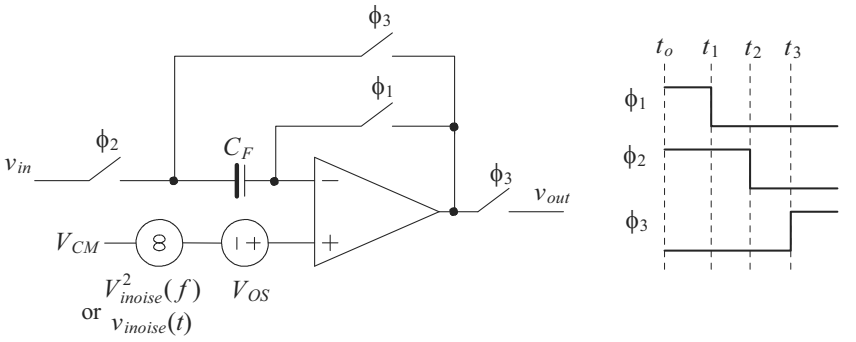

Figure 2.41 S/H with input-referred offset and noise shown.

At a time $T_s/2$ later, the ϕ_3 switches open and the ϕ_1 switches close again to sample the input signal and the noise. Writing the charge on C_F between t_3 and $t_3 + T_s/2$

$$Q_F^{\phi_3} = C_F \cdot (v_{out}(t) - V_{CM} - V_{OS} - v_{inoise}(t)) \tag{2.71}$$

Qualitatively, we can see that if the noise is moving slowly (e.g., Flicker noise) it is removed from the output signal. However, fast moving noise isn't subtracted out during the autozero process. Ultimately the bandwidth of the circuit (say switch resistances and capacitors) and op-amp finite bandwidth limit the frequency content of the noise.

To get a quantitative idea for how the autozero process affects noise in the S/H's output signal we can write

$$v_{out}(t) = v_{in}(t_3) + v_{inoise}(t) - v_{inoise}(t_3) \quad \text{for } t_3 \le t \le t_3 + T_s/2 \tag{2.72}$$

Focusing on the noise and taking the Fourier Transform of each side of this equation gives

$$V_{onoise}(f) \cdot e^{-j2\pi f \cdot t} = V_{inoise}(f) \cdot e^{-j2\pi f \cdot t} - V_{inoise}(f) \cdot e^{-j2\pi f \cdot t_3} \tag{2.73}$$

Note that when t is close to t_3 the output has little noise. The worst case situation is right before the ϕ_3 switches open at a time $t_3 + T_s/2$ (the ϕ_3 switches are on for $T_s/2$ seconds). If we look at this worst-case situation only, then

$$\left| \frac{V_{onoise}}{V_{inoise}} \right| = \left| 1 - e^{-j\pi f \cdot T_s} \right| \tag{2.74}$$

which is essentially the transfer function of a differentiator, Sec. 1.2.2. Note how it would be straightforward to extend this derivation to any arbitrary time that the ϕ_3 switches are on. Borrowing the results seen in Eq. (1.46) we get a noise transfer function, *NTF*, of

$$NTF = \left| \frac{V_{onoise}}{V_{inoise}} \right| = 2 \cdot \left| \sin \frac{\pi}{2} \cdot f \cdot T_s \right| \tag{2.75}$$

This equation is plotted in Fig. 2.42 along with the response of the S/H. Note that at DC (where the op-amp's offset voltage is located) the output of the S/H is noise free. As alluded to earlier, autozeroing works well for reducing the effects of Flicker noise (a low frequency noise that is common in CMOS integrated circuits).