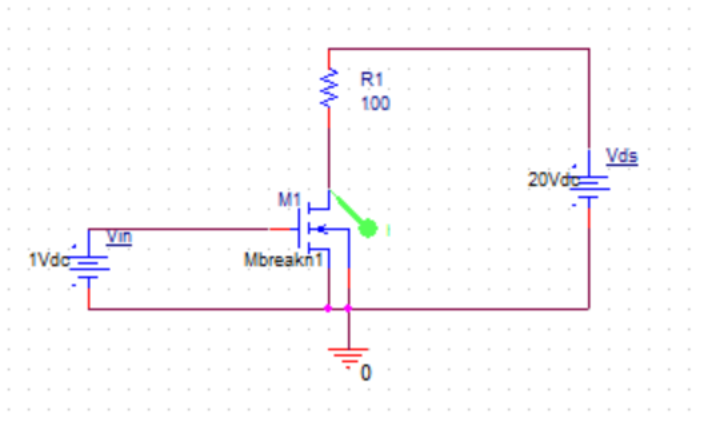

Figure 1: Common Source Amplifier with Passive Load

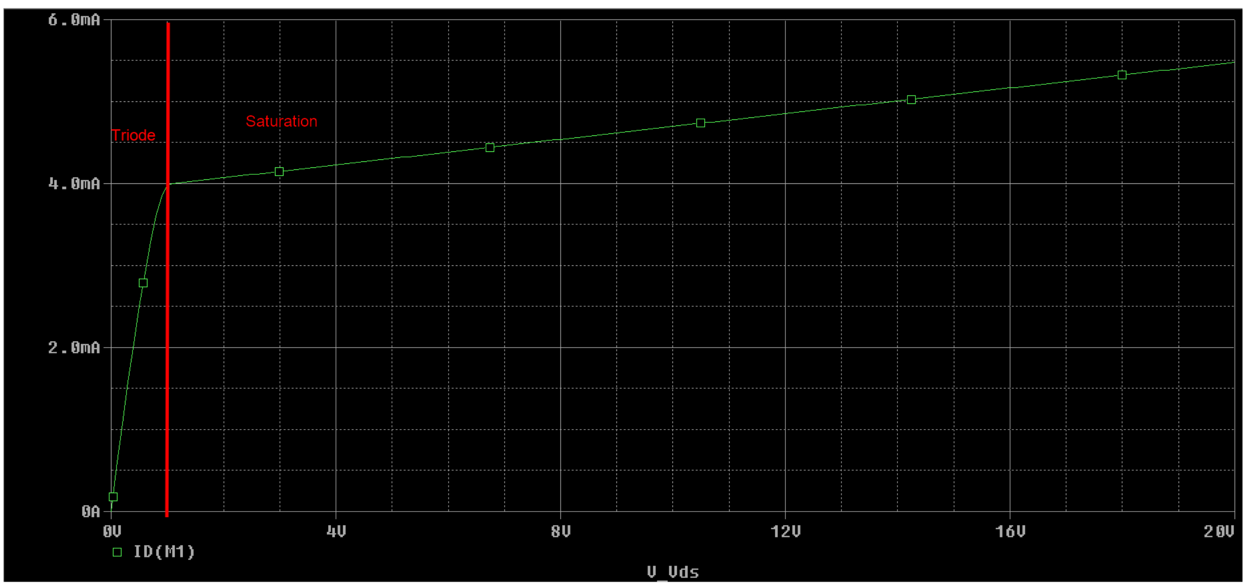

Figure 2: i_D versus V_{DS}

The curve in figure (2) is the expected i_D versus V_{DS} curve of an NMOS transistor with channel length modulation effects. From the diagram, $V_{GS} - V_T$ appears to be 1V since that is where the edge between triode and saturation occurs. The transistor operates in triode for $V_{DS} < V_{GS} - V_T = 1$V, and it operates in saturation for $V_{DS} > 1$V.

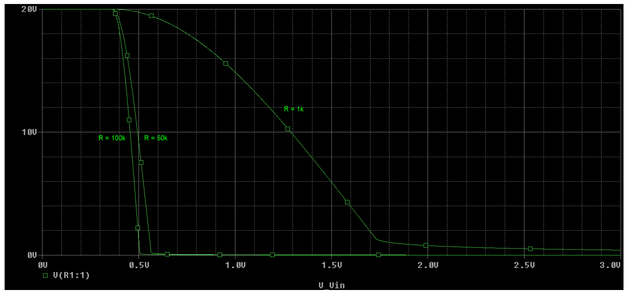

Figure 3: Voltage Transfer Characteristic

For low values of V_{in}, the transistor remains in cutoff. As a result, no voltage drops over the resistor since no current flows. Therefore, $V_{DS} = V_{out}$ is maximized at the supply voltage. As V_{in} is increased, the conductive channel forms and current can flow. However, assuming the current is a continuous function of V_{in}, it starts off at relatively small values, meaning that the voltage drop over the resistor is still small. Thus, the transistor's V_{DS} is still large and far exceeds V_{in}. As V_{in} increases, more current can flow, the resistor eats up more of the supply voltage, and V_{out} rapidly drops. For sufficiently large values of V_{in}, the transistor enters the triode regionsince V_{DS} becomes comparable in magnitude to V_{in}. At this point, the current no longer follows a linear relationship with V_{in}^2 and instead begins following a linear relationship with V_{in}. As a result, the resistor's voltage does not increase as rapidly and V_{out} therefore does not decrease as rapidly as they do in the saturation region.

Certain applications may call for other properties, but the common source amplifier should act as an inverter or a voltage amplifier. As an inverter, the steepest drop from the supply voltage to ground is desired. This occurs when $R = 100\text{k}\Omega$. As a voltage amplifier, high linearity and high small-signal voltage gain are desired. The linearity of the $R = 100\text{k}\Omega$ and $R = 50\text{k}\Omega$ are nearly the same and better than the $R = 1\text{k}\Omega$ curve. Voltage gain is defined as $A_v = \frac{dV_{out}}{dV_{in}}$. Thus, the largest $|A_v|$ occurs when the slope is steepest. The steepest slope occurs when $R = 100\text{k}\Omega$. So, overall, the best choice of resistor value is $R = 100\text{k}\Omega$.

When the common source amplifier is used for its voltage amplification characteristics, a bias current is typically used to tune the amplifier accordingly. The amplifier should operate near the middle of the saturation region. The small-signal gain magnitude is much higher in the saturation region than it is in the triode or cutoff regions. In the middle of the saturation region, the gain's magnitude $|\frac{dV_{out}}{dV_{in}}|$ is maximized. Furthermore, the transistor gets the maximum signal swing at the middle of the saturation region, making it operate over a wider range of input signal amplitudes.