Switched Capacitor TIA for Parallel Scanning Tunneling Microscope

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Scanning Tunneling Microscope (STM) is an instrument for imaging surfaces at the atomic level, which finds tremendous applications in semiconductor physics, microelectronics, and etc. The fact that the amplitude of the tunneling current signal is typically limited to the nanoamp range requires that the front-end TIA provides an ultra-high gain and a low input referred noise. A CMOS Switched-capacitor TIA (SCTIA) is proposed to sense the tunneling current without introducing any large-valued resistors.

The SCTIA is clocked at 166 kHz with three different phases: Φ_1, Φ_2, and Φ_3 (Fig. 1(a)). Fig.1(c) illustrates voltage responses of internal nodes to a sample input current. Charges on C_1 and C_2 (Fig. 1(b)) are depleted during reset phase Φ_1. After Φ_1 goes low at t_1, the input current starts to charge C_1 and v_1 begins to rise with a slope proportional to the magnitude of input current i_{in}. v_2 follows the change of v_1 after Φ_2 is off at t_2. A Sample and Hold (S&H), consisting of a switch Φ_3 and a capacitor C_3, samples v_2 at the end of Φ_3 and hold the value till next period. A Low Pass Filter (LPF) reconstructs the continuous-time signal from v_{out} and filters out noise outside the band of interest. The SCTIA is measured to achieve a gain as high as 88 MΩ with a 40 kHz bandwidth. CDS reduces the input referred noise current to as low as 25fA/√Hz (Fig. 2). This SCTIA, integrated with MEMS probes, enables low-noise low-power, sensing of tunneling current in parallel STM application.
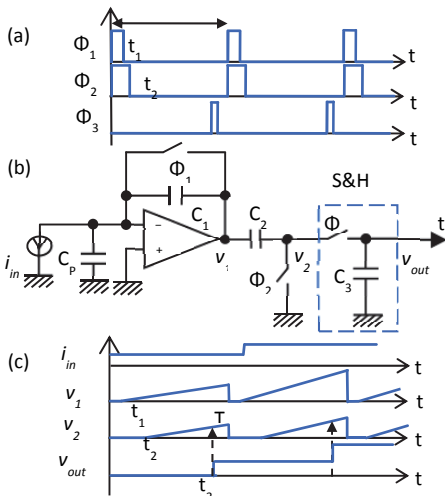
Fig. 1: SCTIA (a) clock diagram; (b) schematic; (c) sample voltage response
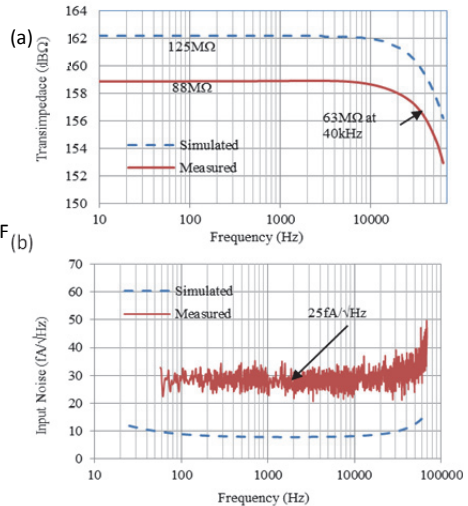
Fig 2: Measurement and simulation of SCTIA performance: (a) transimpedance gain; (b) noise