Example Electronics Project Proposal (based on and liberally quoting Chris Adam's Thesis)

Project Proposal: Scanning Tunneling Microscope Feedback Electronics

Customer Requirements

The device should select and maintain the elevation of a Scanning Tunneling Microscope's tip above a conducting surface as the tip is scanned across the surface. The tip is mounted to a piezoelectric ceramic, so controlling the tip's elevation will require controlling an output voltage which deforms the piezoelectric ceramic. It can be assumed that the horizontal scanning motion of the tip and the voltage difference be between the tip and the sample will be controlled by other circuitry – *this* project is responsible for only controlling the tip's elevation. This circuit should output both the voltage that controls the piezoelectric ceramic's deformation and a voltage that represents the difference between the selected tip-sample separation and the actual tip-sample separation. Either may be monitored on an oscilloscope.

Top-level specification

Input.

The sample will be positively biased relative to the tip, meaning that current into the tip will be positive.

When the tip is the appropriate distance from the surface, a current on order of 10 - 20 nA will pass between the surface and tip. The device should be able to select a tunneling current up to 50 nA.

Response rate.

For horizontal tip velocities up to 30 nm/s, the tip should be able maintain a constant tip-surface separation / a constant tip-surface current by moving up and down. Most surface undulations will be on the order of 0.1 nm wide, thus the circuitry must respond well to an input frequency of 300 Hz. Additionally, the circuitry should be able to avoid crashing into the sides of steep 'cliffs' on the surface which could rise 100 nm for a vertical run of only 1 nm – that means raising the tip 100nm in 0.003s (at maximum horizontal tip velocity.) The piezoelectric ceramics on which the tip is mounted, and which this circuitry must control has a voltage response of 50nm/Volt; thus, avoiding 'cliffs' means changing the output at a rate of 700 V/s.

Output noise.

As the surface undulates beneath the scanning tip, the tip should raise and lower to maintain a constant tip-surface distance to within 10^{-10}m. The piezoelectric ceramic to which the tip is mounted has a voltage response of 500×10^{-10}m/Volt, so output signal noise must be less than 2 mV.

Output range.

The system will be powered by two 9V batteries, so the full range of the output should be roughly -8V to +8V.

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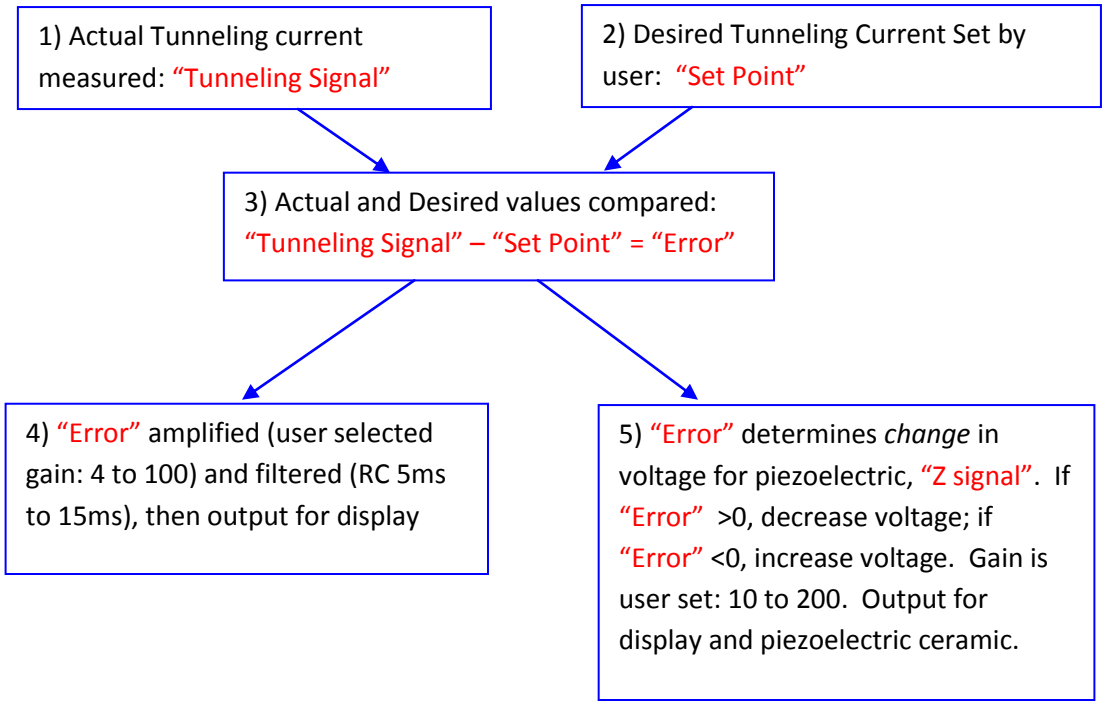
Top-level design

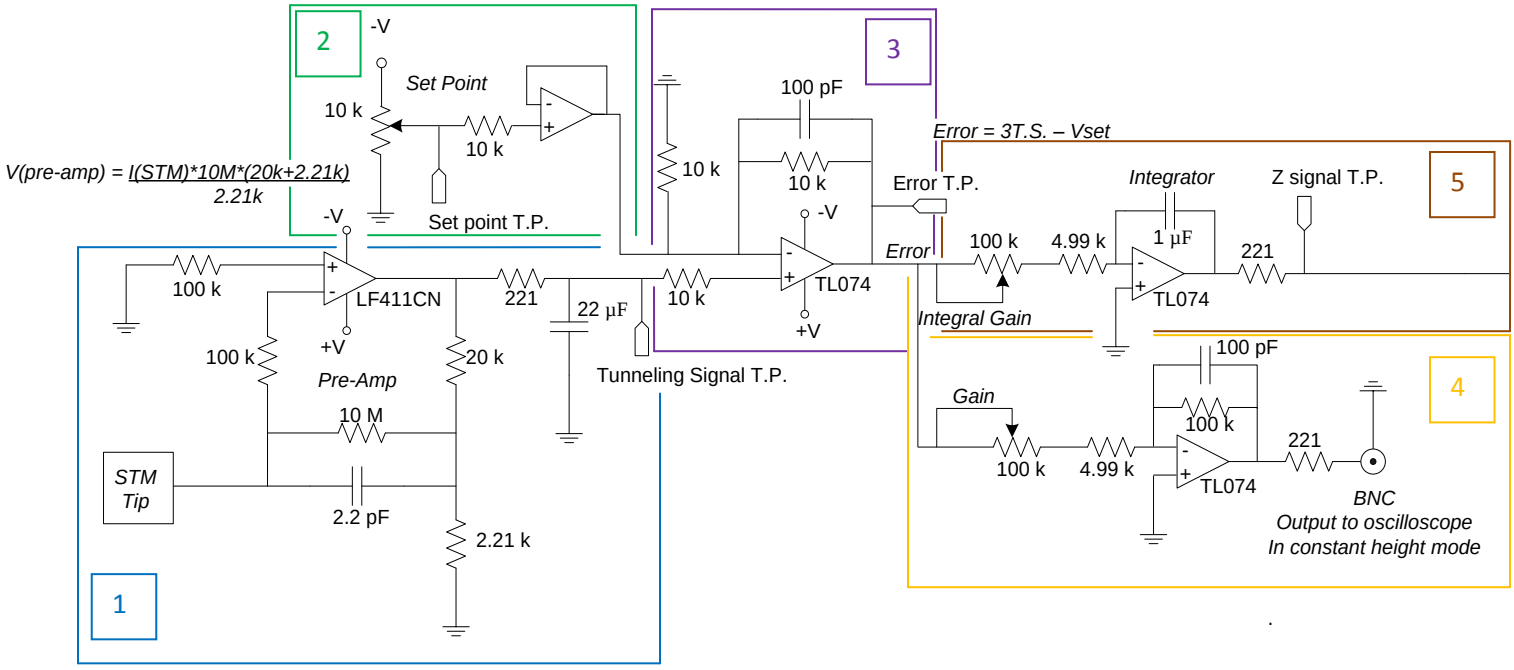


System Tests

1) The pre-amp will be manually tested to ensure proper function. For this, a typical tunneling signal will be simulated by applying 0.1 *volts* to one end of a 10 $M\Omega$ resistor attached to the tip holder. The resulting current going into the tip should be about 10 *nA*. Thus, the voltage out of the pre-amp should equal -0.985 *volts*. The negative sign is due to the fact that op-amps flip the sign of the input voltage, so that a positive signal going in will be negative coming out.
2) This should simply be able to output a voltage from 0V down to the negative rail, when the pot is dialed form one extreme to the other. It should hold this value with a minimum of noise. So this can be monitored by an o'scope and an FFT can be run to determine the noise at different frequencies.
3) The output should be *Error = 3*Tunneling Signal - Test Point* . An o'scope can be used to confirm this.
4) This should output $Zsignal = -\frac{1}{RC}\int_{t_o}^{t} Error \cdot dt$ where C = 1μf and R = 4.99k + (0 to 100k) depending on the set of a pot. This can be tested by feeding a sinusoidal "error" signal from a function generator. Slight offsets aren't that important since, in the context of the STM system, those would be corrected by the feedback of the tip signal increasing/decreasing in response to the resulting tip motion.
5) As with the pre-amp, the difference amplifier and integrator should be manually tested to check for proper performance. This can be done by hooking up a function generator to the 10 $M\Omega$ resistor that was connected to the tip holder. The function generator should output a sine wave

with a frequency of 0.44 *Hz* and amplitude of 0.2 *volts* which corresponds to a tunneling current of about 20 *nA*. The purpose for the sine wave is to simulate a varying tunneling current so that the error and *z* signal could be monitored on an oscilloscope and compared to theoretical expectations. During the sine wave simulation a miniscule perturbation was noticed in the *z* signal near its peak output.

Detailed design



Shopping List

Bread boards	
10 k pot	
100k pot	two
2.21 k	
4.99 k	two
10 k	four
20 k	
100 k	three
10 M	
1µf	
22 µf	
2.2 pf	
100 pf	two
LF411op-amp	
TL074 op-amp	five
221 Ω	three