High-Speed Op Amps For Video Drivers

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This article examines the video applications in which high-speed op amps can be found. An overview of the main consumer video applications is presented, along with a review of analog video formats and bandwidth versus resolution. We then look at some application implementation questions.

Video Applications

There are, currently, two types of video applications: broadcast and graphics. Broadcast video is limited to television signal transmission with specified bandwidth (television, set-top-box [STB], DVD player/recorder, video camera, etc). On the other hand, graphics video meets the needs of computers without bandwidth limitations. This article is mainly concerned with broadcast video applications.

Where Do We Need High-Speed Op Amps?

An amplifier stage is needed to drive analog video signals to a television via a 75-Ω video line. The applications concerned are mostly consumer applications such as set top boxes, DVD players/recorders and video cameras. In these applications, the output capabilities of the amplifier (output current and distortion versus load) are very important, as it must drive a video line characterized by low impedance (75 Ω for video lines).

Televisions also require high-speed op amps to ensure good impedance matching between the video line and the input stage in the TV. The amplifier drives the video signal to the input stage of a chipset, which features high impedance (on the order of several kΩ in parallel with a capacitance on the order of a few pF). In this situation the driver must maintain high stability even under capacitive loads. Set-top boxes can also feature an analog video input under the same constraints. The choice of the video source is selected in the set-top box and could be from a DVD or a video camera, for example.

The amplifier can be very specific, including features such as buffer+filtering or even a video matrix or, linked to market trends, it can be embedded in the chipset.

On the other hand, the amplifier stage can also be a discrete solution using transistors or high-speed op amps. Where the customer’s goals are speed and real estate high-speed op amps provide advantages compared to a transistor solution. For this reason, there is currently a market for the high-speed op amps in broadcast video applications.

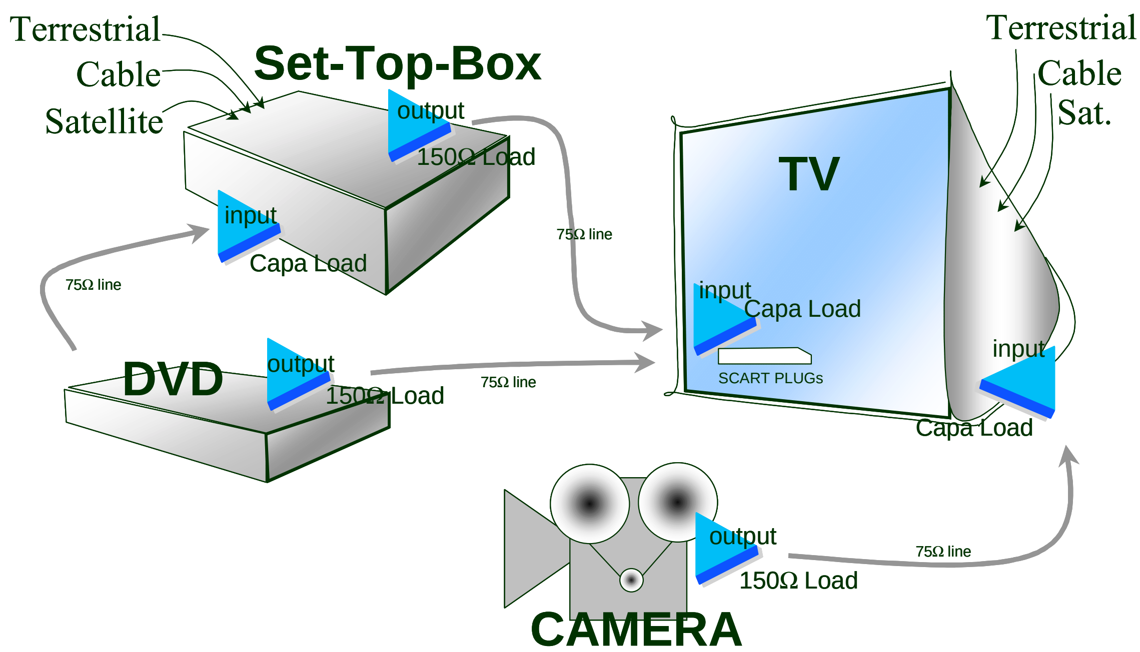

Fig. 1: Location Of Op Amps In Video Applications

Analog Video Formats

The format of the analog video signal is very important in order to evaluate the frequency and amplitude constraints of the high-speed op amp. There are three main divisions of signal format, each giving a different quality of television image.

The first type of signal format is comprised of three separate signals based on the R,G and B signals (RGB, although the broadcast video industry uses GBR because the connection used by the G channel corresponds on most equipment to the luminance channel in other standards). This signal form is the "purest" video signal, providing the highest quality image. The three R, B and G signals have identical bandwidth which is directly linked to the video resolution. In standard video broadcast, we commonly use YIQ, YUV or YPbPr, where Y is the Luminance and the other signals represent blue and red color-difference signals. All these systems use three channels, although a fourth may be needed for separate synchronizing (sync) information.

The second type of signal format is based on two signal channels such as Luminance-Chrominance (Y/C, or S-Video), where C is the Chrominance: the subcarrier modulation from NTSC, PAL and SECAM video standards.

The third type of signal format is composite video (CVBS). The aim of this signal format is to combine all the video components into only one signal channel. CVBS is the sum of Y and C and represents the lowest quality format.

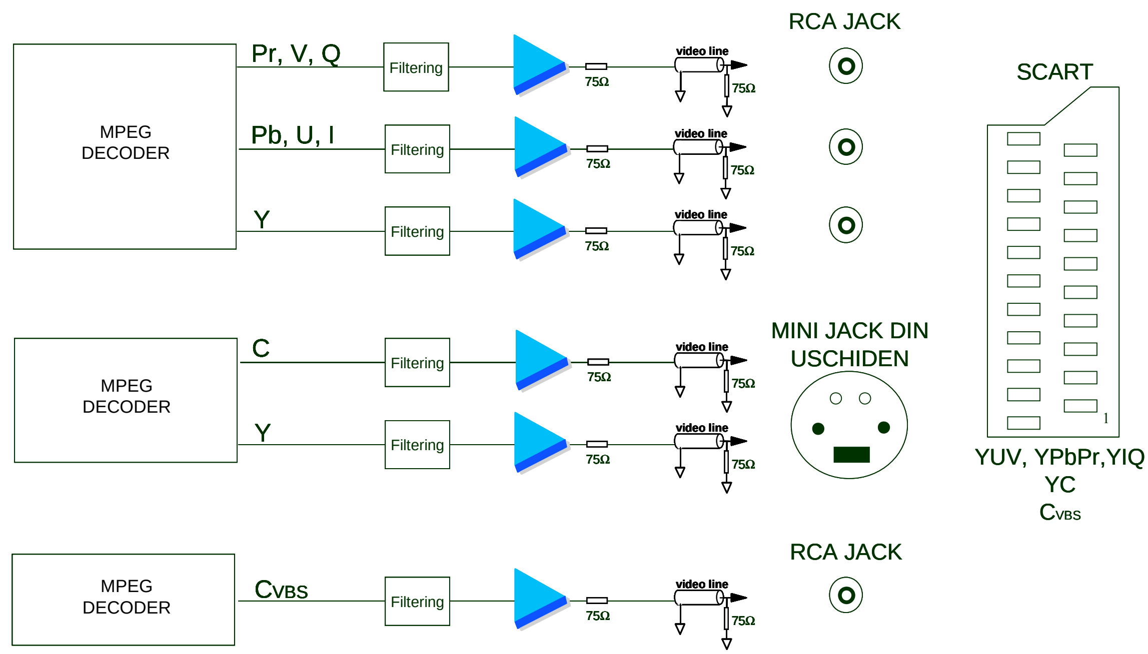

Fig. 2: Video Formats And Standard Connectors

Video Signal Bandwidth Versus Resolution

Standard Definition (SD):

Video signal used in standard interlaced video with a North American TV screen of 720*480 pixels (type: 480I). The bandwidth is up to 6 MHz.

Fig. 3: Video Spectrum For Standard Definition Video

Progressive Video (PV):

The image is not interlaced. The aim is to increase its display quality. The bandwidth of this signal is twice the standard definition bandwidth, at 12MHz. Such a signal fits with progressive TVs, which in North America is 720*480 pixels (type: 480P) and it in increasingly common in DVD players. However, because of competition with 100 Hz TVs, this format is not popular in Europe yet.

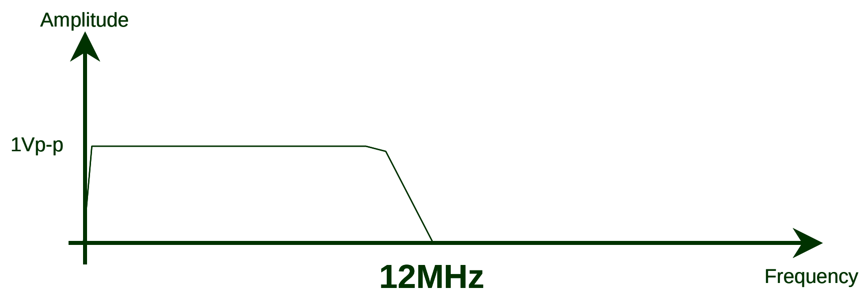

Fig. 4: Video Spectrum For Progressive Video

High Definition (HDTV):

The goal is to improve the definition of the image by increasing the quantity of lines and pixels per line. The bandwidth of the video signal is up to 30 MHz and the signal fits with TV screens of progressive 1280*1920 pixels (type: 1280P, a display standard, not broadcast), progressive 1280*720 (720P) and interlaced 1920*1080 pixels (1080I). HDTV is now popular in the USA, and is starting to become so in Asia and Europe.

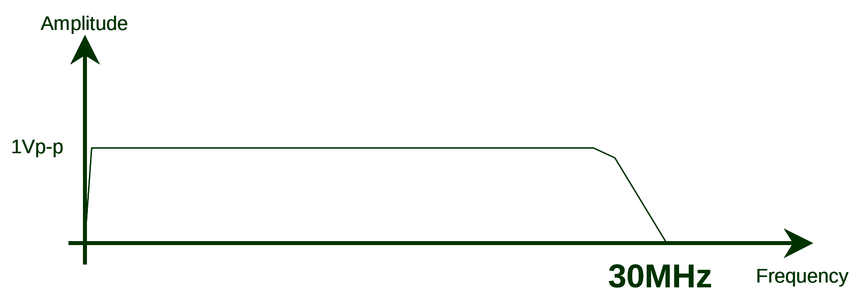

Fig. 5: Video Spectrum For HDTV

Signal Amplitude

Fig. 6 shows the typical amplitude of a video signal including synchronization, black level (as amplitude reference 300 mV), white level (luminance) and color (chrominance). {The amplitudes in Fig. 6 are correct for 625-line video; in 525-line video the 1-V span is divided into 140 IRE -- Institute of Radio Engineers -- units where sync goes from 0 IRE to -40 IRE and the active video extends to 100 IRE. There is also a "set-up" of 7.5 IRE from 0 IRE to offset black by that amount.}

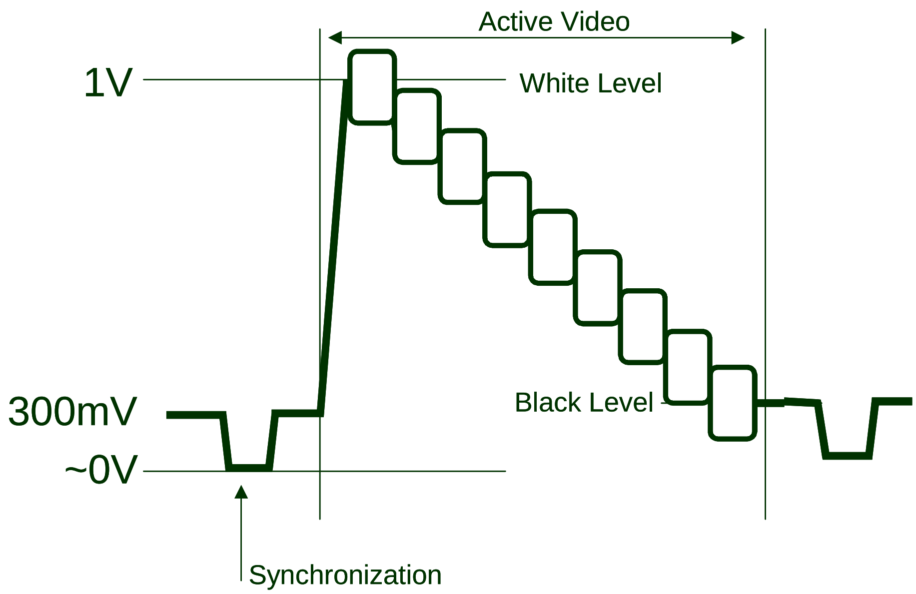

Fig. 6: Video Signal Amplitudes, Including Luminance And Chrominance

Impedance Matching

We can summarize the constraints met when driving a signal on a line (these are constraints that can be found in any textbook on the theory of line transmission):

> In order to remove any reflection factors*, the line must be loaded on both ends by its own characteristic impedance: typically 75 Ω for video lines. We call this impedance matching because the impedance is equivalent at any point in a given line. As the output impedance of the op amp is close to zero, a resistor of 75 Ω is physically implemented on the board to achieve the right value for matching. A second resistor of 75 Ω (TV side) allows matching on the other end.

As shown in Fig. 7, the network behaves like a resistor divider for the signal amplitude. Because of this, half of the output amplitude of the op amp is lost. As the input amplitude of the op amp must be the same as the amplitude required on the line (typically 1 Vp-p in video), a gain of +2 (6 dB) is required from the op amp.

The value of R must be as small as possible to reduce noise and the problems of stability (assuming stray capacitances mainly on the inverting input), but not too small as the 2R network is viewed as a load by the op amp output. For a VFA the value of R is not imposed but 1 kΩ is a good choice and it satisfies the previous requirements. For a CFA, the value of R is imposed and can be found in the relevant data sheet.

*Reflection factor: $\Gamma = \frac{Zload - Zc}{Zload + Zc} = 0$, when the line is loaded by the same value as its own characteristic impedance Zc.

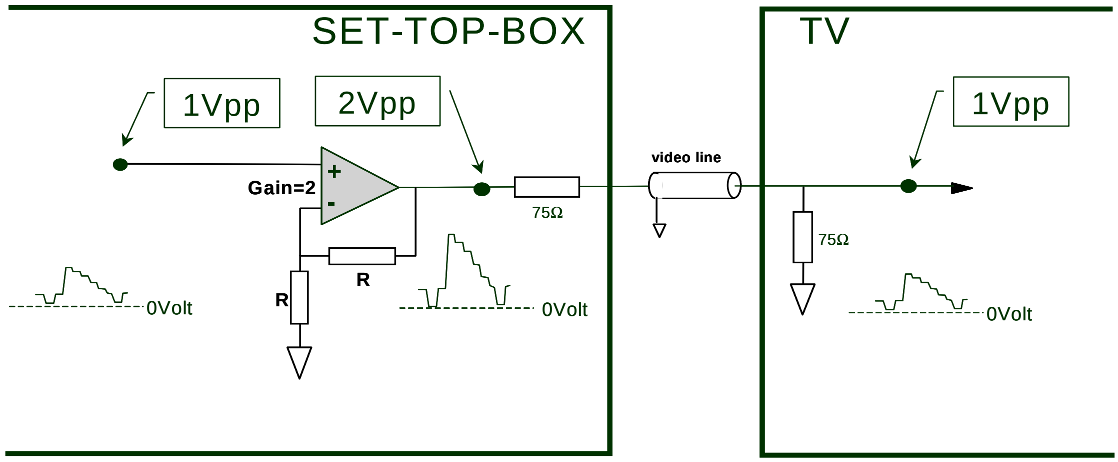

Fig. 7: Typical Connection Between Set-Top Box And TV

Power Supply

A constraint on every designer is to reduce the cost of his application. Split rail supplies of –5 V/+5 V require an investment in a negative supply. One solution is to reduce the supply to a single 0/+5 V. As described in Fig. 6, the synchronization signal extends to 0 V and the best solution is to use an input/output rail-to-rail op amp. Assuming the tested value of the output rail is VOL=150 mV max, the minimum amplitude of the signal guaranteed on the line is 75 mV, which would be the worst clipping of the sync pulse (see Fig. 8)

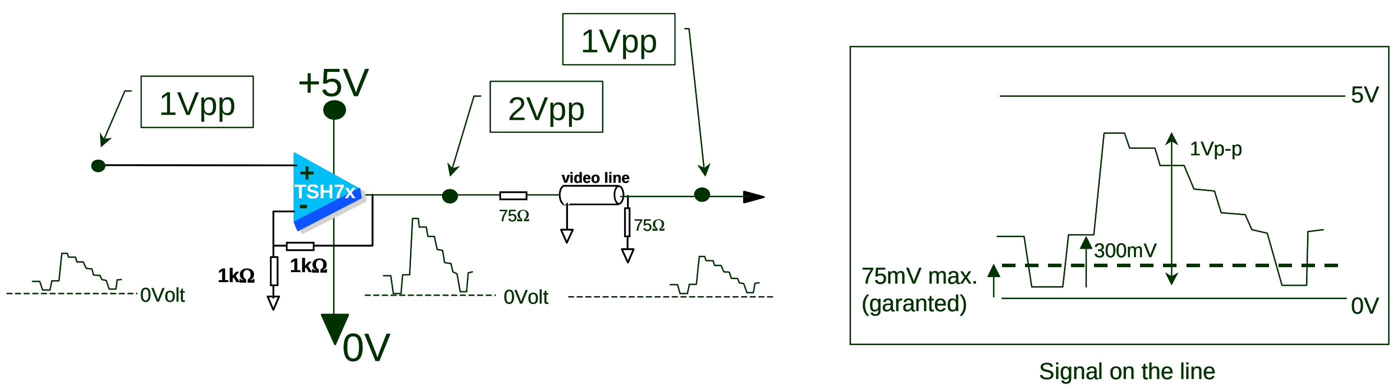

Fig. 8: Implementation Of Single Rail Supply with TSH7x-8x Op Amp

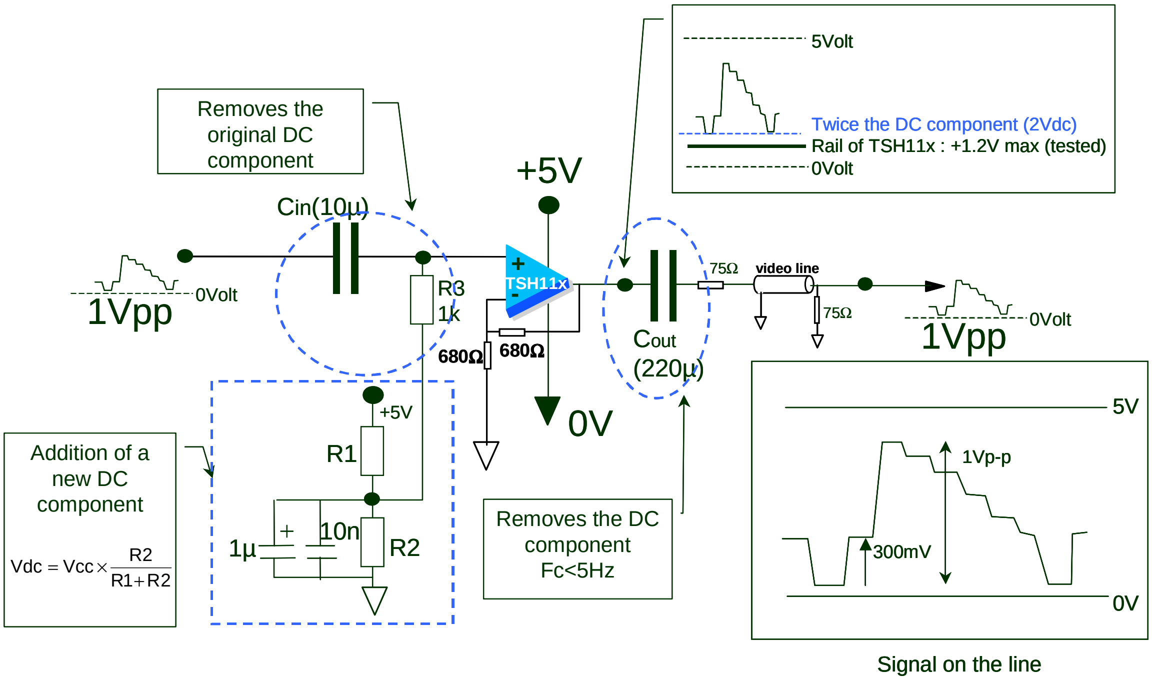

Fig. 9: Adding Dc Offset To Video To Use TSH11x Op Amp And Single Rail

If the op amp is not rail-to-rail, a dc component can be added to the video using a resistive network (see Fig. 8) and the signal is not then clipped by the op amp (VOL=1.2 V max in this case). Cin-R3 behaves like a high-pass filter (fc=16 Hz) removing the dc component. The R1-R2 resistor divider adds a new dc component higher than the ½VOL max tested value of the op amp. To limit the current through R1 and R2, their values should be high with maximum values calculated to set an +Ibias max equal to 1% of the current through them. Cout removes the dc component to go back to the original video signal.

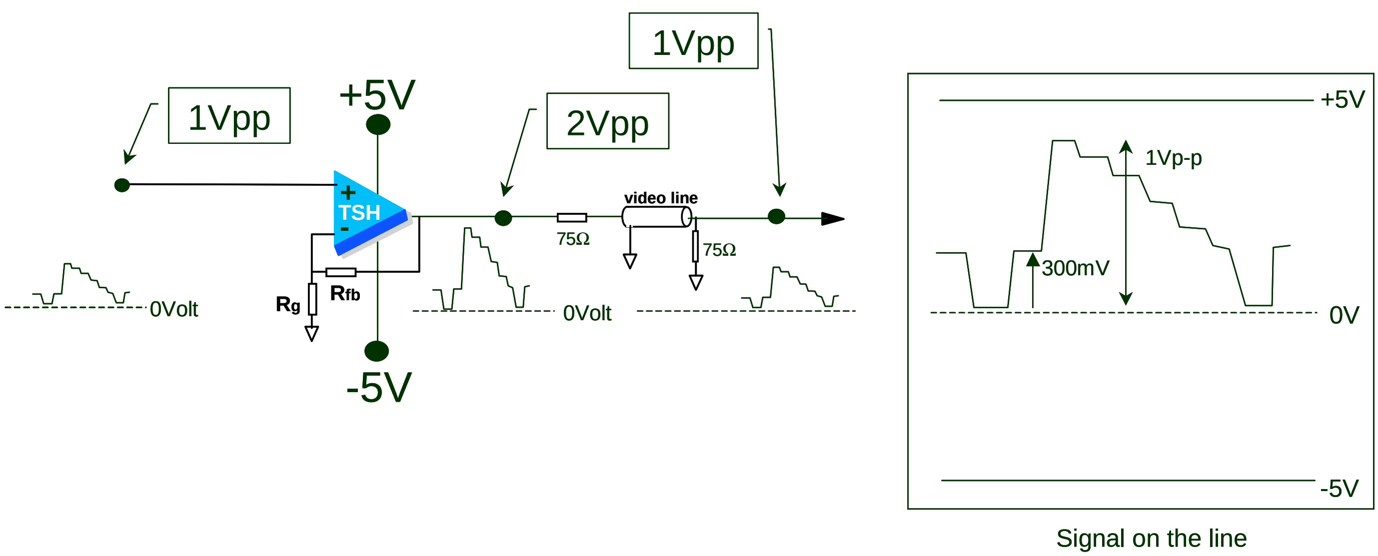

Fig. 10: Implementation With TSH7x-8x-9x-11x Op Amps And Split Rails

The implementation of the op amp here (Fig. 10) is much simpler because the video signal amplitudes are far away from the rails. But the drawback of this solution is the cost of the providing a negative power rail.

Choosing The Op Amp

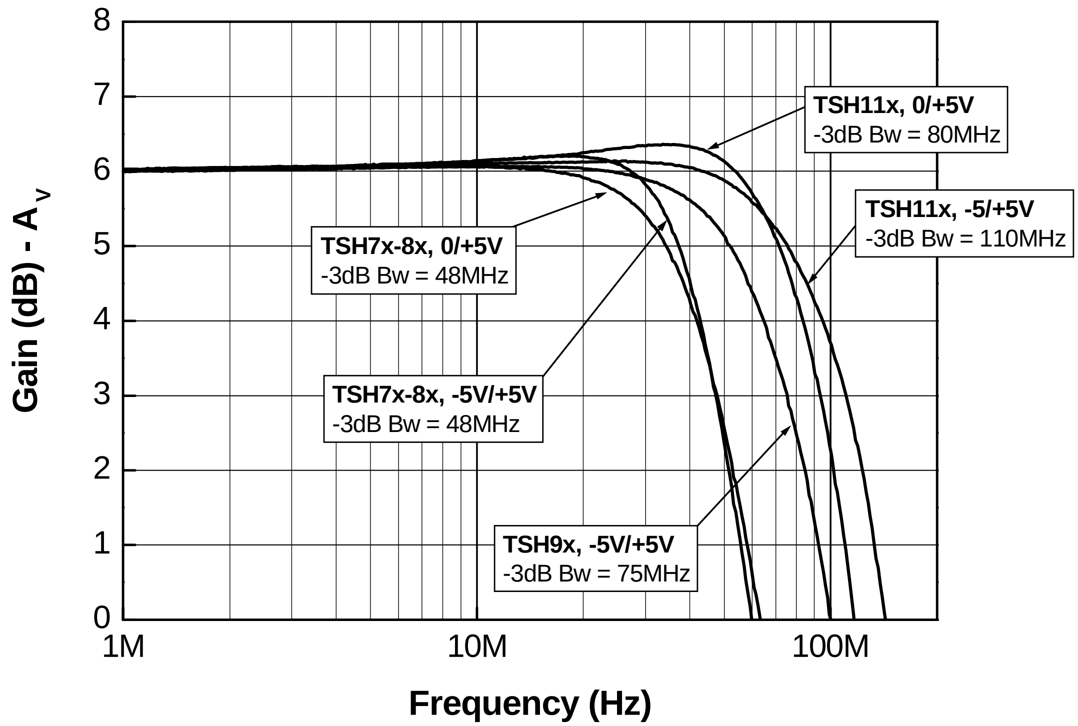

Fig. 11: Typical Small Signal Bandwidths: Gain=+2 (6 dB), Load=150 Ω

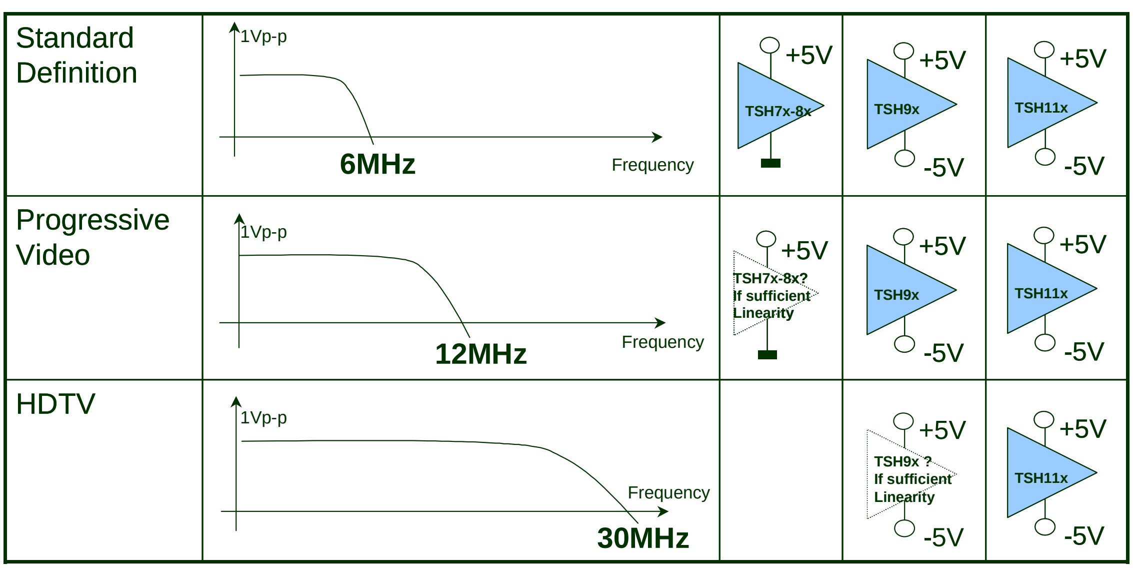

Fig. 12: Choice Of Op Amp By Video Bandwidth Needs

Reconstruction Filtering

The output stage of an MPEG decoder is a DAC creating the analog video signal. During this conversion the sampling frequency will, unfortunately, in the video spectrum as a parasitic causing distortion and noise in the video band. A low-pass filter (known as a reconstruction filter) is used to remove this parasitic with the cut-off frequency matching the video bandwidth (6 MHz, 12 MHz or 30 MHz). Lower order filters can be used with higher sampling frequencies and they may be avoided in the future with faster DACs.

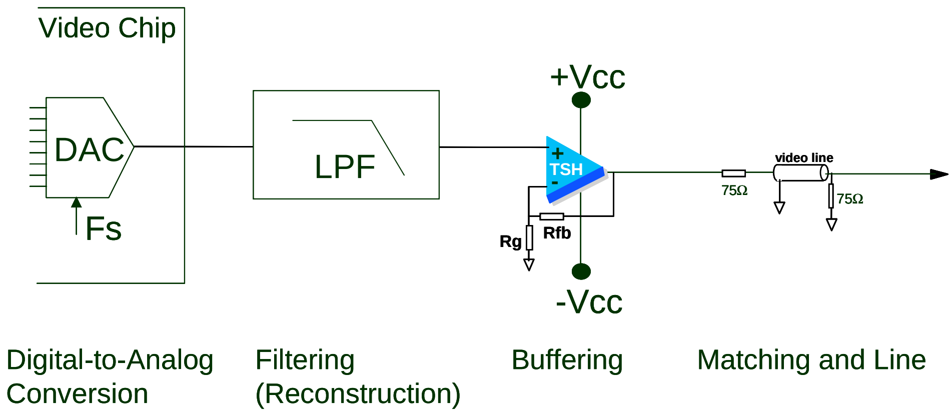

Fig. 13: Reconstruction Filtering Of The Analog Output

Examples:

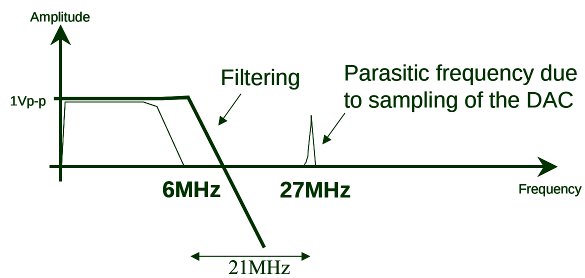

Fig. 14: STi5518 (STB chip). Fs=27 MHz for SD outputs. 6 MHz LPF limits the 27 MHz

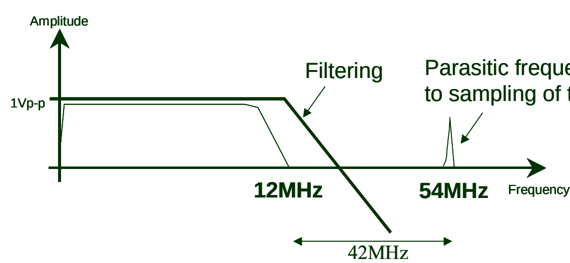

Fig. 15: STm5588 (DVD chip). Fs=54 MHz for PV outputs. 12 MHz LPF limits the 54 MHz

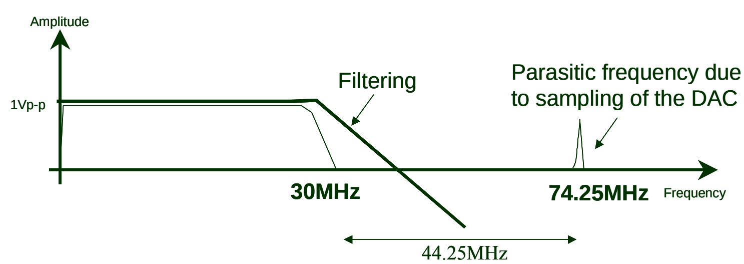

Fig. 16: Fs=74.25 MHz for HD outputs. 30 MHz LPF limits the 74.25 MHz

Behavior With A Capacitive Load

As explained initially, a high-speed op amp can be used for matching the video signal to the input stage of a TV or STB. The input of a chip-set (typically the input of an ADC) is mainly a pure resistor approximately 1 kΩ or 2 kΩ in parallel with a capacitor of some 10 pF. To limit the effect of the capacitance on op amp stability a small series resistance, Rs, is put on the output.

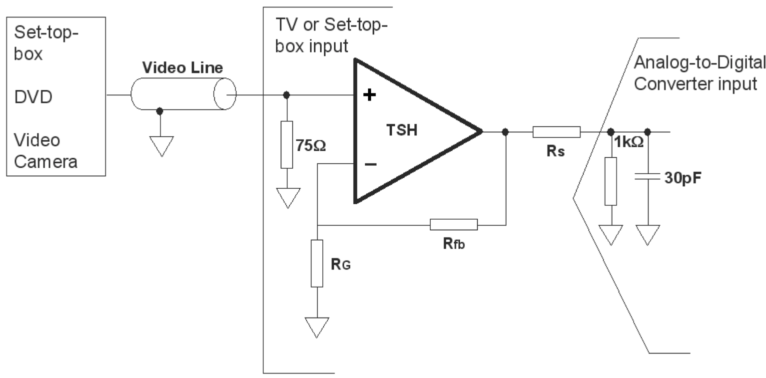

Fig. 17: Typical Capacitive Loading

The following graphs (Figs. 18 and 19) give typical frequency responses when loaded with a worst case 30 pF (10 pF is more common).

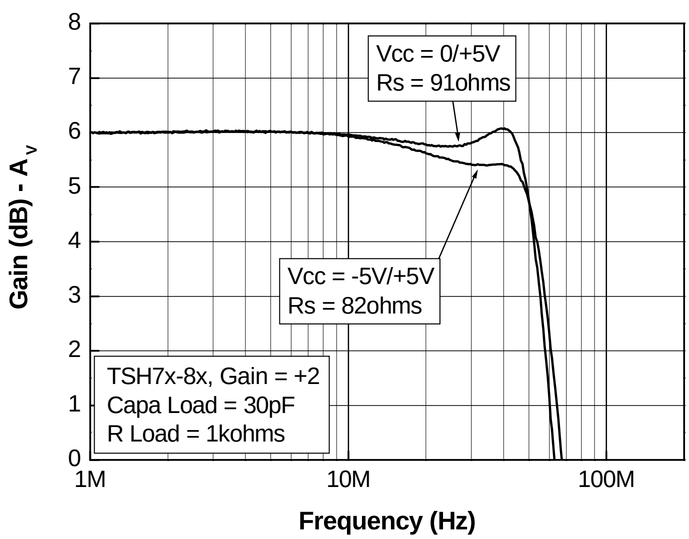

Fig. 18: 30 pF Loading Of TSH7x-8x With Rs

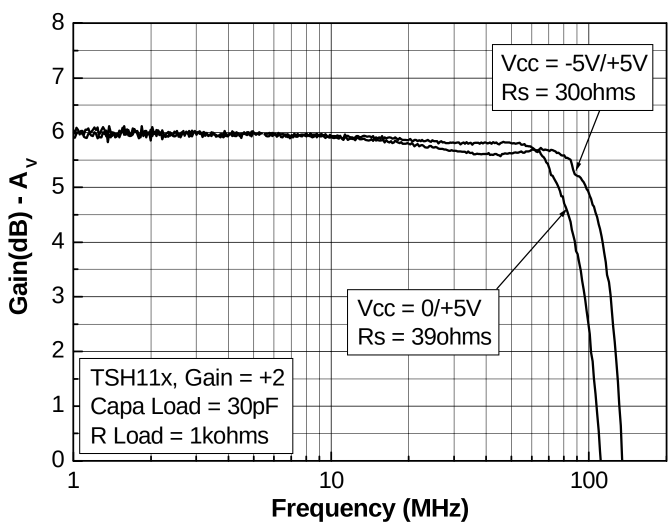

Fig. 19: 30 pF Loading Of TSH11x With Rs

About The Author

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