for the drain current used, the figure provides an estimate for $S_{ID}^{1/2}$ useful for design guidance. Possible small-geometry noise increases described in Section 3.10.2.2 are excluded in the figure.

The gate-referred thermal-noise voltage PSD, S_{VG}, shown in the MOS noise model of Figure 3.60, is important for many applications, including when voltage signals appear at the gate of transconductor input stages. S_{VG} is found by dividing the drain-referred thermal-noise current PSD, S_{ID}, by g_m^2. This refers drain noise current PSD to a gate noise voltage PSD.

Table 3.30 summarizes expressions for S_{VG}. In the first expression, S_{VG} is expressed in terms of device g_m/I_D and g_m where the equivalent noise resistance, R_N, is inversely proportional to g_m as it was for S_{ID}. R_N corresponds to the resistance value giving thermal-noise voltage equal to that effectively

Table 3.30 MOS gate-referred thermal-noise voltage PSD expressions and trends in terms of the inversion coefficient, channel length, and drain current. Voltage density (nV/Hz$^{1/2}$) is found by taking the square root of the convenient PSD expressions

Gate-referred thermal-noise voltage PSD	$IC \uparrow$ L, I_D fixed	$L \uparrow$ IC, I_D fixed	$I_D \uparrow$ IC, L fixed
From g_m: $S_{VG} = 4kT \cdot \frac{n\Gamma}{g_m} = 4kT\left(\frac{n\Gamma}{\frac{g_m}{I_D} \cdot I_D}\right) = 4kT \cdot R_N$ $R_N = \frac{n\Gamma}{g_m}$ Convenient expression: $S_{VG} = \frac{(4.07\,\text{nV})^2}{\text{Hz}}\left(\frac{T}{300\text{K}}\right) n\Gamma\left(\frac{1000\,\mu\text{S}}{g_m}\right)$	$\uparrow$ as g_m/I_D decreases from maximum value in WI	Unchanged, but decreases if less vel. sat. reduction of g_m/I_D	$\downarrow\propto \frac{1}{I_D}$
From IC, L, I_D: $S_{VG} = 4kT\left(n\Gamma\left(\sqrt{IC+0.25}+0.5\right)\left(\frac{nU_T}{I_D}\right)\right)$ $= 4kT\,[(1/2)n^2U_T/I_D]$ in WI $= 4kT\,[(2/3)n^2U_T\sqrt{IC}/I_D]$ in SI without vel. sat. $= 4kT\,[(8/3)n^3U_T(U_T/(LE_{CRIT})')IC/I_D]$ in SI with full vel. sat. Convenient expression: $S_{VG} = \frac{(2.069\,\text{nV})^2}{\text{Hz}}\left(\frac{T}{300\text{K}}\right)^2 \cdot n^2\Gamma\left(\sqrt{IC+0.25}+0.5\right)\left(\frac{100\,\mu\text{A}}{I_D}\right)$ To include velocity saturation and VFMR decreases in g_m, replace IC with $IC(1+IC/IC_{CRIT})$ as described in Table 3.17	Constant in WI $\uparrow\propto\sqrt{IC}$ in SI if no vel. sat. $\uparrow\propto IC$ in SI with full vel. sat.	Unchanged, but decreases if less vel. sat. reduction of g_m/I_D $\downarrow\propto \frac{1}{L}$ in SI with full vel. sat.	$\downarrow\propto \frac{1}{I_D}$

S_{VG} is for saturation where $V_{DS} > V_{DS,sat}$.
Velocity saturation refers to both velocity saturation and VFMR effects.
Γ, given by Equation 3.106, increases from one-half in weak inversion to two-thirds in strong inversion, excluding small-geometry increases described in Section 3.10.2.2. IC and L trends exclude small-geometry increases in Γ.
Convenient expressions assume $k = 1.3806 \times 10^{-23}$ J/K.