$$Q_{chsubs0} = Q_0 \exp\left(\frac{V_{gs} - V_{th}}{nv_t}\right) \tag{3.1.1a}$$

where Q_0 is

$$Q_0 = \sqrt{\frac{q\varepsilon_{si}N_{ch}}{2\phi_s}}\,v_t \exp\left(-\frac{V_{off}}{nv_t}\right) \tag{3.1.1b}$$

$$Q_{chs0} = C_{ox}(V_{gs} - V_{th}) \tag{3.1.2}$$

In both Eqs. (3.1.1a) and (3.1.2), the parameters $Q_{chsubs0}$ and Q_{chs0} are the channel charge densities at the source for very small Vds. To form a unified expression, an effective (V_{gs}-V_{th}) function named V_{gsteff} is introduced to describe the channel charge characteristics from subthreshold to strong inversion

$$V_{gsteff} = \frac{2\,n\,v_t \ln\left[1 + \exp\left(\frac{V_{gs} - V_{th}}{2\,n\,v_t}\right)\right]}{1 + 2\,n\,\,C_{OX}\sqrt{\frac{2\Phi_s}{q\varepsilon_{si}N_{ch}}}\exp\left(-\frac{V_{gs} - V_{th} - 2V_{off}}{2\,n\,v_t}\right)} \tag{3.1.3}$$

The unified channel charge density at the source end for both subthreshold and inversion region can therefore be written as

$$Q_{chs0} = C_{ox}V_{gsteff} \tag{3.1.4}$$

Figures 3-1 and 3-2 show the smoothness of Eq. (3.1.4) from subthreshold to strong inversion regions. The V_{gsteff} expression will be used again in subsequent sections of this chapter to model the drain current.

