SECTION I
INTRODUCTION

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Over the last 25 years, the IC op amp has evolved into a large array of both general purpose and application-specific devices. Although Analog Devices has an amplifier to fit almost any application, the task of selecting the correct amplifier is frequently difficult. The material in this seminar is arranged to highlight a number of specific and different op amp applications in a manner which combines theory with practice. By examining these actual real world state-of-the-art applications, the user will gain insight which will be invaluable in designing systems requiring amplifiers.

The concept of using an op amp as a universal analog computing element predates the integrated circuit by a number of years. Philbrick and others realized the usefulness of the op amp building block approach to analog computing. The three fundamental analog computing functions of integration, differentiation, and multiplication (gain) are easily realized using op amps with passive feedback. Op amps made with vacuum tubes were used with some popularity in large analog computing mainframes. The advent of the planar IC process brought with it the same move to integration for analog functions as for digital functions.

The first truly successful IC op amp was the µA709 introduced more than 25 years ago. It was followed by the internally compensated µA741 and the LM101. These early products marked the beginning of the IC op amp era. Analog Devices and many others have manufactured all of these early devices. The µA741 and the LM101 are still commonly used today. It was also during these early days that the first IC instrumentation amplifier was introduced, the AD520. Analog Devices has continued to maintain a leadership position in instrumentation amplifiers with the industry standard AD524 family and more recently with the AD620 and AD621.

IC designers soon realized that the inherent matching of devices on the same die could be exploited to produce precision amplifiers. This led to the earliest high precision op amps, the OP-07 and the OP-27. These products, however, achieved only modest ac performance. The basic µA741 circuit in BiFET (Bipolar/FET) technology added an improvement in speed at the expense of dc performance.

Analog Devices has been successful in narrowing the performance gap between FET and Bipolar technology by pioneering laser trim technology to provide less than 1µV/°C drift in general purpose BiFET and electrometer amplifiers. The AD549 and AD645 have under one picoampere input bias current and are fabricated on a junction isolated process.

Around 1971, dielectrically-isolated complementary-bipolar processes became available to serve the high speed market. The inherent expense and manufacturing difficulty associated with this process prevented it from becoming universally accepted by IC manufactures of high speed products. Junction isolated complementary-bipolar processes, including Analog Devices' proprietary CB process, have brought both low cost and high performance to high speed amplifiers. A large number of products designed using this technology will be discussed in this seminar, including some recent additions such as the low-power high speed quad OP-467 and the first attempt to combine high speed with true dc precision, the AD797.

THE EVOLUTION OF IC OP AMPS

- Vacuum Tubes
- Analog Computers (Philbrick)
- Planar IC Process
- μA709, μA741, LM101 Op Amps
- Instrumentation Amplifiers: AD520 → AD524 Family → AD620, AD621
- Precision Op Amps: OP-07, OP-27
- Low Bias Current Bipolar/FET Processes (BiFET): AD549 → AD645
- Low Power, Single Supply: OP-90, OP-290, OP-295, OP-490
- High Speed Complementary Bipolar Processes → AD840-Series, OP-467 (Quad), AD797

Figure 1.1

The trends toward higher speeds and greater levels of integration have significantly reduced the role of discrete logic gates in large digital system designs. In this age of Large Scale Integration (LSI) and Very Large Scale Integration (VLSI), one might indeed question the reason for the continued existence and proliferation of more and more varieties of discrete IC amplifiers. The answer lies in the variety of signals which comprise the world of analog signal processing and the increased accuracy requirements placed on both precision and high speed measurements.

For example, accurate measurements in weigh-scale bridges require amplifier accuracies of less than 1mV at impedance levels of hundreds of ohms. Detecting picoamperes of photodiode current or measuring the output of high impedance charge amplifiers requires extremely low bias current and low noise amplifiers. Accurate reproduction of wide bandwidth High Definition Television (HDTV) signals requires that differential gain and phase errors are minimal and that the bandwidth remains flat within 0.1dB up to 30MHz.

Because the amplifier is a fundamental front-end signal conditioning element in most real world signal processing applications, its performance should exceed that of the overall system. It is the exploitation of opportunities for increased system performance in a wide variety of real world signal processing applications that explains the continued popularity of the IC amplifier as a fundamental analog building block.

Offset voltage, bias current, and noise are the basic performance limitations in precision dc applications. Figure 1.2 groups a variety of amplifiers as a function of input bias current and input voltage noise. Figure 1.3 is a technology grouping as a function of input bias current and input offset voltage. Both of these figures show Analog Devices' position at the forefront of amplifier technology. Super-Beta technology fits into the technology profile well in terms of dc precision and low noise, and has allowed an expansion of instrumentation amplifier offerings. The AD620 and AD621 are products which bring new levels of performance and functionality to this exacting market.

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AMPLIFIER GROUPING: INPUT BIAS CURRENT, INPUT VOLTAGE NOISE

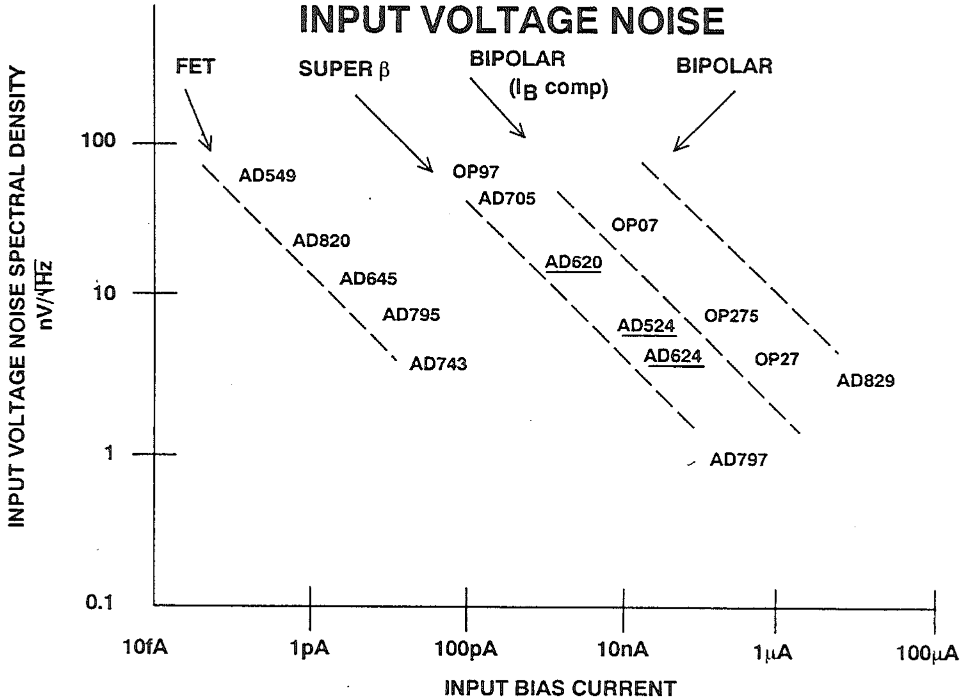

Figure 1.2

AMPLIFIER GROUPING: INPUT BIAS CURRENT, INPUT OFFSET VOLTAGE

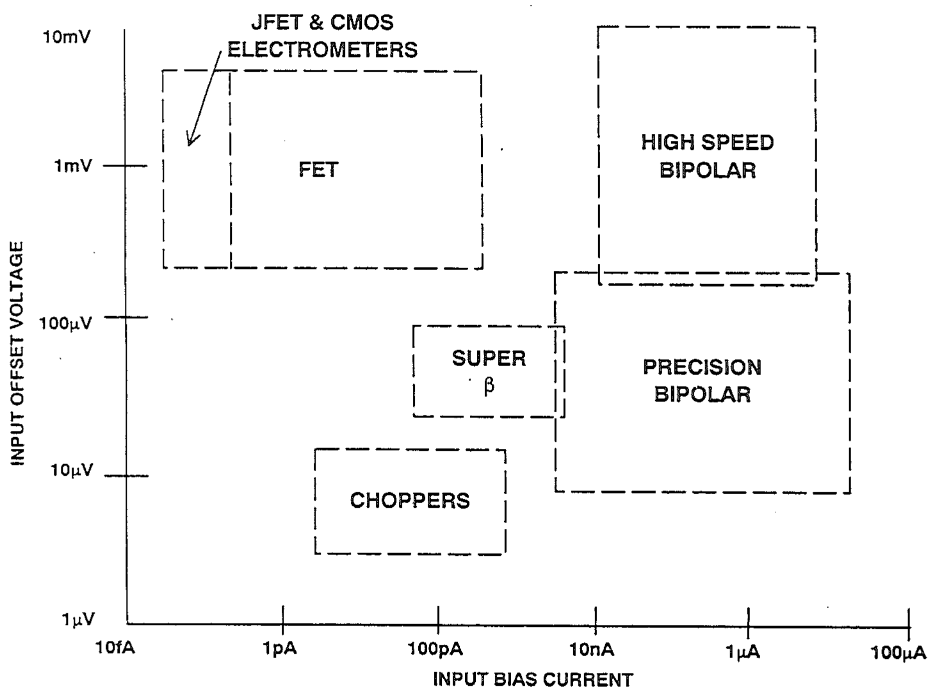

Figure 1.3

The high speed market has recently been the largest driver of amplifier process technology. Because digital techniques are almost universally used in these applications, it is useful to group the requirements in terms of ADC sampling rate and resolution as shown in Figure 1.4. The corresponding implementation of these requirements as a function of process is shown in Figure 1.5, and actual amplifier product offerings in Figure 1.6. The AD9620, AD9630, AD811, and AD797 all stand at the forefront of high speed technology.

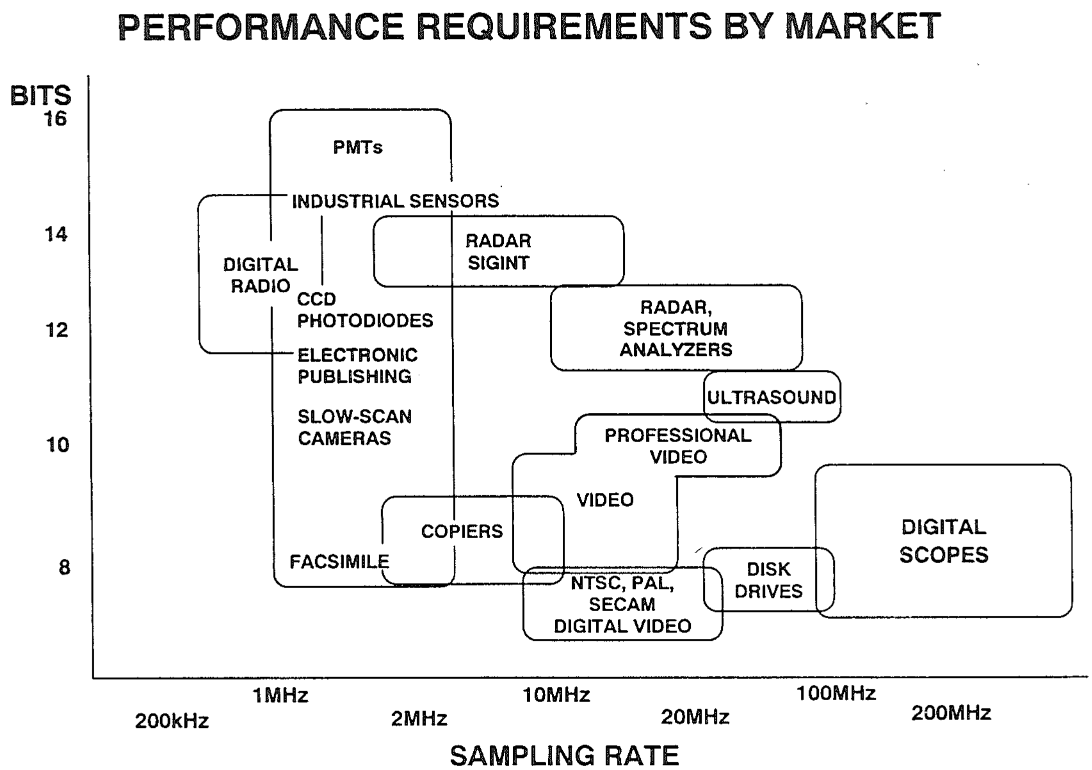

Figure 1.4

PROCESS CAPABILITIES AND DIRECTION BY MARKET

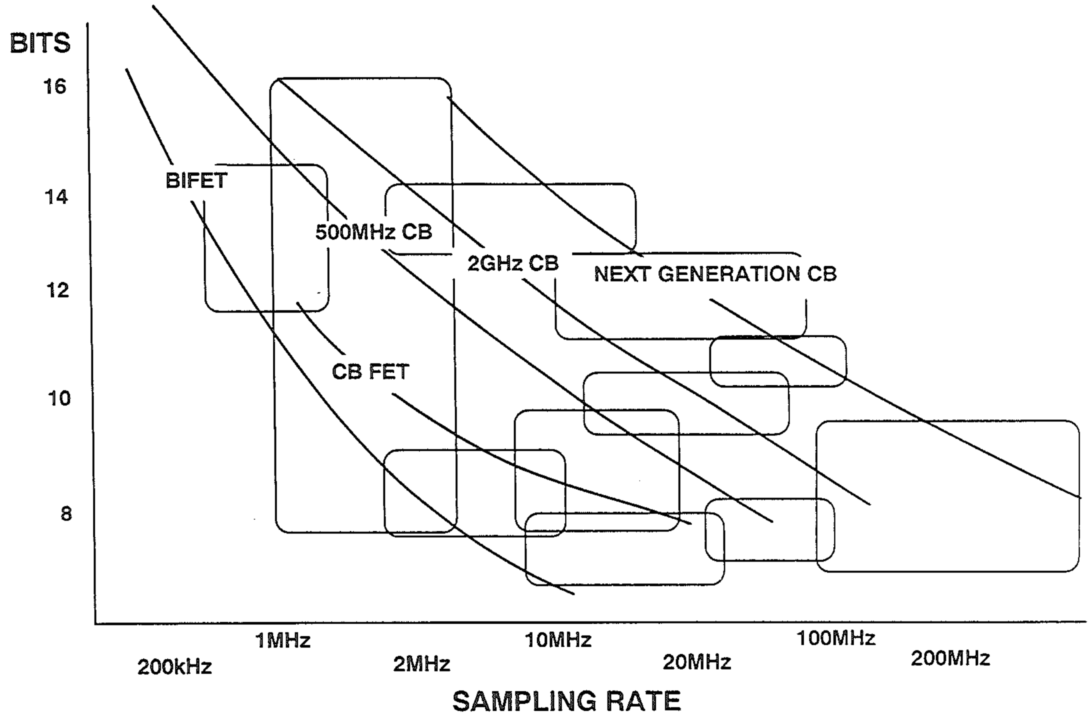

Figure 1.5

AMPLIFIERS BY MARKET

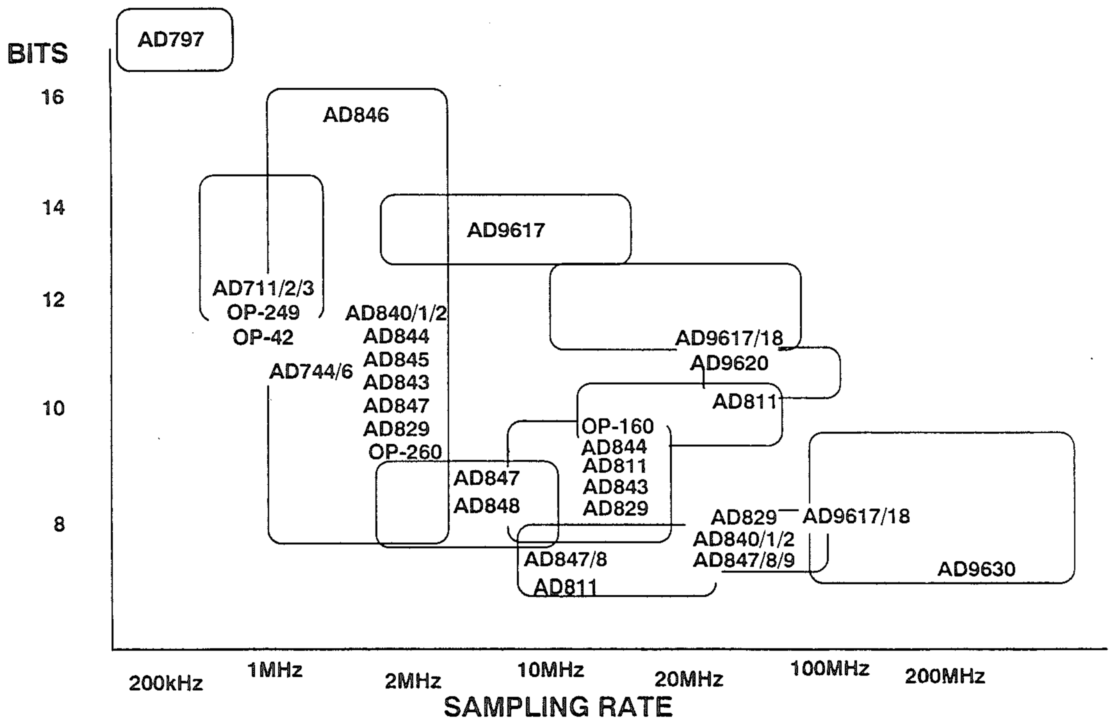

Figure 1.6

Not all amplifiers with fast settling times and wide bandwidths have adequate performance in other ac specifications such as harmonic distortion, spurious free dynamic range, and differential gain and phase. AC dynamic range, usually measured in terms of harmonic distortion or total harmonic distortion, has become an increasingly important amplifier performance indicator. Figure 1.7 shows distortion versus frequency for a variety of state-of-the-art amplifiers. The AD9620, AD9630, AD811, and AD797 again stand out in this area.

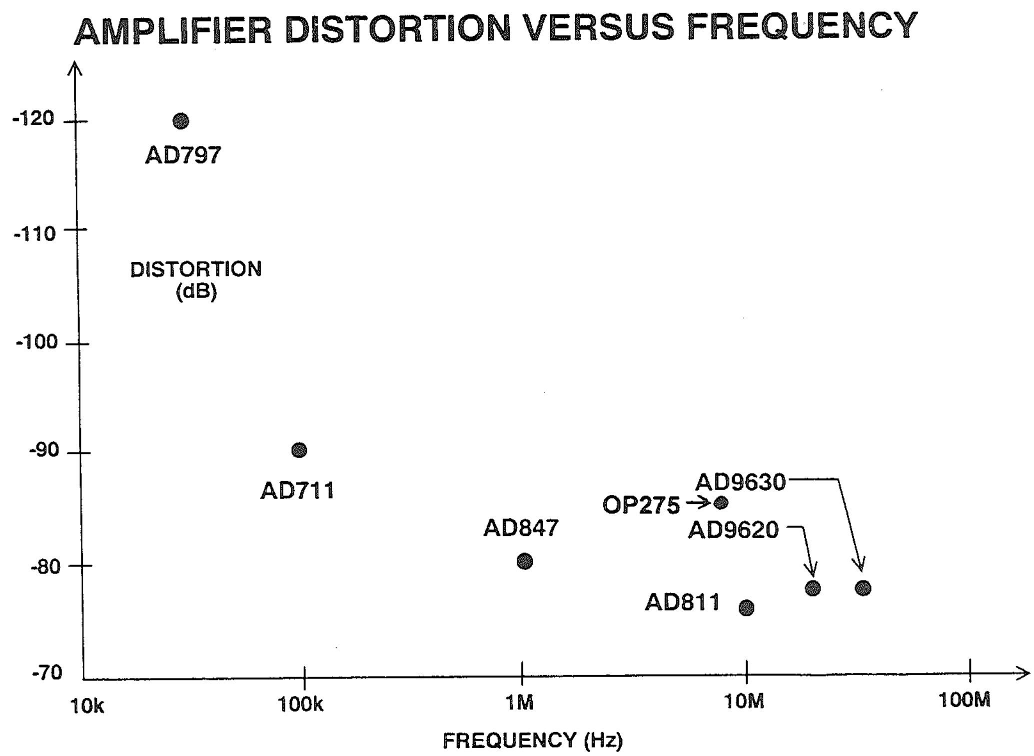

Figure 1.7