High Speed Op Amps

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Introduction

High speed analog signal processing applications, such as video and communications, require op amps that have wide bandwidth, fast settling time, low distortion and noise, high output current, good dc performance, and operate at low supply voltages. These devices are widely used as gain blocks, cable drivers, ADC preamps, current-to-voltage converters, and so forth. Achieving higher bandwidths for less power is extremely critical in today's portable and battery-operated communications equipment. The rapid progress made over the last few years in high speed linear circuits has hinged not only on the development of IC processes but also on innovative circuit topologies.

The evolution of high speed processes using amplifier bandwidth as a function of supply current as a figure of merit is shown in Figure 1-96. (In the case of duals, triples, and quads, the current per amplifier is used.) Analog Devices BiFET process, which produced the AD712 (3 MHz bandwidth, 3 mA current) yields about 1 MHz per mA.

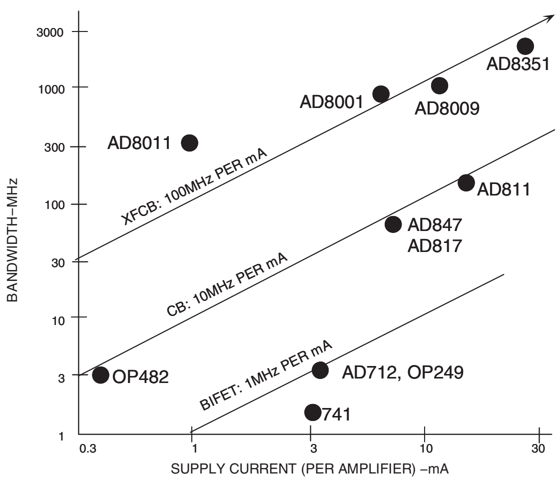


Figure 1-96: Amplifier bandwidth versus supply current for Analog Devices' processes

The CB (Complementary Bipolar) process (AD817, AD847, AD811, and so forth) yields about 10 MHz/mA of supply current. The f_ts of the CB process PNP transistors are about 700 MHz, and the NPNs about 900 MHz. The CB process at Analog Devices was introduced in 1985.

The next complementary bipolar process from Analog Devices was a high speed dielectrically isolated process called "XFCB" (eXtra Fast Complementary Bipolar) which was introduced in 1992. This process yields 3 GHz PNPs and 5 GHz matching NPNs, and coupled with innovative circuit topologies allows op amps to achieve new levels of cost-effective performance at astonishing low quiescent currents. The approximate figure of merit for this process is typically 100 MHz/mA, although the AD8011 op amp is capable of 300 MHz bandwidth on 1 mA of supply current due to its unique two-stage current-feedback architecture described later in this section.

Even faster CB processes have been developed at Analog Devices for low voltage supply products such as "XFCB 1.5" (5 GHz PNP, 9 GHz NPN), and "XFCB 2" (9 GHZ PNP, 16 GHz NPN). The AD8351 differential low distortion RF amplifier (shown on Figure 1-96) is fabricated on "XFCB 1.5" and has a bandwidth of 2 GHz for a gain of 12 dB. It is expected that newer complementary bipolar processes will be optimized for higher f_ts.

In order to select intelligently the correct high speed op amp for a given application, an understanding of the various op amp topologies as well as the trade-offs between them is required. The two most widely used topologies are voltage feedback (VFB) and current feedback (CFB). An overview of these topologies has been presented in a previous section, but the following discussion treats the frequency-related aspects of the two topologies in considerably more detail.

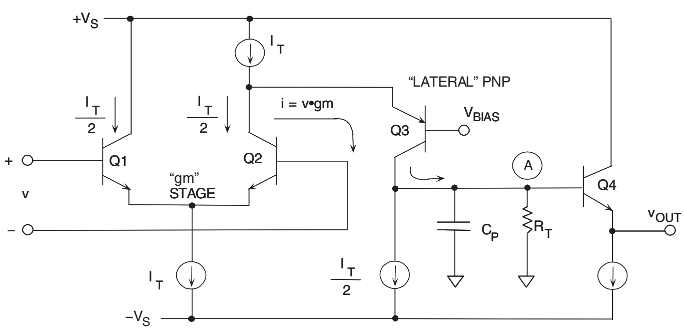
Voltage Feedback (VFB) Op Amps

A voltage feedback (VFB) op amp is distinguished from a current feedback (CFB) op amp by circuit topology. The VFB op amp is certainly the most popular in low frequency applications, but the CFB op amp has some advantages at high frequencies. We will discuss CFB in detail later, but first the more traditional VFB architecture.

Early IC voltage feedback op amps were made on "all NPN" processes. These processes were optimized for NPN transistors—the "lateral" PNP transistors had relatively poor performance. Some examples of these early VFB op amps using these poor quality PNPs include the 709, the LM101 and the 741 (see Chapter 8: "Op Amp History").

Lateral PNPs were generally used only as current sources, level shifters, or for other noncritical functions. A simplified diagram of a typical VFB op amp manufactur ed on such a process is shown in Figure 1-97.

The input stage is a differential pair (sometimes called a *long-tailed pair*) consisting of either a bipolar pair (Q1, Q2) or a FET pair. This "g_m" (transconductance) stage converts the small-signal differential input



$$gm = I_C \bullet \frac{q}{kT} \qquad v_{OUT} = \frac{i}{j\omega C_P} = v \bullet \frac{gm}{j\omega C_P} \text{ @ HF}$$

Figure 1-97: Voltage feedback (VFB) op amp designed on an "all NPN" IC process