Removing the constraints of C-MOS bilateral switches

by W. Chomik and A. J. Cousin
Department of Electrical Engineering, University of Toronto, Canada

Two major limitations imposed on the popular complementary-metal-oxide-semiconductor 4016 switch may be overcome with this circuit. As well as allowing the signal magnitude to exceed the power-supply voltage, it enables unipolar control signals to switch bipolar input signals. Only a second switch and an inverter need be added to a standard circuit to remove these operating constraints on the signal-handling gate.

Usually, the signal voltage to be passed through a single switch must be limited to between $V_{DD} + 0.7$ volt and $V_{SS} - 0.7$ v, where V_{DD} is the positive supply (drain) voltage and V_{SS} is the minus supply (source) voltage. Otherwise, the signal voltage will cause the forward biasing of the diode between the substrate and channel of one MOS field-effect transistor, and the gate may be destroyed.

This problem might arise if the power-supply value applied to some active element in a circuit happened to lie outside the voltage range that could be applied to the switch ($V_{DD} - V_{SS}$), dictating that the gate must be protected from input and control signals that saturate to the supply level.

Furthermore, many circuits, especially those containing operational amplifiers, use bipolar supplies. The resulting signals to be processed are likely to be bipolar as well. Yet the channel-voltage constraints inherent in the design of the 4016 (that is, the fact that the logic 0 control voltage, V_{SS}, must be at or below the most negative signal voltage, and the logic 1 control voltage, V_{DD}, must be at or above the most positive signal voltage) means that bipolar supplies and control signals must also be applied to the switch if these bipolar signals are to be passed. Unfortunately, too, many systems use digital control signals that are unipolar, and so logic-level shifters are needed also, to make this signal symmetrical with respect to ground.

With the addition of a second bilateral switch and an inverter to a standard op-amp circuit, as shown, the signal-handling switch can operate from a single power supply and be driven by unipolar logic at the control input in order to pass bipolar signals. Moreover, the signal can lie outside the $V_{DD} - V_{SS}$ limit of the switches.

The channel voltage of both switches is set by fixing their drain potentials at the virtual ground of the op amp or to circuit ground, depending on which switch is on. Because the virtual ground never strays from true ground by more than a few millivolts, the switches will be protected from burn out, as their channel-voltage limit will never be exceeded.

When switch A is on and switch B is off, node n will be essentially at ground potential. When B is on and A is off, the signal is removed from the op amp's input, but node n will still be at ground (through B), and the same channel-voltage conditions will prevail.

Note that the actual input voltage to the gate at node n will never drop more than a few millivolts below the minimum control voltage, even if the input signal is negative. Thus, the gate's channel-voltage constraint is always met. □

No limitations. Inverter and gate B enable switching of bipolar input signals by unipolar control signals at gate A and also allow magnitude of input to exceed gate's supply voltage. Node n is held near to ground at all times, so that channel-voltage limit of gate is never exceeded. Magnitude of signal at node n never exceeds control-signal potential, enabling gate to switch properly.