HIGH SPEED TECHNIQUES
OPTIMIZING FOR SPEED

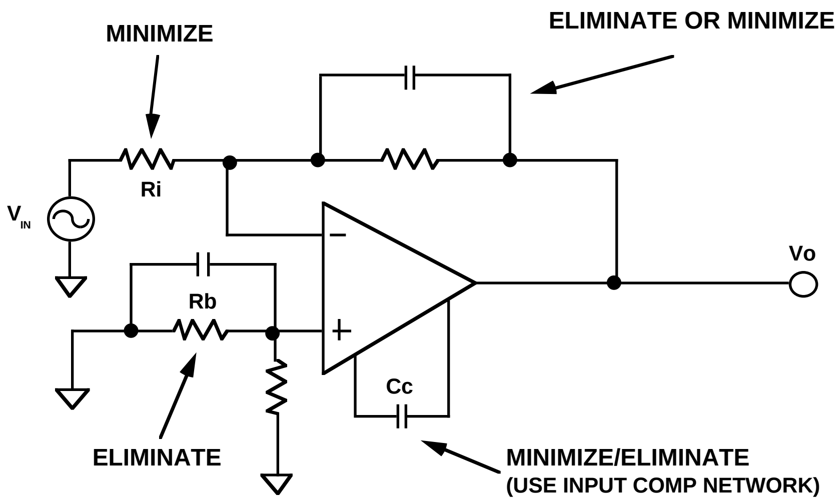
- Minimize Impedances
- Minimize Compensation Capacitance
- Minimize Integration Capacitance (Cf)
- Optimize Small Signal and Large Signal Bandwidths
- Trade-off:
  – Slew Rate
  – Settling Time

Maximum high speed performance with stability are achieved through the use of good high speed techniques and an understanding of the trade-off involved between the various high speed requirements. For instance, small signal and large signal bandwidth requirements are not directly related and the designer mus understand the trade-off between them.

Also, some high speed characteristics have conflicting requirements such as settling time and slew rate.

HIGH SPEED TECHNIQUES

GOOD GENERAL PRACTICES



The basic idea of this "Input Speed-up Network" is to provide a path for the higher frequency components of a step input to overdrive the input of the amplifier to get the output slewing on its way up to a final value. At high frequencies the capacitor CI is a short and the input drives the +input unattenuated. At low frequencies, such as the flat part of a step input, the resistor divider attenuates the signal to achieve the desired final gain for V_O/V_{IN}.

Other ways to maximize high speed performance are to decrease the compensation capacitor Cc to maximize slew rate and to provide large enough drive input signal to cause at least a 1V-2V differential signal at the op amp input. If the amplifier is decompensated for slew rate Noise Gain Compensation may need to be utilized for AC stability. Most amplifier slew rates are specified using a 1V-2V input differential drive voltage into the amplifier. Adequate input signal amplitude will maximize slewing of the output.

Finally, for good settling time, a feedback capacitor, CF can compensate for stray input capacitance as well as provide a path for output voltages to feedback during slew rate limiting to help overdrive the front end of the amplifier.

SLEW RATE AND PBW

$$\text{S.R.} = \left[\frac{\Delta V_{OUT}}{\Delta t} \right]_{max} \quad [\text{ V}/\mu\text{s}]$$

FOR PBW, SET:

$$\text{S.R.} = \frac{dV}{dt} (V_p \sin 2\pi f_t)_{max} \quad [\text{ SINUSOIDS }]$$

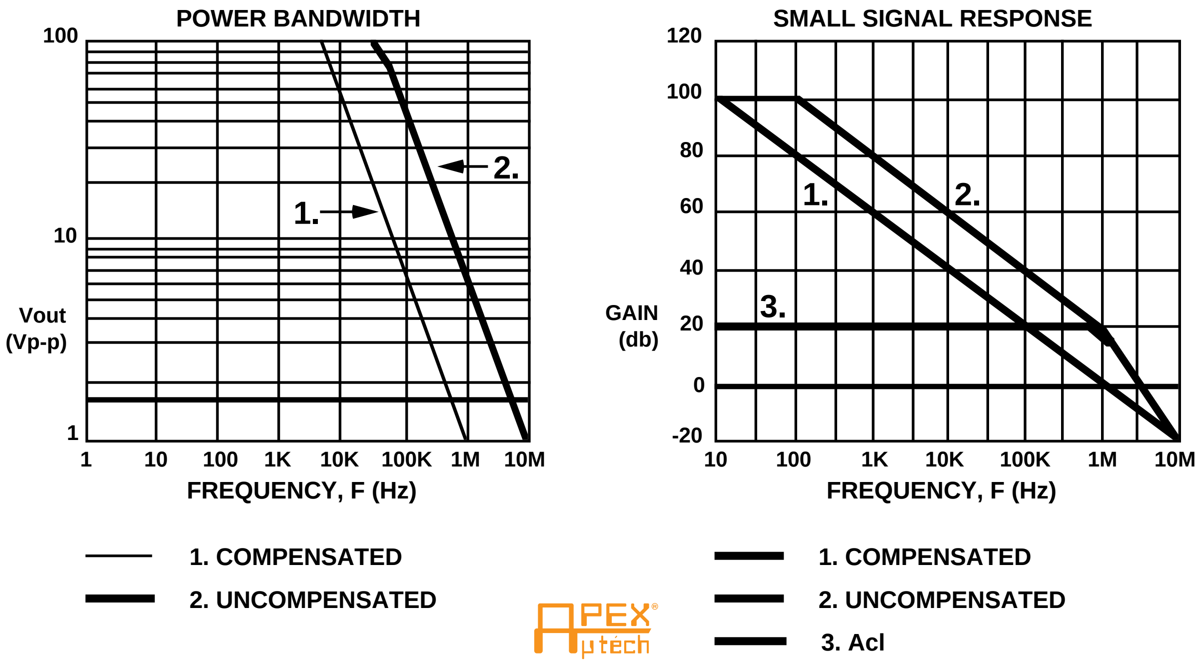
$$\text{S.R.} = 2\pi\,(\text{PBW})\,V_p \; [\text{ SINUSOIDS }]$$

$$\text{PBW} = \frac{SR}{2\pi V_p}$$

Op amps have a maximum rate of change of output voltage that is directly related to the input stage current and the compensation capacitance. The maximum dV/dt of a sine wave occurs as the output passes through zero. Setting the dV/dt max of the amplifier equal to the dV/dt of a sine wave gives a relationship between slew rate and full power bandwidth. The simplicity of this relationship is often complicated by the common practice of specifying slew rates under conditions of extreme overdrive. This overdrive results in operation deep within the non-linear region with apparent slew rates up to several times higher than the slew rate derived from the full power bandwidth formula above.

Full power bandwidth is a “large signal” parameter. It is not directly related to small signal bandwidth.

OPTIMIZE PBW AND SSBW



The trade offs between small signal performance and large signal performance are often misunderstood or misinterpreted. It helps to understand the differences between the two bandwidths.

On the right are the small signal response curves of a typical high speed amplifier with both uncompensated and compensated Aol curves shown. On the left is the large signal or “full power” response curve shown for both compensated and uncompensated conditions.

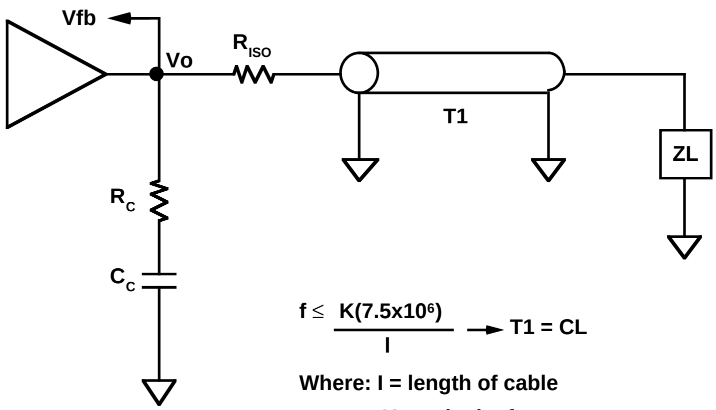
Note that the maximum useful small signal bandwidth of the amplifier is approximately 1MHz with or without compensation. The unity gain amplifier has a maximum bandwidth at unity gain of 1MHz, the uncompensated amplifier has more bandwidth but must be run at higher gains. Therefore its useful bandwidth is also limited to about 1MHz. The full power response curve may extend on up to 10MHz for low amplitude signals, however this power response is not achievable due to small signal bandwidth limits.

The best approach is to start with your maximum peak to peak output voltage requirements for sinusoids and find that peak to peak value on the Full Power Response Graph. Find the intersection of this line with the maximum output frequency required on the horizontal graph. The intersection of these two points will determine the maximum allowable compensation.

Consult the small signal response curve. For the compensation value chosen, find the minimum allowable closed loop gain. the intersection of Acl (min), with the AOL curve for that particular compensation value, gives the maximum useful small signal bandwidth.

Choosing the lowest possible compensation value combined with the lowest possible stable gain gives the maximum full power and small signal bandwidth combination.

CABLE LOADS



$$f \leq \frac{K(7.5\times10^{6})}{l} \longrightarrow T1 = CL$$

Where: l = length of cable

K = velocity factor

Beware of coaxial cables which can appear capacitive. A coaxial cable appears capacitive, instead of its desired transmission line impedance, resistive, if the length of the cable is one-fortieth of the wavelength at the frequency of interest, f. This length, l, is given by:

$$l \leq \frac{1}{40} \quad \frac{Kc}{f} \quad \text{(meters)}$$

where K is a propagation constant that is sometimes called the velocity factor (0.66 for coaxial cable) and c is the velocity of light (3×10^{8} m/s)

EXAMPLE: If f = 10KHz

$$l \leq \frac{1}{40} \quad \frac{(0.66)\ (3 \times 10^{8})}{10^{4}} \quad = 495 \text{ meters (1624 feet)}$$

Cables less than 495 meters will appear capacitive for 10KHz signals at the rate of 95 pF/meter (29 pF/foot) for RG-58A/U, a commonly used coaxial cable.

You may find that Rc, Cc, and Riso will be required for stability, especially if ZL is capacitive.

NOTE: Cable capacitance formulae from—Frederiksen, Thomas M., INTUITIVE IC OP AMPS, R.R. Donnelley & Sons, 1984—an excellent “must-have” reference for anyone using op amps of any form.