the *Vacuum flange & feedthrough* instructions in the *Micromanipulator Installation Handbook* in order to install the flange required for the MIS feedthroughs.



Mount the electrical and liquid feedthroughs in the appropriate holes in the flange. Attach the syringe holder to the flange. Use a piece of tube to connect the syringe to the outside part (air side) of the liquid feedthrough. Place the syringe in the syringe holder. Connect the feed cable to the electrical feedthrough.

Connect the microvalve plug to the inside part (vacuum side) of the electrical feedthrough. Attach a piece of tube to the inside part of the liquid feedthrough.

Attach the other end of the tube to the microvalve. Mount the microvalve in the microvalve holder and slide the holder into the hole at the front of the manipulator.



The last step is to attach the micropipette to the front of the microvalve, but this should only be done once the system has been prepared for your application. Further details can be found on page 27.

When working in normal SEM mode without the MIS, remove the liquid feedthrough from the flange and insert the blind plug provided in its place.

## Operation

When the chamber is pumped, a pressure difference is created within the microinjection system. Air pressure is present in the tube behind the microvalve, and in the micropipette at the front of the microvalve there is a vacuum. The difference is about 1000 hPa. When the microvalve is opened, the pressure difference causes the liquid inside the tube to be pushed through the micropipette and into the vacuum chamber.

Every liquid has a specific vapour pressure. If you are using a liquid with a vapour pressure that is below the environmental (chamber) pressure, the behaviour of the injection process will be similar to an ordinary daily experience with liquid. However, if the vapour pressure is higher than environmental pressure, the liquid will start to evaporate as soon as it enters the vacuum chamber. This may also cause all the liquid in the tube behind the microvalve to flow out of the injection pipette uncontrollably. There are unfortunately no physical means to avoid this. The amount of liquid that passes through the injection pipette is only limited by the internal friction of the liquid inside the pipette and by the surface tension at the opening of the pipette.

Pressing the **continuous** button will hold the microvalve open for as long as the button is held depressed. When using this mode, be careful with low viscosity liquids, because a large volume might be injected at once.


Pressing the **pulse** button will open the microvalve for a certain amount of time and then close it again. The time interval is adjusted using the **pulse width** knob. After a few attempts, you will recognise that there is a minimum pulse width below which no liquid will be injected. This behaviour is normal and every microvalve has a specific minimum.




## Application


Before starting, ensure that the micropipette is *not* attached to the microvalve. Fill the syringe with the liquid you require. Press the plunger of the syringe and at the same time press the **continuous** button until the liquid flows from the front of the microvalve. This will push the remaining air out of the system.

Attach the micropipette to the front of the microvalve. Press **continuous** again until you see liquid flow out of the micropipette. This will ensure that there are also no air bubbles left in the micropipette.

Pump the chamber and press the plunger further in order to ensure that there is a pressure difference at the microvalve.

Getting the right vacuum level is tricky. If the pressure is too low, the liquid will freeze quickly and break the micropipette. If the pressure is too high, the SEM picture will be poor.

Leaving a gap of a few µm (depending on the quantity of liquid you want to inject) between the micropipette and the sample surface usually makes the injection process easier to control.

For a detailed explanation on how to approach sample surfaces using the manipulator, please read the *Micromanipulator Application Handbook*.

# STA Safe tip approach

## Main components


STA controller

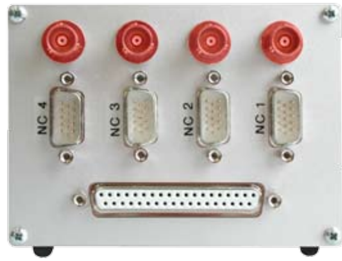
## Installation

The Safe Tip Approach (STA) replaces the splitter box in the standard MM3A-EM system with multiple manipulators. Install the system as described in the *Micromanipulator Installation Handbook*, but use the STA in place of the splitter box.

The substrate of the sample must be properly connected to the **Sample** BNC plug. The signal is fed through the centre of this plug and the outside of the plug is connected to the housing of the STA (shield). Make sure that the resistance between the substrate of the sample and the **Sample** plug is less than 1 kΩ.


The other four BNC plugs on the front of the STA are for direct access to the tip signals from the manipulators. Connect your parameter analyser to these BNC plugs. As with the **Sample** plug, the outsides of the plugs are connected to the housing of the STA. The tip signal is not fed through to the NanoControl.




The STA-LCMK differs from the STA-EM in that it contains additional triax inputs for the feed cables of up to four LCMK-EMs. If you are working with currents exceeding several nA, your parameter analyser can remain connected to the **Tip** BNC plugs on the front panel. For low-current measurements, the feed cables should be unplugged and connected directly to your parameter analyser after the sample has been contacted with the help of the STA. Operation and functionality of the STA-LCMK and STA-EM are otherwise identical.

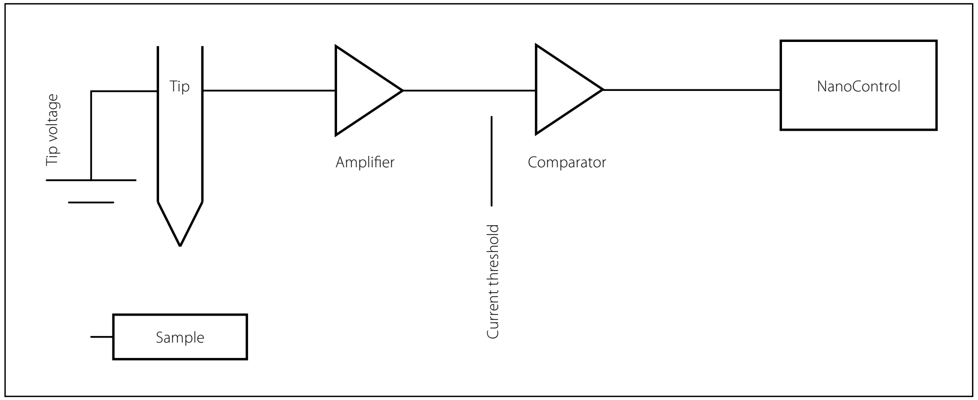
## Operation

The primary function of the STA is to allow probe tips to be landed quickly and safely on sensitive conductive sample surfaces, even for inexperienced users. Tip damage is prevented and damage to the sample is drastically reduced. It can be used with up to four manipulators.

The operating principle of the STA is based on the tunnelling current effect. A current will flow between a conducting tip and a conducting sample when a DC voltage is applied to the sample. The size of this current relies heavily on the distance between the tip and the sample. As a rule of thumb, the current increases by a factor of 10 if the distance between the tip and the sample is decreased by 0.1 nm. The current can be measured at distances of about 0.5 nm and less.

The current from the sample to the tip is amplified and converted to a voltage. During tip approach, the current between the tip and the sample is continuously monitored by a comparator and the alarm signal is triggered if the current threshold is exceeded. The alarm is a TTL signal that is polled by the NanoControl during movement of the manipulator. If a low TTL signal is detected by the NanoControl, any further movement is stopped until the alarm is switched off or the distance between the sample and the tip has increased.

The STA allows the tunnelling current threshold and the DC voltage between the tip and the sample to be set. The voltage of the tip can be positive or negative with reference to the sample. It ranges from -3 volts to +3 volts. The tunnelling current threshold can be adjusted between 10 nA and 150 nA. These settings are valid for all channels. Each channel is equipped with a switch to select an operation mode, an LED to indicate if the current threshold has been exceeded, and a BNC plug that outputs the tip signal from the manipulator.




The STA switch for each channel has three operating modes:

- **STA**: The STA is active and the tip is only connected to the STA circuit.
- **BNC**: The STA is switched off and the tip is only connected to the BNC.
- **GND**: The STA is switched off and the tip is only connected to ground.


STA mode is used for approaching the sample and BNC mode allows electrical measurements between the tips to be conducted once the sample has been contacted.



## Application

The manipulator should be operated in a vibration-free environment for the STA to function reliably. The amplitude of the vibrations must be less than the distance between the tip and the sample at a current of 10 nA. The length of the probe tip is also important because of its sensitivity to vibration: it should be as short as possible.

The attack angle of the probe tips should be between 30° and 60°. The greater the angle, the higher the tunnelling current and thus the greater the sensitivity of the STA.

Place your sample on a stub and connect the substrate to the stub using a conductive pad or silver glue).


The tip voltage must be set according to the requirements of the application. The higher the voltage, the earlier the tip will stop, but be sure to select a voltage that corresponds to the maximum ratings of the semiconductor technology that you are examining.

In most cases a positive voltage is applied. A negative voltage is only needed if you are examining semiconductors that are separated along the substrate by a reverse diode. In this case, a positive voltage would interrupt the current.


Activate the alarm circuit by switching to STA mode for the respective channel before moving the tip towards the sample.

For the first tip approach the current threshold should always be set to its lowest value, that is 10 nA.


Approach the object of interest with the manipulator as described in the *Micromanipulator Application Handbook*. The object should be connected to the substrate. When the STA is switched on, the movement of the manipulator in coarse mode might be slower than normal.

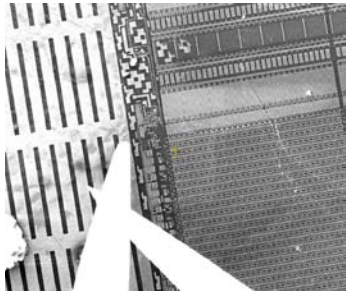
During a quick movement of the manipulator in coarse mode, one or more of the four LEDs may flicker. This occurs due to capacitive coupling from the piezo motor signals to the tip signals that are fed through the same cable and does not influence the functionality of the STA.

In fine mode, flickering of the LEDs may be caused by:

- Contacting samples with a resistance in the order of a few MΩ.
- Bad tunnel contacts due to oxidised tungsten tips or oxidised samples.
- By vibration of the sample or the tip.

As soon as the alarm is triggered, the LED for the respective channel will light up and all movement will be stopped. If you are in fine mode, the NanoControl will beep as well. The channel should then be switched to BNC for electrical measurements or to GND for further manipulation.



When using the STA, the fastest method of landing the remaining tips is to apply a ground potential to the first tip and to switch on the STA for the other tips. As soon as you touch the first tip with one of the others, downward movement will be automatically halted.

The STA can also be used to check the contact resistance:

- Switch the respective tip to STA.
- Set the voltage to be applied to the contacted pad to a positive value (depending on the maximum ratings of the semiconductor, for example 1 V).
- Set the current threshold to 100 nA.
- The LED will turn on if the current exceeds 100 nA. This means that the resistance is 1 V / 100 nA = 10 MΩ.
- Set the voltage to 0.1 V. If the LED is still on, the resistance is 0.1 V / 100 nA = 1 MΩ.
- Continue reducing the voltage until the LED turns off and use this voltage value to estimate the resistance. If the LED only turns off at 0 V, the resistance is usually small enough for I-V curves to be measured.


Use the BNC ports to apply voltages or currents to the tips or to measure voltages or currents from the tips.

For a detailed explanation on how to contact objects of interest using the manipulator and further application-specific information, please read the *Micromanipulator Application Handbook*.

# M4PP Micro four-point probe

## Main components

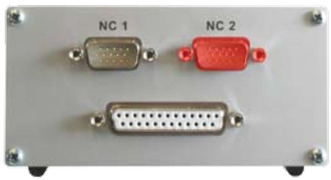
M4PP holder

Capres probe selection kit

Alignment tool

## Installation

Connect the input port of the Capres SEM module or your measurement device to the splitter box using the 15-pin cable provided. Any port labelled **NC** can be used.

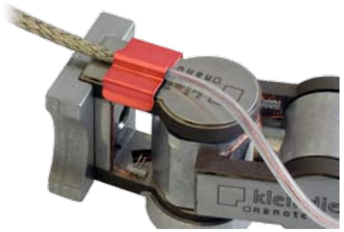



Plug the green connector on the M4PP holder into the splitter board. Use the slot with the same number as the port you used on the splitter box.

You can also bypass the splitter board and box by plugging the M4PP holder directly into the input port of the Capres SEM module or your measurement device by using the SMC to DSUB adaptor provided.

Slide the M4PP holder into the front of the manipulator.





Attach the cable clip to the top of the manipulator.

For additional information and instructions please read the Capres documentation.

## Operation

Please refer to the Capres documentation.

## Application

Please refer to the Capres documentation.

For a detailed explanation on how to contact objects of interest using the manipulator, please read the *Micromanipulator Application Handbook*.

# RT-STEM Rotational axis

Rotational axis

Quickfoot

Spring-loaded mounting foot

Insulation disc & screw

Can be used instead of the quickfoot

Y-cable

Adaptor plate

## Installation

Attach the quickfoot to the base of the rotational axis and slide it into an available position on your adaptor plate in the same way as you would install a manipulator. Alternatively, it can be mounted in your microscope using the insulation disc and plastic screw.



In some microscopes (usually FEI models), you can also use the adaptor plate provided to mount the rotational axis:

- Use the adjustable top piece of the microscope stage to clamp the adaptor plate to the stage.
- Screw the rotational axis into the bolt in the adaptor plate and adjust the bolt to the correct height.

Plug the green connector on the rotational axis into one of the numbered slots on the splitter board. Take note of the numbers of the plugs that you used for one of your manipulators and for the rotational axis (for example MM3A = 1, RT-STEM = 3).


Attach the Y-cable to the ports on the splitter box with the same numbers as the slots that you used on the splitter board.

You can also bypass the splitter board and box by plugging the Y-cable into the **Out** port of the NanoControl and attaching both the rotational axis and the manipulator to the Y-cable using the SMC to DSUB adaptors provided.

Various holders for your samples (for example a TEM grid holder) can be inserted into the front of the rotational axis. For custom-built holders speak to your local distribution partner or contact us directly.

## Operation

The rotational axis operates in the same way as one of the rotational motors of the manipulator (up/down or left/right). Basic operation is explained here, but please refer to the *Micromanipulator Operation Handbook* for additional information and NanoControl settings.

### Adjusting the NanoControl settings

In order to operate the rotational axis with the Joypad, you need to assign one of the Joypad axes to channel D. The Joypad axis numbers are shown in *Axis mapping* in the *Micromanipulator Operation Handbook*.

Press the **menu** button to open the menu and scroll to **04 Joypad Mapping**. Turn the third knob (axis 3) to set its value to **D**. Test the new settings using the Joypad.


To save the changes to the current profile, press and hold the menu button until the NanoControl beeps.

### Using the NanoControl

The rotational axis can be controlled using the D channel knob of the NanoControl (default setting is knob number 4).


### Using the Joypad

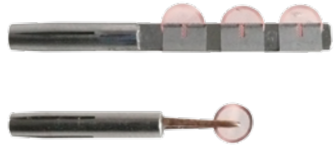
The rotational axis can be controlled using the Joypad axis that you assigned earlier.



### Using the Cube

The Cube is designed to drive only three NanoControl channels. If you are using the Cube in conjunction with the rotational axis, we recommend that you control it using the NanoControl or Joypad.

## Application



Use the TEM grid holder or TEM grid tweezer to comfortably position and rotate TEM grids when preparing your TEM samples in SEM or FIB.

For a detailed explanation on how to perform specific tasks with the manipulator and rotational axis, please read the *Micromanipulator Application Handbook*.

# EBIC/RCI Amplifier

## Main components

EBIC/RCI amplifier


Video cable


External voltage cable

Power supply


RCI grounding cable

## Installation

Start by installing your MM3A-EM & LCMK-EM systems as described in the respective documentation and then continue here.

Connect the power supply unit to the power mains using the multiple socket outlet provided. In order to avoid ground loops, it must be connected to a power supply socket on your microscope. Connect the power supply to the **Power** port using the 15-pin cable provided.



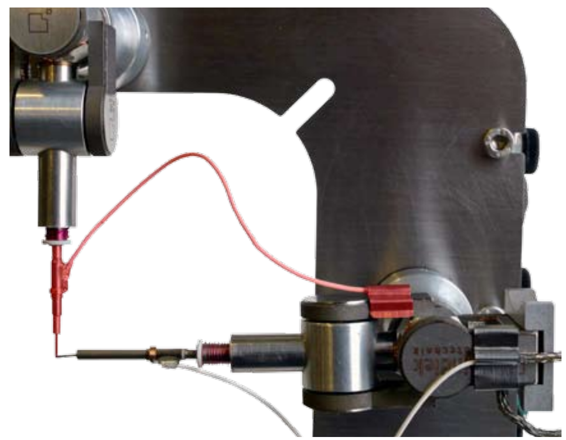


Connect the LCMK feed cable to the port labelled **EBIC In**.

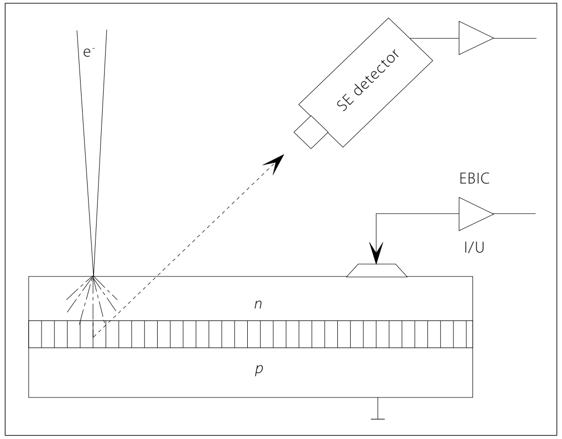

Connect the video input of your SEM to the port labelled **Video out**. Please contact your SEM supplier if you cannot locate the video input port.


Some RCI measurements require a voltage to be applied between two contacted structures on the sample. In this case an external voltage source can be connected to the **Ext. Voltage In** port.

For special applications like Resistive Contrast Imaging (RCI), a second manipulator may be required in order to ground specific structures on the sample. For this you need to use the RCI grounding cable. Clip the cable onto the side of the first manipulator and insert the probe tip holder of the RCI grounding cable into the front of the second manipulator.



## Operation




The signal from the manipulator is fed through vacuum compatible triax cables and out of the chamber to the EBIC/RCI amplifier. A fast, low-noise technique is used to convert the current signal to a voltage. A 50 Ω BNC plug is used for output to the microscope's video input port. The gain can be varied over a large range to match the needs of both EBIC and RCI signal levels. Currents as low as 1 pA and up to 10 µA can be measured and visualised. A separate offset regulator is used to adjust the signal level to the respective input range of the microscope. Larger currents can be handled by switching to AC mode where the input is separated from the amplifier by a capacity that can be selected with the **Cap. (AC)** switch. Depending on the capacity, changes in the current can be visualised. In AC mode the **Ext. Voltage In** port can be used to apply a voltage to the sample. The voltage range is limited to ± 25 V as a surge protection for the video amplifier input.

### Imaging using EBIC

EBIC images are created from electrons with energies of about 5 keV that penetrate through the semiconductor's oxide and metal layers to the p-n junction. If the junction is at the surface of the sample, smaller energies are sufficient. The electron hole-pairs that are generated in this process are separated by the diffusion voltage and measured as a current that flows through the probe tip of the manipulator. The current signal is converted to a voltage and fed back to the SEM to obtain a current image of the sample. The light and dark areas in the image indicate p-n junctions (n- and p-wells to the substrate). In the grey regions no current is flowing. A great advantage of EBIC is the ability to generate electron hole-pairs at specific depths by selecting an appropriate electron beam energy. The higher the beam energy, the deeper the penetration into the sample. By taking pictures using different energies, a three-dimensional image of the p-n junctions can be created. Offset and amplification are adjusted using the EBIC/RCI amplifier to enhance the details of the area of interest.



### Imaging using RCI

RCI differs from EBIC in that the current for the image is generated by electrons diffusing into metal wires that are being contacted by the probe tips of the manipulators. Typically, a contact is made with two wires that are spread over the whole area of interest, like VDD or GND. The result is a resistance image of the current flow from the electron beam position to the contact points. The higher the current, the brighter the image at the electron beam position will be. The beam energy is usually set below 5 kV to avoid penetration down to the p-n junctions but can be higher in the absence of p-n junctions. As the current is very small, a low-noise amplifier with high bandwidth is needed to get good images within reasonable time. Changes in the resistance can be seen in AC mode where large (EBIC) currents can be suppressed.

**Note:** As two manipulators are used for RCI, additional noise is coupled in by the area that is spanned by the additional cable and/or by the capacity between the two contacted points.

## Application

### Getting started

1. Place a sample in the SEM chamber.
2. Insert a probe tip into the tip holder and plug it into the LCMK. For RCI, insert a probe tip into the second manipulator as well.
3. Close the SEM chamber and pump the system.
4. Start SEM imaging and move the area of interest to the centre of the beam.
5. Contact the point of interest with the probe tip by following the *Electrical probing* instructions in the *Micromanipulator Application Handbook*. For RCI, contact the point of interest with the grounded probe tip.
6. Switch on the power supply.
7. Open a second viewing window for EBIC imaging if your microscope GUI allows this.
8. Select the video input port as the detector (for example AUX In or External).
9. Switch to the SEM image and start scanning with a dwell time of 100 µs.
10. Switch to the video input image.

11. Set the **Gain 1-100** to 1.
12. Adjust the brightness using the knobs labelled **Offset Coarse**.
13. Adjust the contrast with the knobs labelled **Gain $10^X$** and **Gain 1-100**.
14. Readjust the brightness using the knobs labelled **Offset Coarse** and **Offset Fine**.

**Image optimisation**

An image can be influenced in four ways by the SEM:

- By changing the electron beam acceleration voltage.
- By changing the electron beam current / beam aperture.
- By changing the electron beam dwell time / scanning rate.
- By applying an additional noise reduction like line averaging, pixel averaging, etc.

A higher acceleration voltage causes the electron beam to penetrate deeper into the sample. By changing the acceleration voltage the information depth can be changed. However, the interaction volume between the electron beam and the sample increases as acceleration voltage increases which leads to reduced resolution.

A higher beam current generates more secondary electrons and therefore more electron hole-pairs at p-n junctions. This may be desired in order to increase the signal-to-noise ratio but will contaminate the sample more quickly.

A longer dwell time increases the number of electrons captured by the SE detector and the EBIC/RCI amplifier and produces higher quality images. The disadvantage is a decrease in the image refresh rate (a few minutes per image). Different dwell times often result in different images as regions of different diffusion length contribute to the image at different speeds.

The higher the gain of the preamplifier ($10^x$), the smaller the bandwidth. The second stage gain (1 - 100) has no influence on the bandwidth.

In order to reduce contamination, small beam currents, high scan rates and high amplifications should be selected. In order to make fast images, high beam currents, high scan rates, small preamp gains ($10^x$) and highest second stage gains (1 - 100) should be selected. In order to make good quality images, medium beam currents, slow scan rates, high preamp gains ($10^x$) and small second stage gains (1 - 100) should be selected.



# Pin assignments

## FMS controller: Tip port

| Pin | Signal |
|---|---|
| 1 | GND |
| 2 | U*in* - |
| 3 | U*b* |
| 4 | U*in* + |
| Shield | Connected to housing |

## LCMK: Triax adaptor

| Plug | Signal |
|---|---|
| Red | Inner (signal) conductor |
| Blue | Guard |
| Black | Shield |