

# RHK Technology

## Application Note:

### Manual Controller of the $\Delta f$ setpoint in NC-AFM measurements with RHK R9

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#### Introduction

The development of measurement devices in the last decade leads more and more to digital-only hardware with a purely software-based user interface. The advantages of this approach are very low noise and flexible devices, because every analog signal path adds some noise to the signal and analog circuits are “hardwired” and not easy to upgrade or replace. From the perspective of the R9, this means that there are no buttons on the front panel while all functions are controlled via the software application. Besides the advantages there is a trade-off, namely losing the possibility to operate the device with the sure instinct of a human. Sure instinct is, however, most important for the variation of some critical parameters like the frequency shift setpoint  $\Delta f_{\text{set}}$  in high resolution NC-AFM measurements. Here, the human interface offered by software menus can complement but not fully substitute manual control. A sophisticated solution allowing a precise and delicate adjustment of  $\Delta f_{\text{set}}$  in NC-AFM measurements is presented in this application note.

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This solution consists of two parts, a piece of hardware and a software extension of the RHK R9 control. The software is implemented as a MATLAB script and works as a bridge between the hardware interface and the R9. As described later, it can also be used for the RHK PLLPro2 with a small modification of the software



Figure 1: Manual Control Box

### Manual Controller Hardware

Figure 1 shows the Manual Controller with two dials acting on 10-turn potentiometers for coarse and fine  $\Delta f_{set}$  adjustment. Each of them basically acts as a precision voltage divider to provide a variable, highly stable voltage between -9.82 to +9.82 volts at the device output. The supply voltage is taken from the R9 “DC Power Out” via a 9pin D-Sub female connection and used to

create 10.000 V reference voltages for the potentiometer network. Operational amplifier circuits are used to, combine the voltages from the potentiometers and to provide a well buffered and noise filtered output voltage that is routed to the BNC connector of the R9 “Analog Input CH 3” or to the “A/D input 2” of the PLLPro2, respectively. The connection between the Manual Controller and the R9/ PLLPro2 shown in Figure 2 consist of shielded cables in a braided hose split into the D-Sub and BNC connections at one end. A detailed circuit diagram and the cable connector outline are shown in Figure 5. The ratio of turns needed to achieve the same change in  $\Delta f_{set}$  for the “coarse” and “fine” dial is about 1:5 but may be altered for an individual implementation by changing the value of the resistor following the impedance converter connected to the wiper of the “fine” potentiometer.

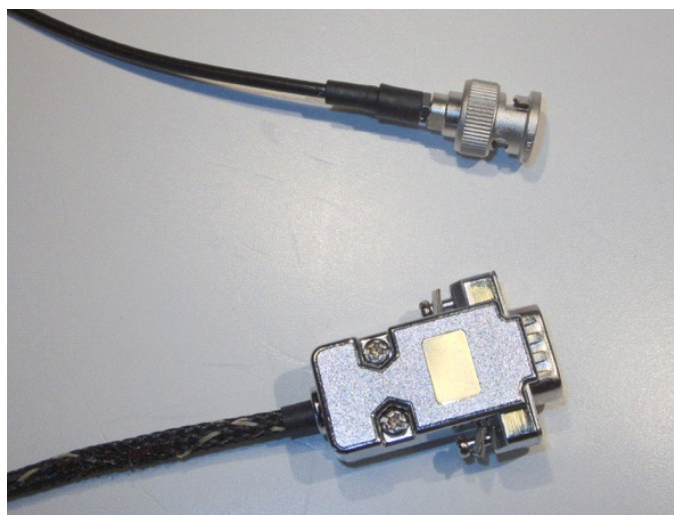


Figure 2: A Photo of Some Homemade Cables

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## Operating the Manual Controller

For operating the Manual Controller, the IHDL workspace is configured and a MATLAB script is started on a PC connected to the local network to communicate with the R9 or PLLPro2 via TCP/IP.

Operation with R9. In the IHDL workspace, the analog input CH 3 is routed to a “Network Stream Item”. A free UDP port has to be chosen and the IP address of the PC where the MATLAB script is running is inserted in the corresponding field. Furthermore, the “External Command Receiver” item is configured through inserting it into the workspace – the associated TCP port is used later when starting the MATLAB script.

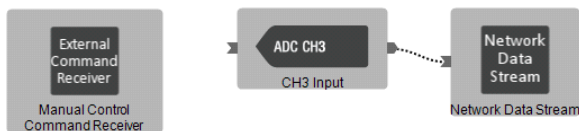


Figure 3: IHDL Configuration

The MATLAB script is started as “manualcontrol.exe R9 ipaddress tcpport udpport”. For example, if the IP address of the PC controlling the R9 is “192.168.1.10”, the TCP port of the “External Command Receiver” is 12600 and the UDP port of the “Network Stream Item” is 12502, the call should read “manualcontrol.exe R9 192.168.1.10 12600 12502”.

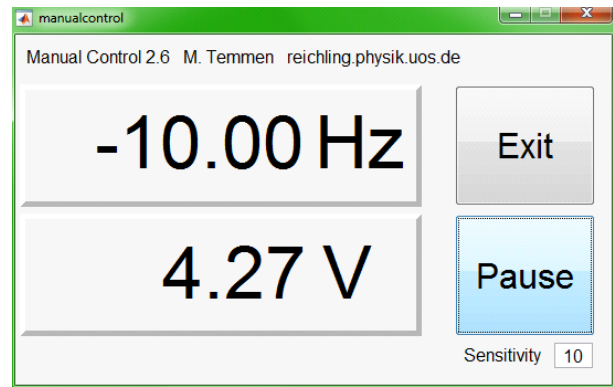


Figure 3: Manual Control Box Interactive Readout Window

## Operating the Manual Controller

The PLLPro2 software is started as “PLLPro2.exe -cport UDPport” so that it listens to an unused UDP port UDPport and returns remote commands to the same port. Here, it is mandatory to run the MATLAB script on the same PC as the PLLPro2 software since it only accepts commands from the IP address localhost. The MATLAB script is started as “manualcontrol.exe PLLPro2 127.0.0.1 UDPport”. For instance, the call should read “manualcontrol.exe PLLPro2 127.0.0.1 1234” if the UDP port where the PLLPro2 software listens is “1234”.

## The MATLAB Script

There are 32 and 64-bit versions available, which can be downloaded from **TO DO**. To use them, install the free to use MATLAB Runtime Environment (version 2014b) [1] and start the script as described above

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## The Graphical User Interface

After launching the MATLAB script, the graphical user interface (GUI) appears and shows the actual frequency shift setpoint  $\Delta f_{set}$  for the cantilever oscillation in units of Hz as exemplified in Figure 4. By turning the hardware dials, the Manual Controller shifts  $\Delta f_{set}$  in the PLL controller. The value of  $\Delta f_{set}$  is directly coupled to the voltage value, so if one of the cables of the Manual Controller is disconnected, the  $\Delta f_{set}$  will change immediately, hence, this should be avoided. The pause button disconnects and reconnects the Manual Controller from the R9 or PLLPro2 controller, so that other external network processes can access the controller.

The second number shown in the GUI is the actual  $\Delta f_{set}$  control voltage in units of V defined by the number of turns of the “coarse” and “fine” dials. It helps the user to determine how much room is left to turn the dials. If the voltage exceeds 8 V, the color of the second number turns red to indicate that the voltage is close to the border. The “Sensitivity” represents the conversion factor between the  $\Delta f_{set}$  control voltage and  $\Delta f_{set}$  and can be adjusted by the user within a range of 0 to 100, where 10 is a good balance between range and sensitivity. The MATLAB script can easily be modified to satisfy different needs, for example to use another input channel or to control another parameter.

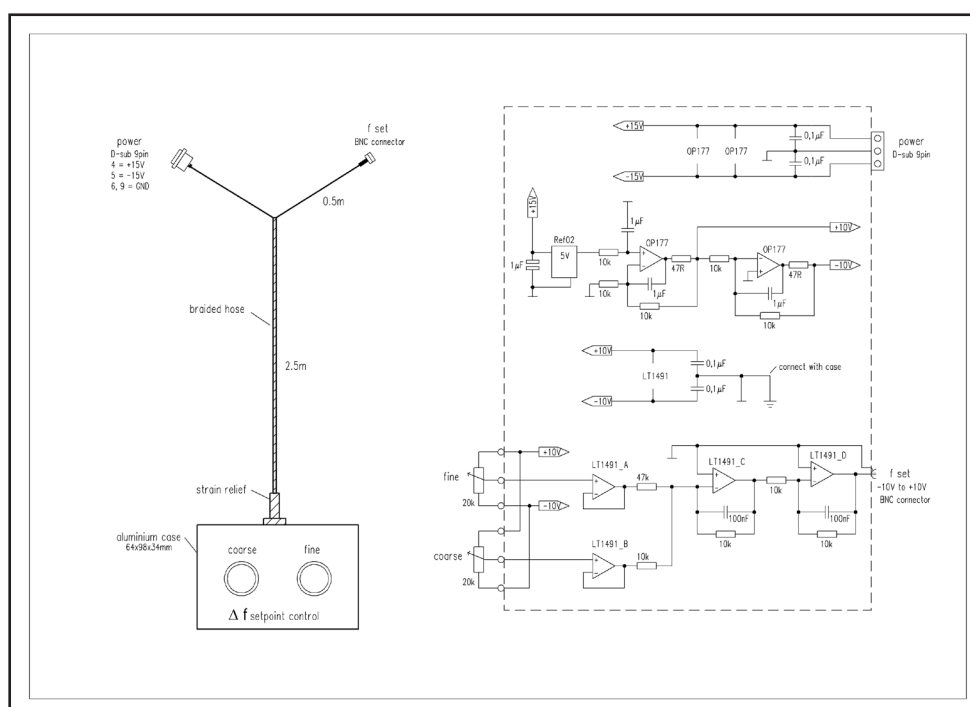


Figure 1: Manual Control Box Schematic

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### References

1. <http://www.mathworks.com/products/compiler/mcr/>
2. index.html

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