STM Electronics Design

Tunneling Current Preamplifier

The Pre-amplifier is a current to voltage pre-amp, The op-amp is always trying to maintain the Tip's voltage at ground potential. There is a resistor T circuit in the feed back loop to increase the effective sense resistance to 100 Mega-Ohms. The two 100K resistors are to protect the op-amp's FET inputs from possible ESD damage when changing the tip. The 220-Ohm resistor right after the pre-amp was added to prevent the pre-amp from oscillating, because it is driving the cable.

Calculating the Error signal (Difference Amplifier)

Following the preamplifier is a difference amplifier. This is just subtracting the Set Point from the pre-amp's tunneling current signal to generate an error signal. The set point is adjusted by turning the potentiometer. See note for switching sample bias. The Set Point voltage is the Tunneling Current signal voltage the servo will try to maintain. In the circuit shown 0.1 Volts corresponds to 1-nano-Ampere.

Integral Gain control (Integrating Amplifier)

Next in the feed back loop is a simple integrating amplifier with adjustable time constant (period of integration). The time constant is determined by feed back capacitor value in Farads multiplied by the input resistance in Ohms. You might also see integrator circuits with a large value resistor across the integrating capacitor such as 1 to 10-Mega-Ohms. This increases the stability but causes some minor error increase. I left it off in my circuit. There is also a 220-Ohm resistor on the output of the integrator this is to prevent the op-amp from oscillating when driving the cable and capacitance of the piezo disk electrode.

Sample Bias Buffer

The sample Bias is just a voltage follower circuit attached to a potentiometer. I had a spare op-amp on the first quad op-amp chip I thought this would be the best use to lower noise pickup, by lowering the impedance of the bias signal to the sample.

The Scope Output Amplifier

The Oscilloscopes' Z input controls the brightness of the trace. For high speed imaging at constant height mode the tip is scanned very fast over an atomically flat surface such as graphite. The Z servo does not have time to respond to the corrugations of individual atoms but the tunneling current an error signal do respond to the tiny changes in height as the tip goes over each atom. This mode is some times called real time imaging. I believe Cal Quate, Et Al, first described it in an article on video rate imaging back in 1987. This mode is best for normal oscilloscopes, the non-storage type. I have an amplifier that has adjustable gain and offset that amplifies the error signal. The output of this amplifier is put in to the Z input of the oscilloscope. The offset and gain are adjusted to make a reasonable range of brightness change on the trace. This has to be readjusted for each setup such as changing set point or scan speed will effect the brightness. The Scope is set into an XY display mode with the X and Y inputs connected to the X and Y scan signals.

Storage Oscilloscope

This method is better for large scan areas and rough surfaces. For my slow speed scans on the gold grating I used this method. Using a storage oscilloscope you can build up images by scanning slowly. I connected a probe to the integrator output (Z piezo drive) and added this to the Y scan signal. The addition was done at the oscilloscope by just adding the two input channels. The X input is still connected to the X scan signal. The Z input is used to blank out the return lines in the X direction by connecting it to Reference output of the X signal generator. This return blanking is not necessary but it does give a cleaner image.

Disks of opposite polarity

I have been lucky but I am not sure if every one else will be. The piezo material on the disk is polarized. If the polarization is opposite of the configuration I have, the feedback loop will cause the tip to move into the surface when the it first senses a tunneling current, thus destroying the tip and digging a tiny hole in the sample. The clue here is that there is no stable tunneling current, it is either full on or off. If this is the case, try swapping the Tunneling Current signal and the Set Point signal inputs to the difference amplifier. The alternative is to switch which side of the disk has the tip mounted on it.

Note: Switching sample bias polarity

Some materials image better with the opposite polarity sample bias. The simplest way to switch the sample bias from positive to negative requires some change in the feedback loop first the Tunneling Current signal and Set Point signal inputs to the difference amplifier need to be switched. The set point needs to be changed from a negative bias to a positive bias. Then the feed back will work correctly. I left these switches out of the design for simplicity reasons. If you can find a quadruple throw double pole switch you could change all of this with one switch. The more complicated way is to place an absolute value amplifier on the tunneling current signal before the difference amplifier. It is not so easy to build a really good absolute value amplifier. There are lots of small offset problems and non-linearity issues caused by mismatched parts, so I have skipped that option.

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