TA0310
TECHNICAL ARTICLE

High Speed Operational Amplifiers for 75Ω Video Lines

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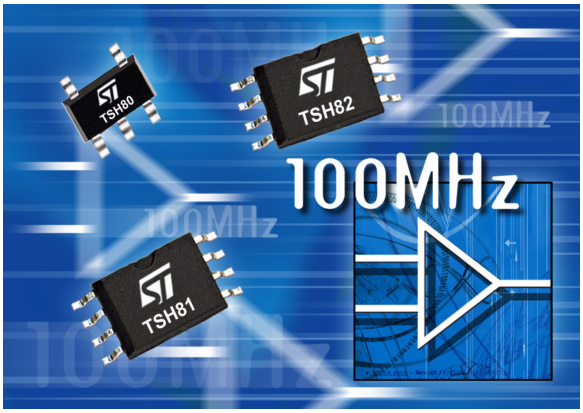


1 Introduction

This paper 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.

Finally, we present ST's current high-speed op-amp portfolio and give technical support for the implementation of these products in application.

2 Video applications

Currently, there are two types of video applications: broadcast video and graphics video. Broadcast video is limited to television signal transmissions with specified bandwidth (Television, Set-Top-Box, 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.

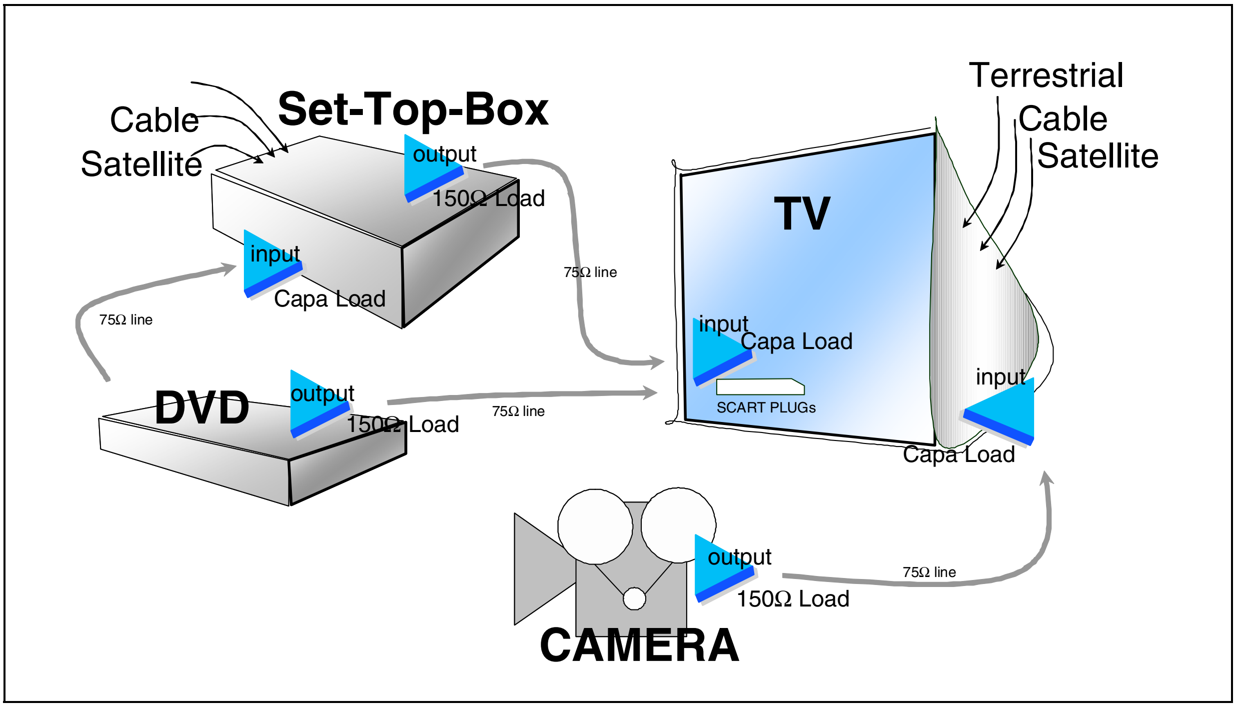
3 Where do we need high-speed op-amps?

An amplifier stage is needed to drive analog video signals to the television via a 75Ω video line. The applications concerned are mostly consumer applications such as set top boxes, DVD player-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 (75Ω for video lines).

Televisions also require high-speed op-amps. In TVs; the amplifier ensures 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 pF. In this situation, the driver must maintain high stability even under capacitive loads. Set-top boxes can also feature an analog video input featuring the same constraints.

The choice of the video source is done via the set-top box. The source signal can be delivered from a DVD or a video camera, for example.

Figure 1: Location of op-amps in video applications



The amplifier can be very specific, including features such as buffer+filtering (ex: STv6433) or video matrix (STv6412), or, linked to the market trend, 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 space-saving, high-speed op-amps provide an advantage as compared to a transistor solution. For this reason, there is currently a market for the high-speed op-amps in broadcast video applications.

4 Analog video formats

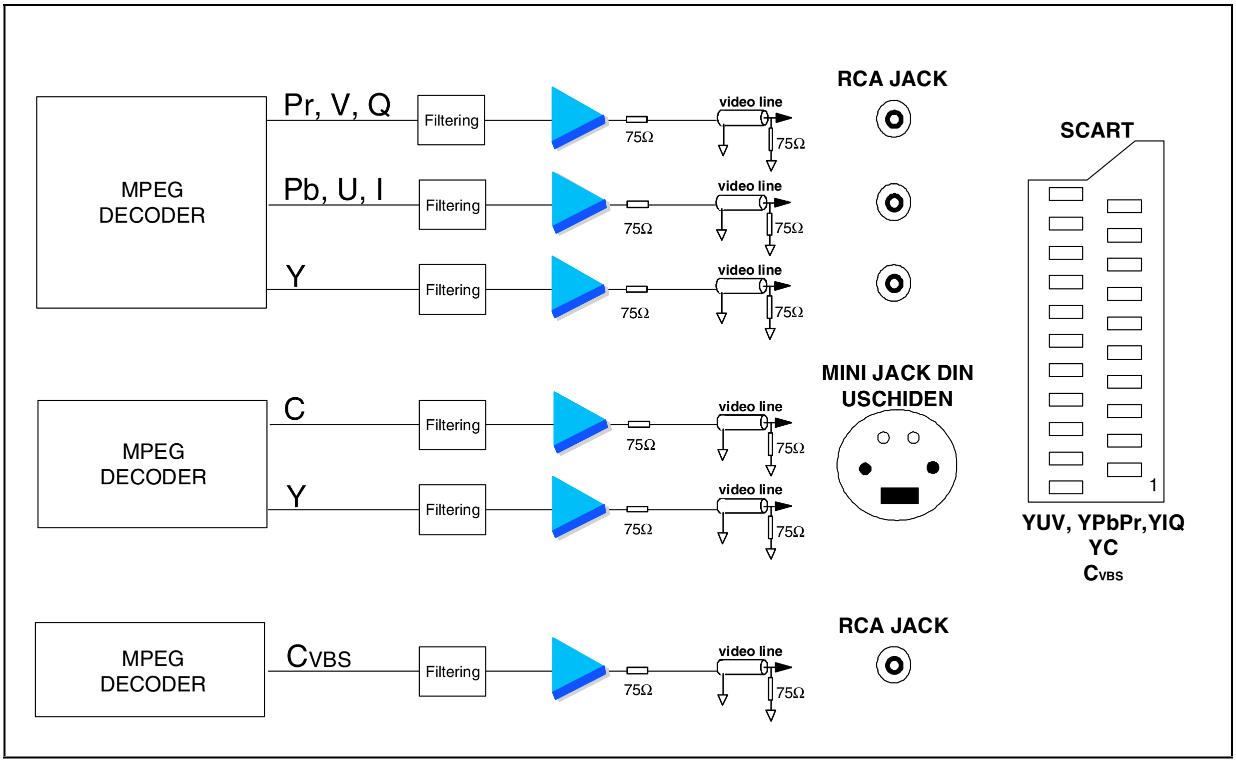
The format of the analog video signal is very important in order to evaluate the frequency and amplitude contraints required of the high-speed op-amp. There are three main division of signal formats, each giving a different quality of television image.

The first type of signal format is comprised of three separate signals based on the R,G and B signals. This signal form is the "purest" video signal, providing the highest quality image. The three R, B and G signals feature the same bandwidth. This bandwidth is directly linked to the video resolution. In standard video broadcast, we use commonly YIQ, YUV or YPbPr, where appears the Luma (Y), (I,U,Pb) and (Q,V,Pr) are a component of R, B and Y. In of all these formats, three signals are driven.

The second type of signal format is based on two signals, such as Luma-Chroma (Y/C) or S-Video, where C is the Chroma. Both are a coding of RGB signals linked to the NTSC, PAL and SECAM video standards developed in the USA, Europe and Asia.

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. CVBS is the sum of Y and C. This signal format is the lowest quality format.

Figure 2: Video formats and standard plugs

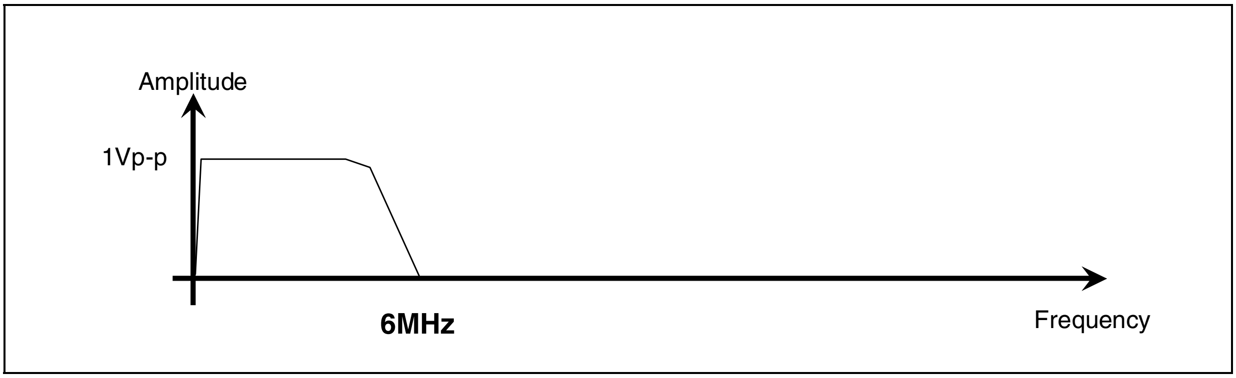


5 Video signal bandwidth versus resolution

Standard Definition (SD):

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

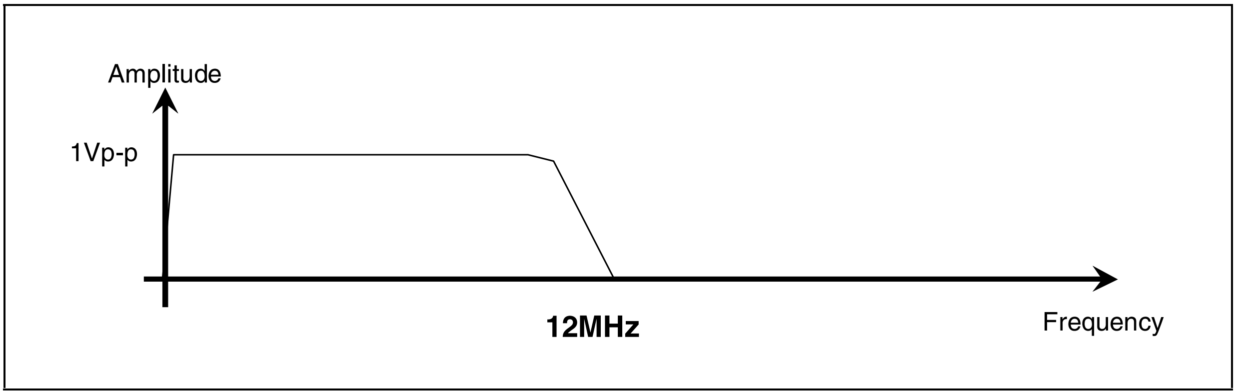
Figure 3: Video spectrum for Standard Definition



Progressive Video (PV):

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

Figure 4: Video spectrum for Progressive video



High Definition (HDTV):

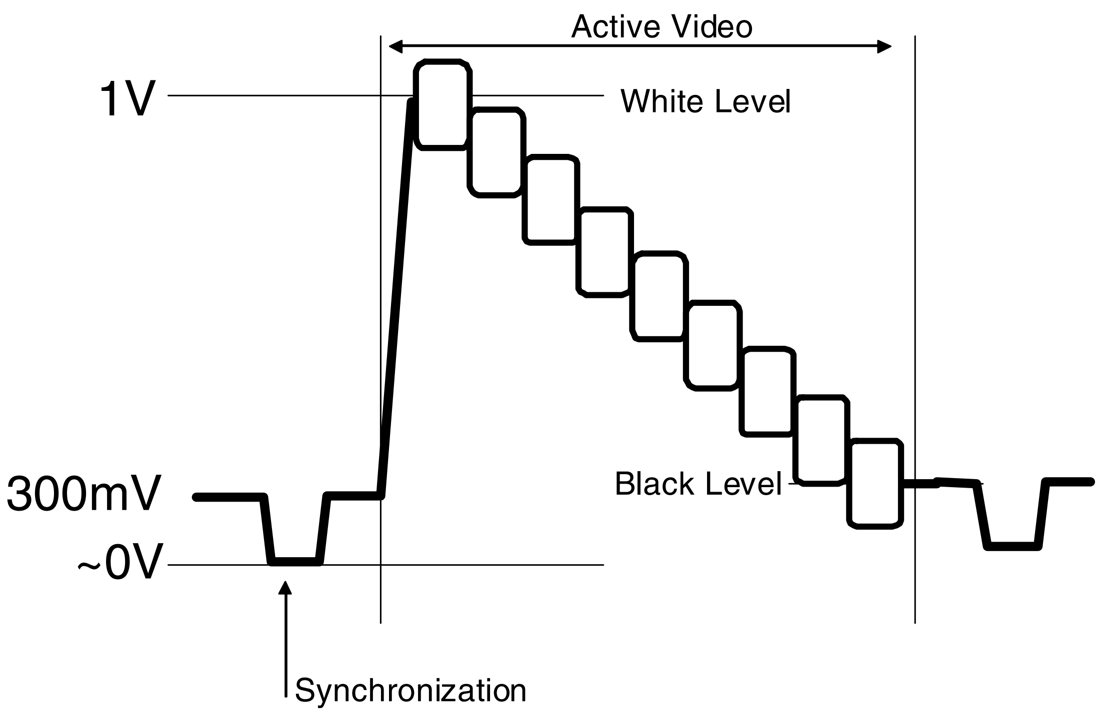
The goal is to improve the definition of the image by increasing the quantity of lines and pixels per line. The bandwidth of the video signal is up to 30MHz and the signal fits with TV screens of progressive 1280*1920 pixels (type: 1280P) and interlaced 1920*1080 pixels (1080I). HDTV is now popular in the USA, and is starting to become so in Asia and Europe.

Figure 5: Video spectrum for HDTV

6 Signal amplitude

Figure 6 below shows the typical amplitude of a video signal including synchronization, black level (as amplitude reference 0), white level and colours.

Figure 6: Video signal amplitudes including colours and luma



7 ST's high-speed op-amps

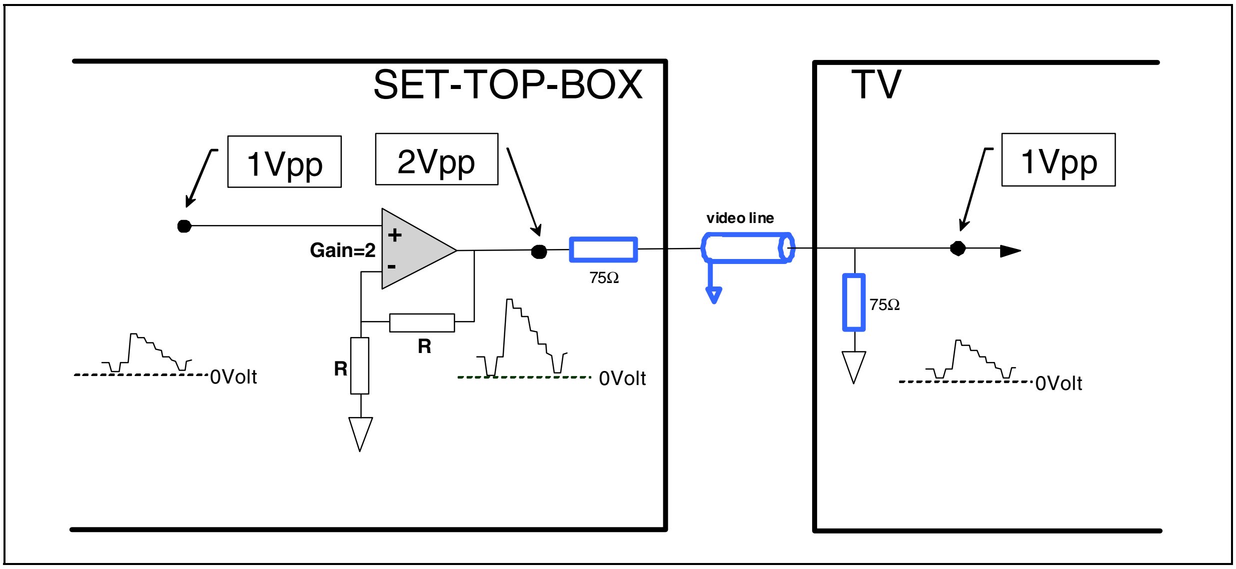
Available in full production, ST offers 4 op-amp families in the high-speed op-amp portfolio that provide a broad choice to customers. These 4 families are complementary.

- **TSH7x**: VFA, GBP=100MHz, 3V to 12V power supply, input/output rail to rail.
- **TSH8x**: VFA, GBP=100MHz, 4.5V to 12V power supply, input/output rail to rail.
- **TSH9x**: VFA, GBP=130MHz, 12V power supply, noise=4.2nV/√Hz, consumption=4.5mA
- **TSH11x**: CFA, -3dB Bw=100MHz, 5V to 12V power supply, noise=3nV/√Hz, consumption=3mA

(datasheets available on www.st.com)

8 Impedance matching

Figure 7: Typical connexion between set-top-box and TV



We can summarize as follows 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[1], the line must be loaded on both sides by its own characteristic impedance; typically 75Ω 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 75Ω is physically implemented on the board to achieve the right value for matching. A second resistor of 75Ω (TV side) allows matching on the other side.

As show in *Figure 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 1Vpp in video), a gain of +2 (6dB) is required on 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 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. 1kΩ is a good choice and it satisfies the previous requirements. For a CFA, as TSH11x, the value of R is imposed and it is available in the datasheet (R=680Ω for gain=+2).

9 Power supply

A constraint belonging to every designer is the need to reduce the cost of his application. A dual power supply -5V/+5V requires an investment in a negative -5V supply circuit. One solution is to reduce the power supply to a single supply 0/+5V. As described in *Figure 6*, the synchronization signal descends to 0V (sometimes only 10mV). In cases such as these, the best solution is to use an input/output rail-to-rail op-amp such as TSH7x-TSH8x families. Assuming the tested value of the output rail is VOL=150mV max.

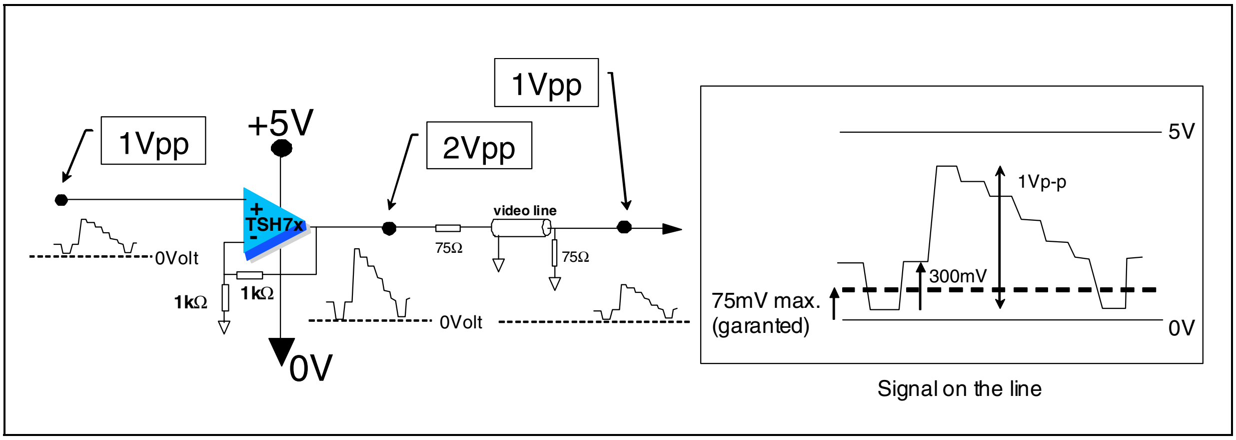
1 Reflection factor occurs when the line is loaded by the same value as its own characteristic impedance Zc.

(see datasheet), the minimum amplitude of the signal guaranteed on the line is 75mV. This results in a loss of the bottom signal which is only 75mV (at worst).

10 Notes on video line driving

Implementation of TSH7x-TSH8x families in single supply 0/+5V:

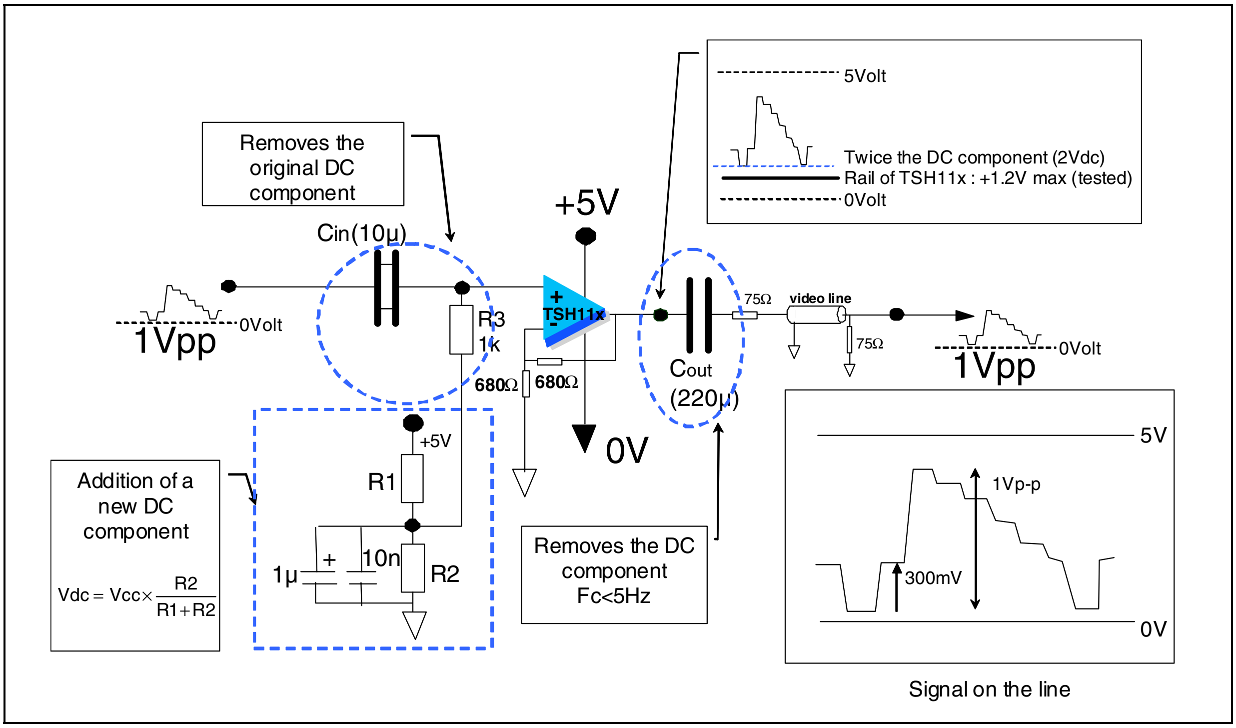
Figure 8: Implementation of the TSH7x-8x in single supply 0/+5V



If the op-amp is not rail-to-rail, the DC component of the video signal must be shifted to a higher value using the networks described in *Figure 8*. In this way, the video signal is not truncated by the output stage of the op-amp (VOL=1.2V max., see datasheet).

Implementation of TSH11x family in single supply 0/+5V:

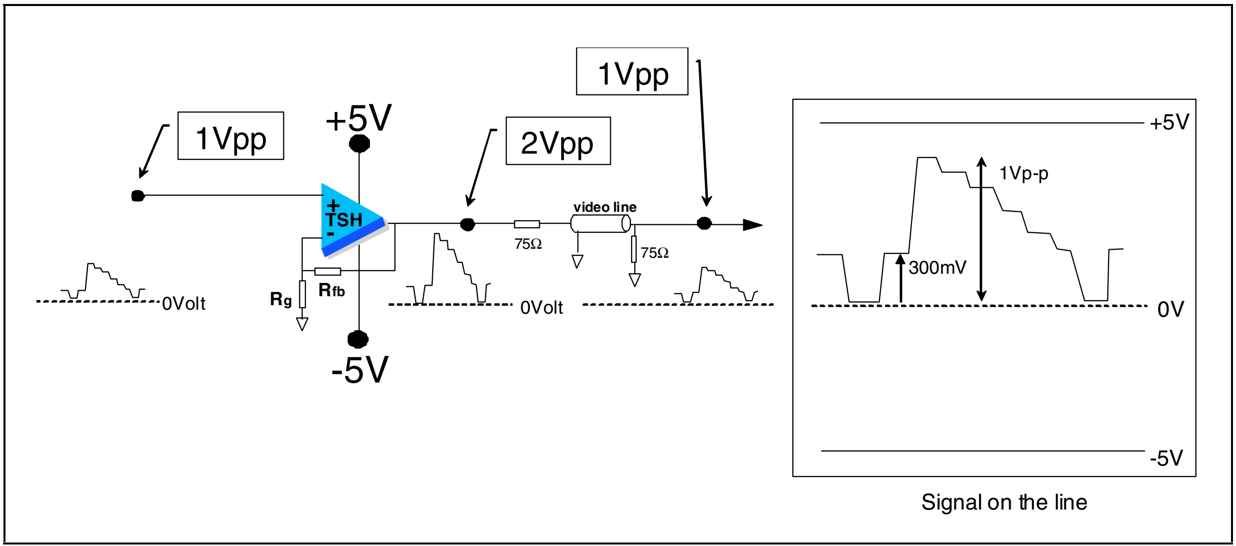
Figure 9: Implementation of the TSH11x in single supply 0/+5V



Cin-R3 behaves like a high pass input filter (fc=16Hz) and removes the original DC component of the video signal to create a "floating" signal. The R1-R2 resistor divider provides the new DC component. The minimum level of that DC component must be ½VOL max (tested value). In order to limit the current through R1 and R2, the value of these resistances must be sufficiently high. The maximum values of R1 and R2 are calculated to in order to arrive at +Ibias max (see datasheet) equal to 1% of the current through R1 and R2. Cout removes the DC component to go back to the original video signal to fit with TV requirements.

Implementation of TSH7x-TSH8x-TSH9x-TSH11x families in dual supply -5V/+5V:

Figure 10: Implementation of the TSH7x-8x-9x-11x in dual supply -5V/+5V



In this scenario, the implementation of the op-amp is much more simple because the video signal amplitudes are far away from the rails. But the drawback of this solution is the cost of the providing a power supply of -5V.

Note: Rfb can eMqual 1kΩ for TSH7x-8x-9x, 680Ω for TSH11x (see datasheet).

Frequency response of TSH7x-8x-9x-11x:

Figure 11: Small Signal Bandwidth. Gain=+2, Rload=150ohms

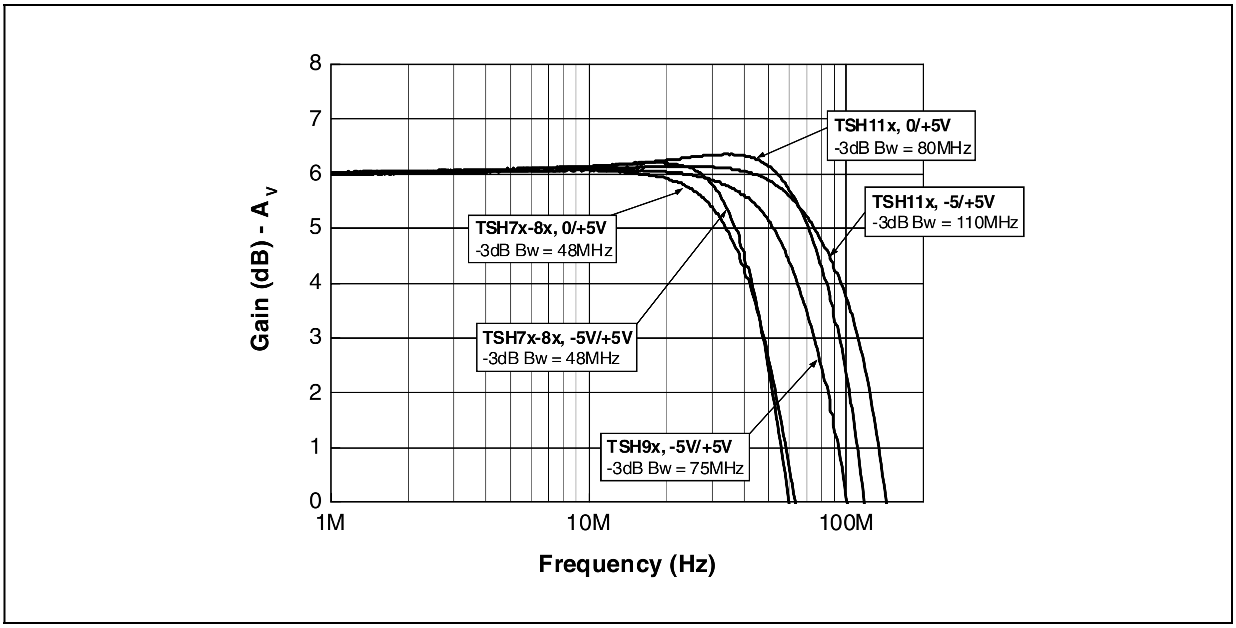
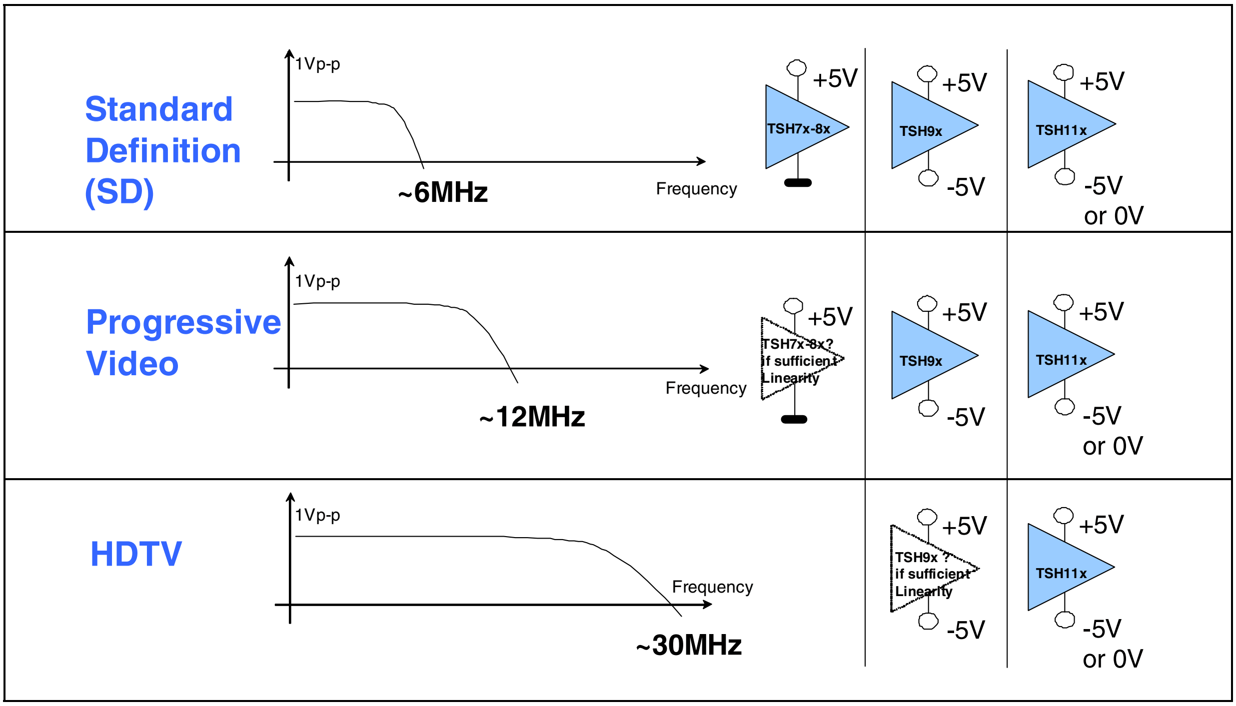


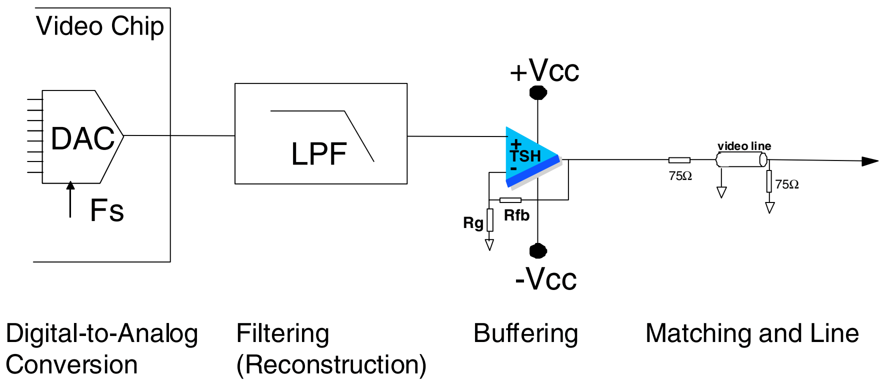
Figure 12: Choice of the op-amp versus a video bandwidth



Reconstruction Filtering:

The output stage of an MPEG decoder is a DAC (digital analog converter). This DAC makes an analog video signal from the digital one used for video treatments on previous stages. During this conversion the sampling frequency will be unfortunately in the video spectrum as a parasitic frequency which causes distortion and noise in the video band. A low-pass filter (called a reconstruction filter) is used to remove this parasitic frequency. The cut-off frequency of this filter fits with the useful video bandwidth (6MHz, 12MHz or 30MHz). The order is directly linked to the value of the sampling frequency compared to the video band. An increasing of the sampling frequency allows a lower order of the filter. Some of the newer designs of DAC target a higher frequency sampling in order to remove the filtering on the future solutions.

Figure 13: Filtering of the analog output



Examples:

Figure 14: STi5518 (set-top-box chip). Fs=27MHz for SD outputs. 6MHz LPF to limit the 27MHz

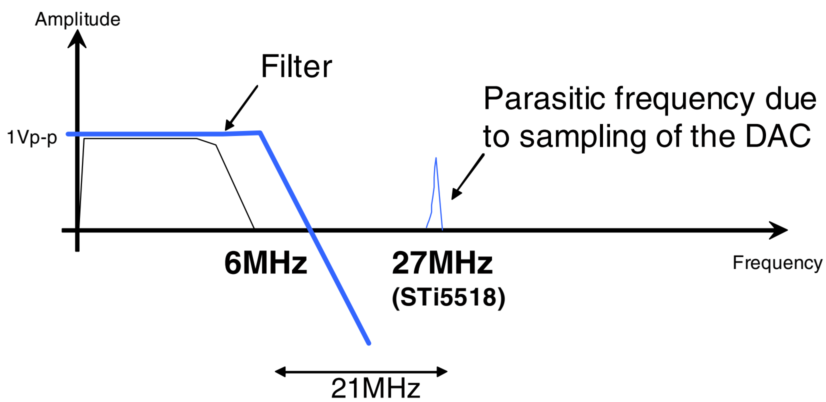


Figure 15: STm5588 (DVD chip). Fs=54MHz for PV outputs. 12MHz LPF to limit the 54MHz

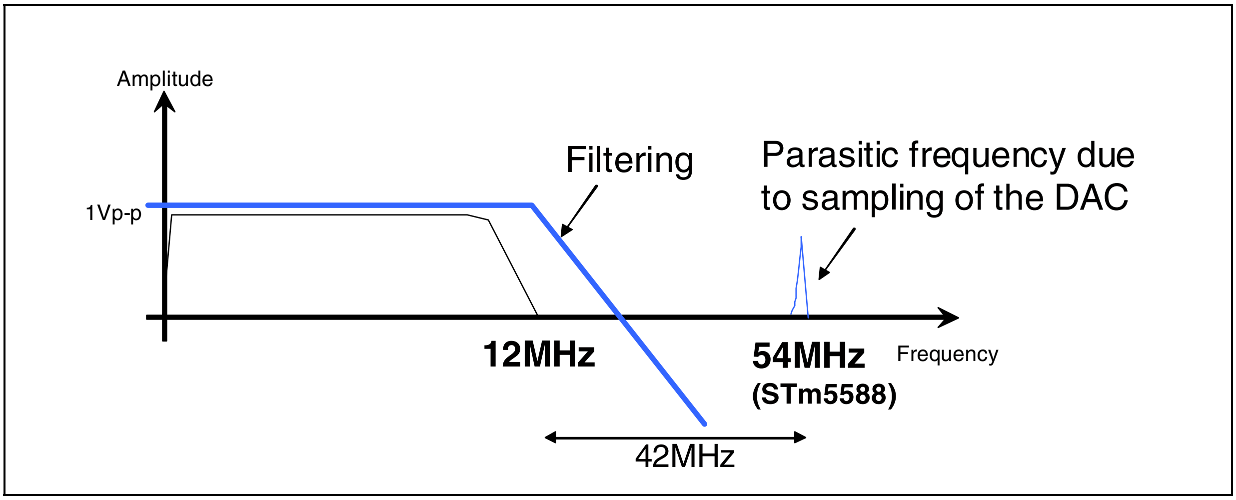
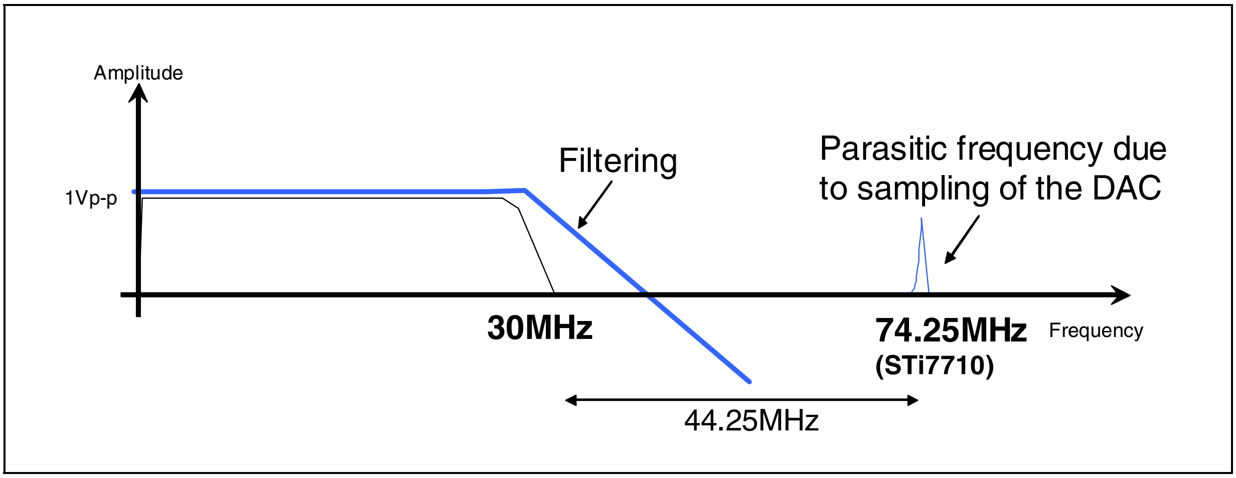


Figure 16: Fs=74.25MHz for HD outputs. 30MHz LPF to limit the 74.25MHz



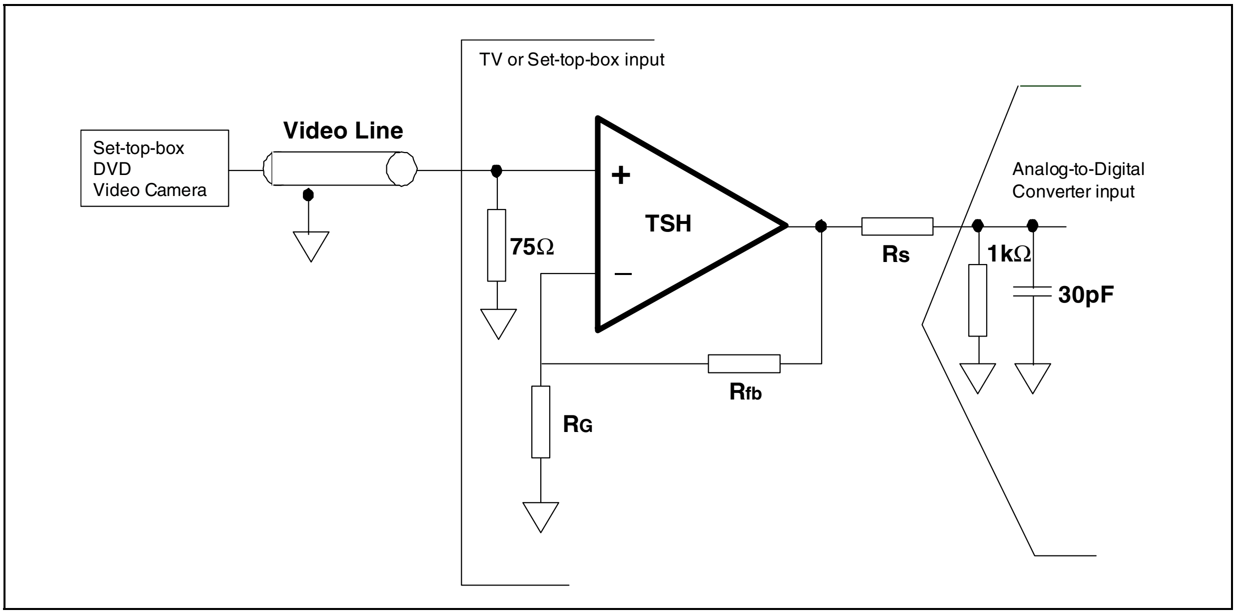
Notes concerning the video input stage

Behavior on capacitive load

As explained in *Section 3* on page 1, a high speed op-amp can be used for matching the video signal to the input stage of a TV or set-top-box. The input of a chip-set (typically the input of an analog to digital converter) is mainly a pure resistor approximately 1kΩ or 2kΩ in parallel with a capacitor of some of 10pF.

Because of this, in series we place a resistance, Rs, which is used as isolation in order to limit the effect of the capacitor on the op-amp stability.

Figure 17: Typical load



The following graphs in *Figures 18* and *19* give the frequency response of the TSH7x-8x and TSH11x family when loaded by a chip-set input. 30pF is the worst case; a typical value is 10pF).

Figure 18: TSH7x-8x behavior on capa-load

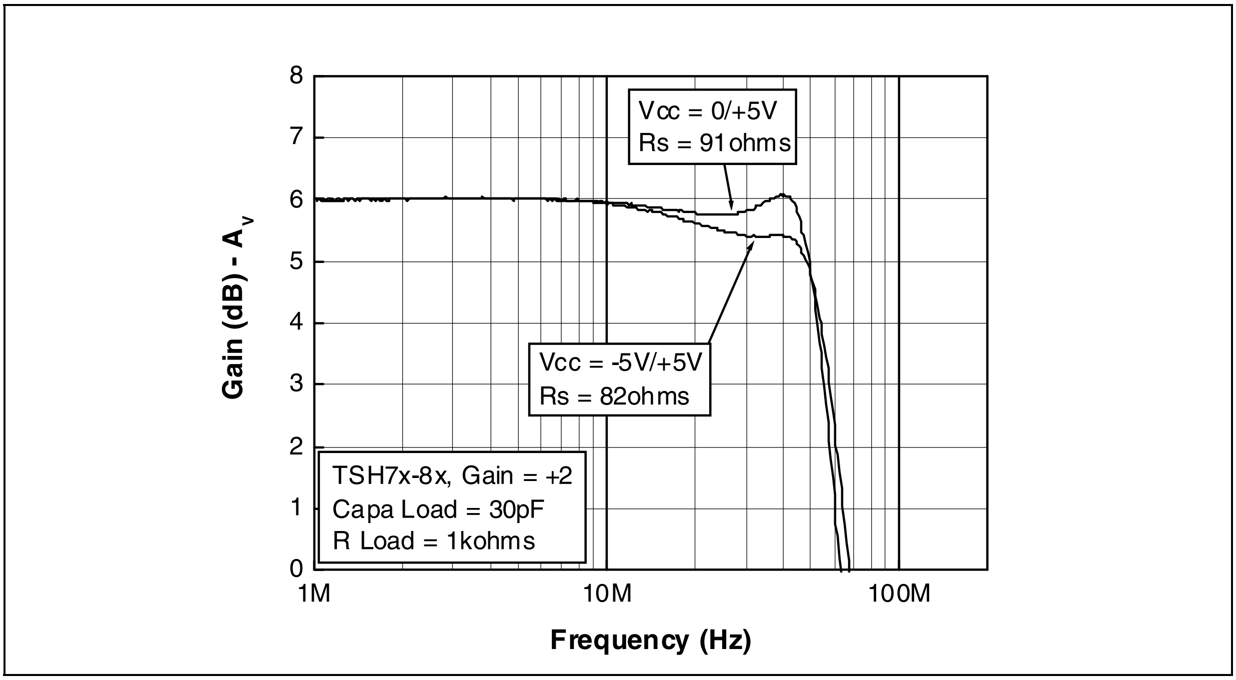


Figure 19: TSH11x behavior on capaload