Chapter 10

BiCMOS Circuits

BiCMOS circuits consist of both bipolar junction transistors (BJTs) and MOSFETs on a single substrate. The existence of parasitic bipolar transistors in CMOS structures is well known; for example, latch-up and subthreshold current flow are commonly analyzed using bipolar models as discussed in Chapter 6. BiCMOS technology is different from the classical analysis in that the process flow is specifically designed to allow for both bipolar and MOS transistors. Combining technologies in this manner allows for circuits which have the "best of both worlds": fast switching due to bipolar transistors and low-power/high integration density of CMOS. This evolving field has generated much excitement in recent years.

Many different BiCMOS logic circuits have been discussed in the literature. The most common approach is to use MOSFETs to implement the logic and bipolar transistors to provide a fast, high-current output driver stage. This structuring can be seen in the generalized BiCMOS logic gate shown in Figure 10.1. The inputs are connected to MOSFETs through the logic blocks shown as $F$ and $\overline{F}$ in the drawing. The logic blocks are constructed using transistor switch arrays. Bipolar transistors $Q1$ and $Q2$ are connected in a non-inverting stack to drive the output capacitance. When $F = 1$, $Q1$ is turned on and provides charging current to $G_{out}$; the circuit specifics determine $V_{OH}$ for this case. If $F = 0$ so that $\overline{F} = 1$, $Q2$ obtains bias from the output node and conducts to ground. This drains charge off of $C_{out}$ and defines the value of $V_{OL}$. Two additional impedance devices ( $Z_1$ and $Z_2$ in the drawing) are included to provide a path to remove base charge when the bipolar transistors are switching off. These are used to increase the switching speed. Either passive resistors or active loads may be used for this purpose.

The intent of this chapter is to introduce the basic properties of BiCMOS
logic circuits. Bipolar junction transistors are characterized first, and then specific circuits are presented as examples. Alvarez [2] provides thorough discussions of many important topics in BiCMOS.

10.1 Bipolar Junction Transistors

Bipolar junction transistors are three terminal devices formed by layering alternate n-type and p-type regions. This gives two basic BJT types, namely, the npn and the pnp. Although the current flow is due to both positive and negative charges (hence, bipolar), npn transistors are dominated by electron currents, while pnp transistors depend primarily on holes. The npn transistor will be analyzed in this section; the behavior of a pnp is the complement of the npn.

10.1.1 Structure and Operation

Figure 9.1 shows the cross-section for an integrated npn BJT. The terminals are termed the emitter, the base, and the collector, corresponding to the respective n⁺-p-n sections. Current flow through the npn transistor relies on the motion of electrons from the emitter n⁺-region to the collector n-type layer as controlled by the p-type base.

The three voltages are $V_{BE}$, $V_{BC}$ and $V_{CE}$, two of which are independent. For the purposes of analysis, $V_{BE}$ and $V_{BC}$ are chosen as the variables. Similarly, the collector current $I_C$ and the emitter current $I_E$ are assumed to be the independent quantities such that the base current is given by