

## Ultra-low Power, 1-Channel 6<sup>th</sup>-Order SD Video Filter Driver

### Features

- Single SDTV Filter
- 6<sup>th</sup>-order Butterworth Low-Pass Filter:  
9MHz -3dB Bandwidth, 57.2dB Attenuation(27MHz)
- Support Multiple Input Biasing:
  - Provide 80-mV Level-Shift when DC-Coupled
  - Transparent Input Clamping when AC-Coupled
  - Support External DC Biasing when AC-Coupled
- Very Low Quiescent Current: 3.85mA (Typical)
- Slew Rate: 38V/μs
- 6dB Gain (2V/V) with Rail-to-Rail Output
- AC- or DC-Coupled Output Driving Dual Video Loads (75Ω)
- Wide Operation Range: +2.85V to +5.5V Single Supply
- Robust ESD Protection:
  - HBM 8KV, CDM 2KV
- Lead-Free SC70 Package Available

### Applications

- Video Signal Amplification
- Set-Top Box Video Driver
- PVR、DVD Player Video Buffer
- Video Buffer for Portable or USB-Powered Video Devices
- HDTV

### Description

TPF111 is a low-cost reconstruction video filter optimized for consumer video devices. With its exceptional video performance and very low power consumption, it is excellent choice for portable video applications. Integrated with a 6<sup>th</sup>-order Butterworth filter, TPF111 can be used as a DAC reconstruction filter or ADC anti-aliasing filter. With its -3dB frequency of 9MHz, it is an ideal choice for SD video applications including NTSC and PAL.

TPF111 accepts both AC- and DC-coupled inputs and its flexible biasing options meet the requirement of the most demanding applications. The integrated Transparent Sync-tip Clamp circuit restores DC voltage level of an AC-coupled Video signal. It translates the sync tip of a CVBS, Y', or RGB signal to a fixed 40mV. External biasing resistors can be used to restore signals without sync tip such as Pb' or Pr'. Integrated level shifter then raises the clamped video signal by 80mV, assuring passing through of video signal without being distorted. When the signal is DC-coupled, the level shifter will raise the signal by 80mV.

TPF111 may be used for different kinds of video buffering with 6dB gain(2V/V) and rail-to-rail output. It supports AC- and DC-coupling at the output.

TPF111 is designed to have exceptional ESD rating. It is a great choice of protecting the main video processor chip from ESD or surge strikes in applications such as set-top-boxes.

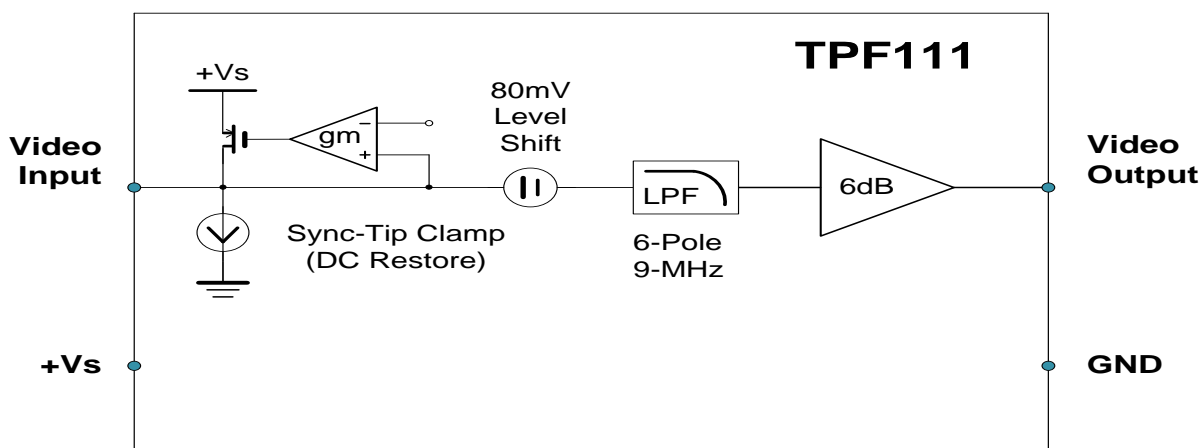
TPF111 operates from a single supply with wide voltage range from +2.85V to +5.5V. Its very low quiescent current of 3.85mA makes it an perfect choice for battery-power or USB-power applications.

TPF111 is available in SC70-5 package (TPF111-C) and SOIC-8 package (TPF111-S). Its operation temperature range is from -40°C to +85°C.

### Related Resources

AN-1201: Application notes of TPF1xx

### Function Block

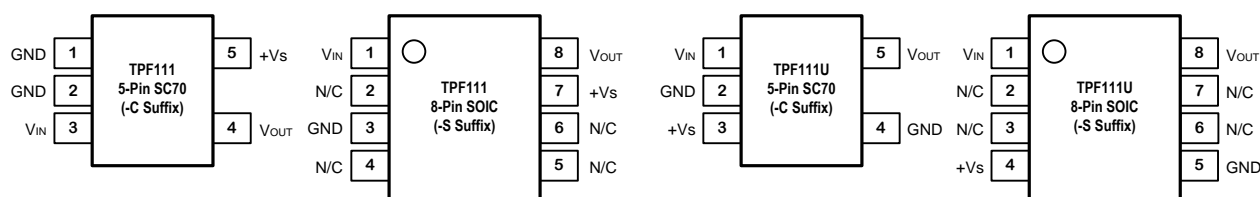


## Order Information

| Order Number | Marking Information  | Operating Temperature Range | Package     | Transport Media, Quantity |
|--------------|----------------------|-----------------------------|-------------|---------------------------|
| TPF111-CR    | F1YW <sup>(1)</sup>  | -40 to 85°C                 | 5-Lead SC70 | Tape and Reel, 3,000pcs   |
| TPF111-SR    | TPF111               | -40 to 85°C                 | 8-Lead SOIC | Tape and Reel, 4,000pcs   |
| TPF111U-CR   | F1UYW <sup>(1)</sup> | -40 to 85°C                 | 5-Lead SC70 | Tape and Reel, 3,000pcs   |
| TPF111U-SR   | TPF111U              | -40 to 85°C                 | 8-Lead SOIC | Tape and Reel, 4,000pcs   |

Note: (1). 'YW' is date coding scheme. 'Y' stands for calendar year, and 'W' stands for single workweek coding scheme.

## Pin configuration (Top View)



## Pin Functions

| SC70        | SOIC                    | Pin Name         | Function              |
|-------------|-------------------------|------------------|-----------------------|
| 3 / 1       | 1 / 1                   | V <sub>IN</sub>  | Video Input           |
|             | 2, 4, 5, 6 / 2, 3, 6, 7 | N/C              | No Connect            |
| 1, 2 / 2, 4 | 3 / 5                   | GND              | Ground                |
| 5 / 3       | 7 / 4                   | +V <sub>S</sub>  | Positive Power Supply |
| 4 / 5       | 8 / 8                   | V <sub>OUT</sub> | Filtered Video Output |

## Absolute Maximum Ratings<sup>Note</sup>

| Parameters                           |                                                        | Value                                | Unit |
|--------------------------------------|--------------------------------------------------------|--------------------------------------|------|
| Power Supply, V <sub>DD</sub> to GND |                                                        | 6.0                                  | V    |
| PD                                   | Power dissipation, T <sub>A</sub> = 25°C, 5-Lead SC70  | 300 <sup>(1)</sup>                   | mW   |
|                                      | Power dissipation , T <sub>A</sub> = 25°C, 8-Lead SOIC | 800 <sup>(1)</sup>                   |      |
| V <sub>IN</sub>                      | Input Voltage                                          | V <sub>DD</sub> + 0.3V to GND - 0.3V |      |
| I <sub>o</sub>                       | Output Current                                         | 65                                   | mA   |
| T <sub>J</sub>                       | Maximum Junction Temperature                           | 150                                  | °C   |
| T <sub>A</sub>                       | Operating Temperature Range                            | −45 to 85                            | °C   |
| T <sub>STG</sub>                     | Storage Temperature Range                              | −65 to 150                           | °C   |
| TL                                   | Lead Temperature (Soldering, 10 sec)                   | 300                                  | °C   |
| θ <sub>JA</sub>                      | 5-Lead SC70                                            | 430 <sup>(2)</sup>                   | °C/W |
|                                      | 8-Lead SOIC                                            | 130 <sup>(2)</sup>                   |      |

(1) This data was taken with the JEDEC low effective thermal conductivity test board.

(2) This data was taken with the JEDEC standard multilayer test boards.

**\* Note:** Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

## ESD, Electrostatic Discharge Protection

| Symbol | Parameter                | Condition                  | Minimum Level | Unit |
|--------|--------------------------|----------------------------|---------------|------|
| HBM    | Human Body Model ESD     | MIL-STD-883H Method 3015.8 | 8             | kV   |
| CDM    | Charged Device Model ESD | JEDEC-EIA/JESD22-C101E     | 2             | kV   |

## Electrical Characteristics

All test condition is VDD = 3.3V, TA = +25°C, RL = 150Ω to GND, unless otherwise noted.

| SYMBOL                          | PARAMETER                                          | CONDITIONS                                                       | MIN  | TYP  | MAX   | UNITS |
|---------------------------------|----------------------------------------------------|------------------------------------------------------------------|------|------|-------|-------|
| Input Electrical Specifications |                                                    |                                                                  |      |      |       |       |
| V <sub>DD</sub>                 | Supply Voltage Range                               |                                                                  | 2.85 |      | 5.5   | V     |
| I <sub>DD</sub>                 | Quiescent current (I <sub>Q</sub> ) <sup>(1)</sup> | V <sub>DD</sub> = 3.3V, V <sub>IN</sub> = 500mV, no load         |      | 3.85 | 4.85  | mA    |
|                                 |                                                    | V <sub>DD</sub> = 5.0V, V <sub>IN</sub> = 500mV, no load         |      | 5.00 | 6.25  | mA    |
| V <sub>CLAMP</sub>              | Input Voltage Clamp                                | I <sub>IN</sub> = -100μA                                         | -40  | 0    | +40   | mV    |
| I <sub>CLAMP-CHG</sub>          | Clamp Charge Current                               | V <sub>IN</sub> = V <sub>CLAMP</sub> - 200mV                     | -1.5 | -1.7 |       | mA    |
| I <sub>CLAMP-DCHG</sub>         | Clamp Discharge Current                            | V <sub>IN</sub> = 500mV                                          | 1.5  | 2.0  | 5.1   | μA    |
| R <sub>IN</sub>                 | Input Impedance                                    | 0.5V < V <sub>IN</sub> < 1.0V                                    | 0.5  | 3    |       | MΩ    |
| A <sub>V</sub>                  | Voltage Gain <sup>(1)</sup>                        | V <sub>IN</sub> =0.5V, 1V and 2V<br>R <sub>L</sub> = 150Ω to GND | 5.9  | 6.01 | 6.025 | dB    |
| V <sub>OLS</sub>                | Output Level Shift Voltage                         | V <sub>IN</sub> = 0V, no load, input referred                    | 53   | 80   | 124   | mV    |
| V <sub>OH</sub>                 | Output Voltage High Swing                          | V <sub>IN</sub> = 3V, R <sub>L</sub> = 150Ω to GND               |      | 3.18 |       | V     |
| V <sub>OL</sub>                 | Output Voltage Low Swing                           | V <sub>IN</sub> = -0.3V, R <sub>L</sub> =75Ω                     |      | 0.05 |       | V     |
| PSRR                            | Power Supply Rejection Ratio                       | ΔV <sub>DD</sub> = 3.3V to 3.6V                                  |      | 61   |       | dB    |
|                                 |                                                    | ΔV <sub>DD</sub> = 5.0V to 5.5V, 50Hz, V <sub>IN</sub> =0.7V     |      | 67   |       | dB    |
| I <sub>SC</sub>                 | Short-circuit current                              | V <sub>IN</sub> =2V, output to GND through 10Ω                   | 65   |      |       | mA    |
|                                 |                                                    | V <sub>IN</sub> =100mV, output short to V <sub>DD</sub>          | 65   |      |       | mA    |
| AC Electrical Specifications    |                                                    |                                                                  |      |      |       |       |
| f <sub>-1dB</sub>               | -1dB Bandwidth                                     | R <sub>L</sub> =150Ω                                             | 7.6  | 8.2  | 9.1   | MHz   |
| f <sub>-3dB</sub>               | -3dB Bandwidth                                     | R <sub>L</sub> =150Ω                                             | 7.8  | 9    | 10.5  | MHz   |
| Att <sub>27MHz</sub>            | Stop Band Attenuation                              | f = 27MHz                                                        | 38.2 | 57.2 | 73.6  | dB    |
| dG                              | Differential Gain                                  | Video input range 1V                                             | -0.1 | 0.4  | 0.8   | %     |
| dP                              | Differential Phase                                 | Video input range 1V                                             | -1.1 | 0.7  | 1.1   | °     |
| THD                             | Output Distortion(All Channel)                     | f=1MHz, V <sub>OUT</sub> =1.4V <sub>PP</sub>                     | 0.03 | 0.1  | 0.2   | %     |
| D/DT                            | Group Delay Variation                              | f = 100kHz, 5MHz                                                 |      | 5.4  |       | Ns    |
| t <sub>PD</sub>                 | Propagation Delay                                  | Maximum delay from input to output:<br>100kHz to 4.43MHz         | 54   | 80   | 127   | Ns    |
| SNR                             | Signal-to-Noise Ration                             | f= 100kHz to 4.43MHz                                             | 65   | 69   |       | dB    |
| R <sub>OUT_AC</sub>             | Output Impedance                                   | f = 4.2MHz                                                       |      | 1.5  |       | Ω     |
| CLG                             | Chroma-Luma-Gain                                   | 400kHz to 3.58MHz and 4.43MHz                                    |      | 0.18 | 0.4   | dB    |
| CLD                             | Chroma-Luma-Delay                                  | 400kHz to 3.58MHz and 4.43MHz                                    |      | 5    |       | ns    |

## TPF111/TPF111U

### Ultra-low Power, 1-Channel 6<sup>th</sup>-Order SD Video Filter Driver

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Note: (1). 100% tested at  $T_A=25^{\circ}\text{C}$ .

**Typical Performance Characteristics** All test condition is  $V_{DD} = 3.3V$ ,  $T_A = +25^{\circ}C$ ,  $R_L = 150\Omega$  to GND, unless otherwise noted.

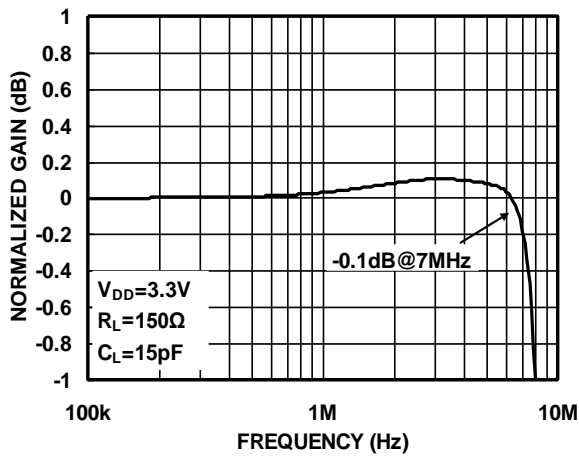


Figure1. Small-Scale Frequency Response

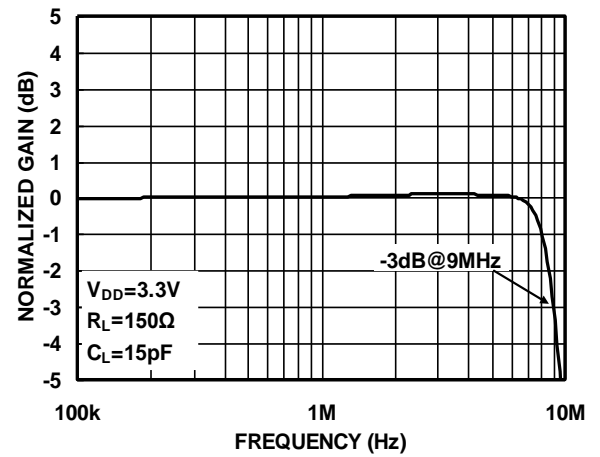


Figure2. Large-Scale Frequency Response

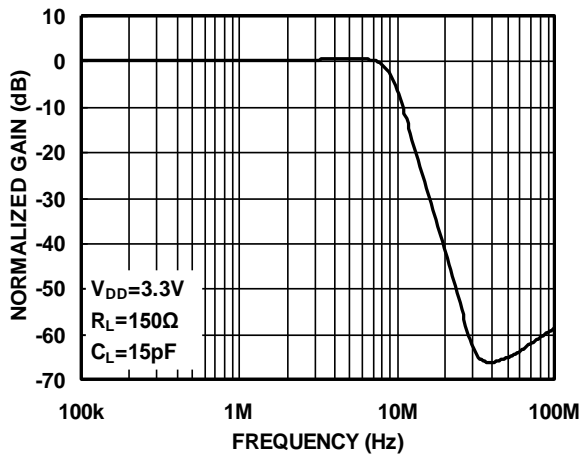


Figure3. Gain Vs. Frequency

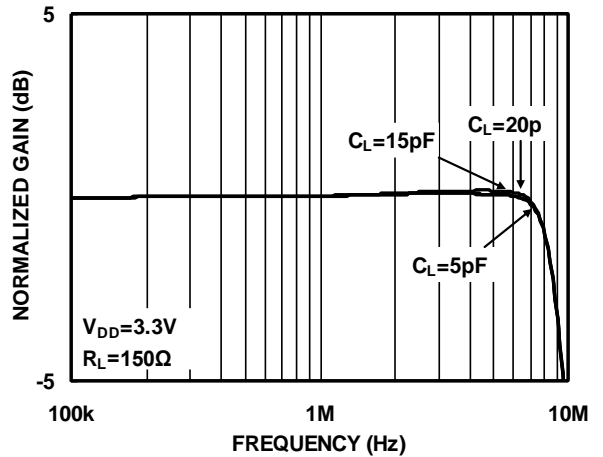


Figure4. Gain Vs. Frequency With  $C_{LOAD}$

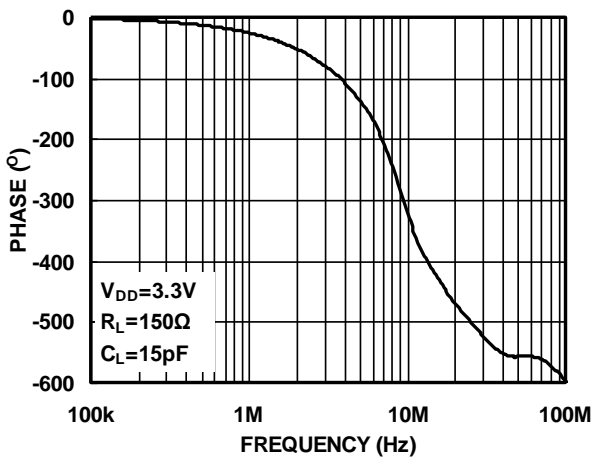


Figure5. Phase Vs. Frequency

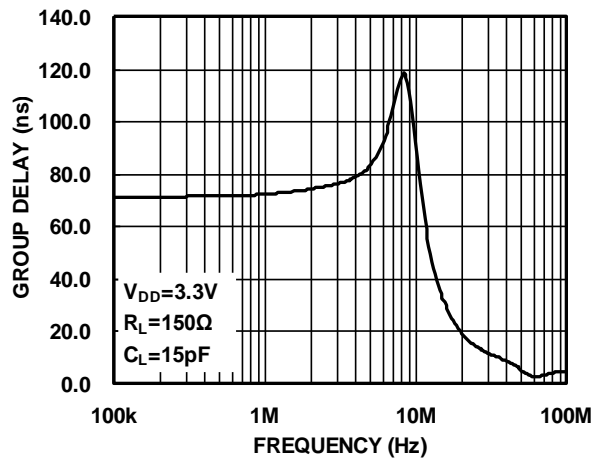


Figure6. Group Delay vs Frequency

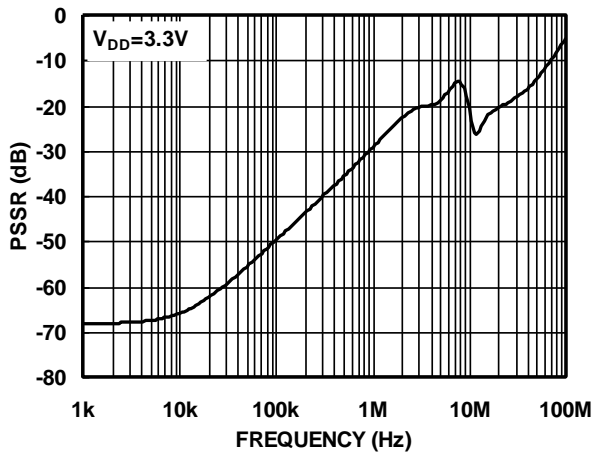


Figure7. PSRR Vs. Frequency

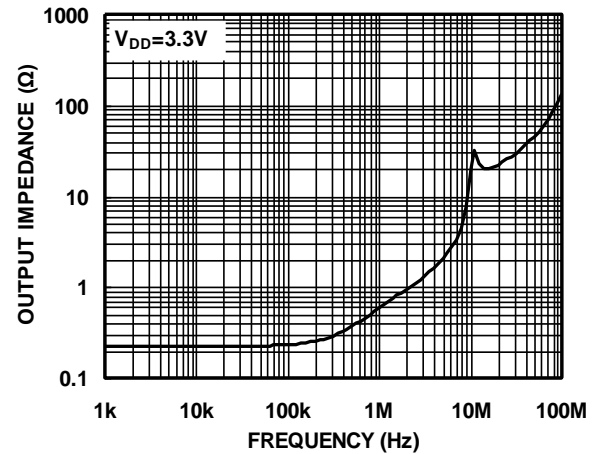


Figure8. Output Impedance Vs. Frequency

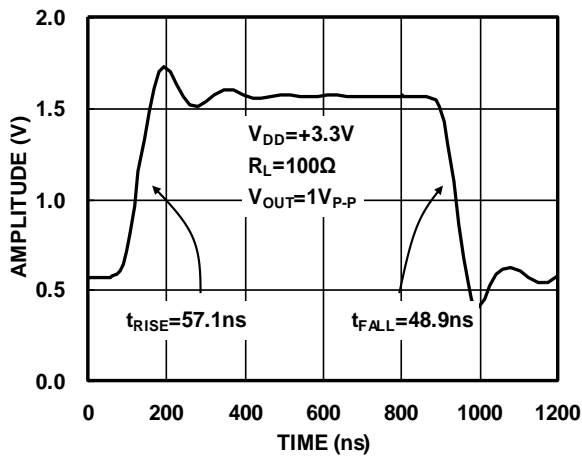


Figure9. Large-Signal Pulse Response Vs. Time

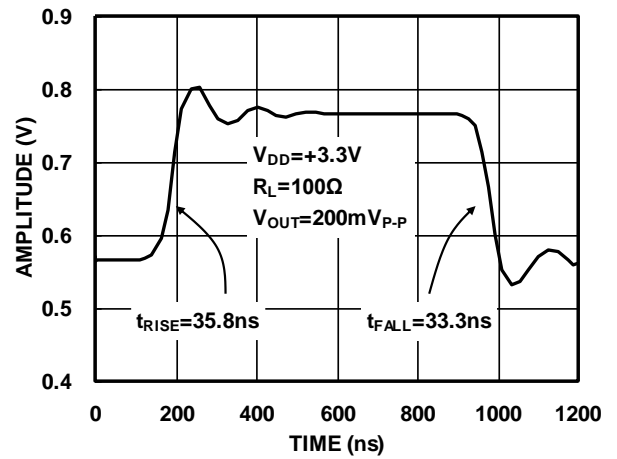


Figure10. Large-Signal Pulse Response Vs. Time

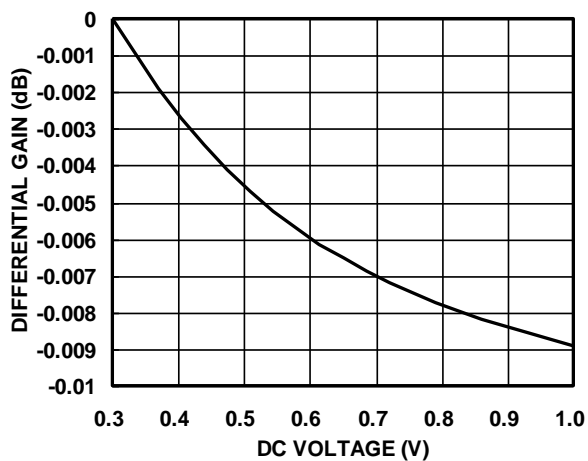


Figure11. Differential Gain(dG)

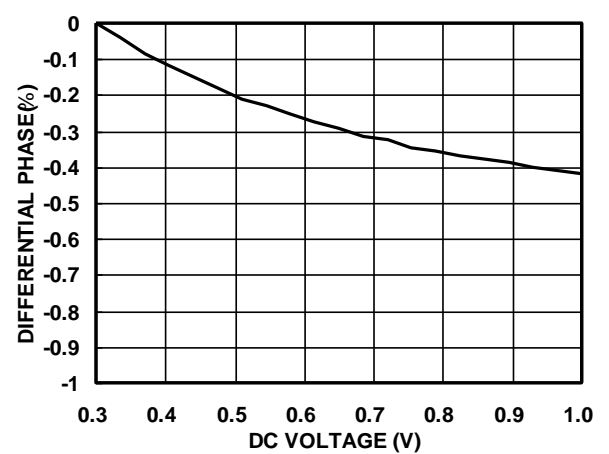


Figure12. Differential Phase(dP)

## Application Information

The TPF111 is a single supply rail-to-rail output amplifier achieving a -3dB bandwidth of around 9MHz and slew rate of about 38V/ $\mu$ s while demanding only 3.85mA of supply current. This part is ideally suited for applications with specific micropower consumption and high bandwidth demands. As the performance characteristics above and the features described below, the TPF111 is designed to be very attractive for portable composite video applications.

## Internal Sync Clamp

The typical embedded video DAC operates from a ground referenced single supply. This becomes an issue because the lower level of the sync pulse output may be at a 0V reference level to some positive level. The problem is presenting a 0V input to most single supply driven amplifiers will saturate the output stage of the amplifier resulting in a clipped sync tip and degrading the video image. A larger positive reference may offset the input above its positive range.

The TPF111 features an internal sync clamp and offset function to level shift the entire video signal to the best level before it reaches the input of the amplifier stage. These features are also helpful to avoid saturation of the output stage of the amplifier by setting the signal closer to the best voltage range.

The simplified block diagram of the TPF111 in Page-1. The AC coupled video sync signal is pulled negative by a current source at the input of the comparator amplifier. When the sync tip goes below the comparator threshold the output comparator is driven negative, The PMOS device turns on clamping sync tip to near ground level. The network triggers on the sync tip of video signal.

## Droop Voltage and DC Restoration

Selection of the input AC-coupling capacitance is based on the system requirements. A typical sync tip width of a 64 $\mu$ s NTSC line is 4 $\mu$ s during which clamp circuit restores its DC level. In the remaining 60 $\mu$ s period, the voltage droops because of a small constant 2.0 $\mu$ A sinking current. If the AC-coupling capacitance is 0.1 $\mu$ F, the maximum droop voltage is

about 1mV which is restored by the clamp circuit. The maximum pull-up current of the clamp circuit is 1.7mA. For a 4 $\mu$ s sync tip width and 0.1 $\mu$ F capacitor, the maximum restoration voltage is about 80mV.

The line droop voltage will increase if a smaller AC-coupling capacitance is used. For the same reason, if larger capacitance is used the line droop voltage will decrease. Table 1 is droop voltage and maximum restoration voltage of the clamp for typical capacitance.

**Table 1. Maximum restoration voltage and droop voltage of Y and CVBS signals for different capacitance**

| CAP VALUE<br>(nF) | DROOP IN 60 $\mu$ s<br>(mV) | CHARGE IN 4 $\mu$ s<br>(mV) |
|-------------------|-----------------------------|-----------------------------|
| 100               | 1.2                         | 68                          |
| 1,000             | 0.12                        | 6.8                         |

## Low Pass Filter--Sallen Key

The Sallen Key is a classic low pass configuration. This provides a very stable low pass function, and in the case of the TPF111, a six-pole roll-off at around 9MHz. The six-pole function is accomplished with an RC low pass network placed in series with and before the Sallen Key.

## Output Couple

TPF111 output could support both "AC Couple" and "DC Couple", if use "AC Couple", this capacitor is typically between 220- $\mu$ F and 1000- $\mu$ F, although 470- $\mu$ F is common. This value of this capacitor must be this large to minimize the line tilt (droop) and/or field tilt associated with ac-coupling as described previously in this document.

The TPF111 internal sync clamp makes it possible to DC couple the output to a video load, eliminating the need for any AC coupling capacitors, thereby saving board space and additional expense for capacitors. This makes the TPF111 extremely attractive for portable video applications. Additionally, this solution completely eliminates the issue of field tilt in the lower frequency. The trade off is greater demand of supply current. Typical load current for AC coupled is around 1mA, compared to typical 6.6mA used when DC coupling.

## Output Drive Capability and Power Dissipation

## TPF111/TPF111U

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With the high output drive capability of the TPF111, it is possible to exceed the +125°C absolute maximum junction temperature under certain load current conditions. Therefore, it is important to calculate the maximum junction temperature for an application to determine if load conditions or package types need to be modified to assure operation of the amplifier in a safe operating area. The maximum power dissipation allowed in a package is determined according to Equation:

$$PD_{MAX} = \frac{T_{JMAX} - T_{AMAX}}{\theta_{JA}}$$

Where:

$T_{JMAX}$  = Maximum junction temperature

$T_{AMAX}$  = Maximum ambient temperature

$\theta_{JA}$  = Thermal resistance of the package

The maximum power dissipation actually produced by an IC is the total quiescent supply current times the total power supply voltage, plus the power in the IC due to the load, or: for sourcing:

$$PD_{MAX} = V_s \times I_{SMAX} + (V_s - V_{OUT}) \times \frac{V_{OUT}}{R_L}$$

Where:

$V_s$  = Supply voltage

$I_{SMAX}$  = Maximum quiescent supply current

$V_{OUT}$  = Maximum output voltage of the application

$R_{LOAD}$  = Load resistance tied to ground

By setting the two PD<sub>MAX</sub> equations equal to each other, we can solve the output current and R<sub>LOAD</sub> to avoid the device overheat.

### Power Supply Bypassing Printed Circuit Board Layout

As with any modern operational amplifier, a good printed circuit board layout is necessary for optimum performance. Lead lengths should be as short as possible. The power supply pin must be well bypassed to reduce the risk of oscillation. For normal single supply operation, a single 4.7μF tantalum capacitor in parallel with a 0.1μF ceramic capacitor from VS+ to GND will suffice.

## VIDEO FILTER DRIVER SELECTION GUIDE

| P/N      | Product Description                                                                              | Channel       | -3dB Bandwidth | Package             |
|----------|--------------------------------------------------------------------------------------------------|---------------|----------------|---------------------|
| TPF110   | Low power, enable function and                                                                   | 1-SD          | 9MHz           | SC70-5              |
| /TPF110L | SAG correction, 1 channel 6 <sup>th</sup> order<br>9MHz                                          |               |                | SOT23-6             |
| TPF113   | Low power 3 channel, 6th-order<br>9MHz SD video filter                                           | 3-SD          | 9MHz           | SO-8                |
| TPF114   | Low power 4 channel, 6th-order<br>9MHz SD video filter                                           | 4-SD          | 9MHz           | MSOP-10<br>TSSOP-14 |
| TPF116   | Low power 4 channel, 6th-order<br>9MHz SD video filter for CVBS,<br>SVIDEO                       | 6-SD          | 9MHz           | TSSOP-14            |
| TPF123   | 3 channel 6th-order 13.5MHz,<br>960H/720H-CVBS video filter or<br>Y'Pb'Pr 480P/576P video filter | 3-ED          | 13.5MHz        | SO-8                |
| TPF133   | Low power 3 channel, 6th-order<br>36MHz HD video filter                                          | 3-HD          | 36MHz          | SO-8                |
| TPF134   | Low power 3 channel, 6th-order<br>36MHz HD video filter and 1 channel<br>SD video filter         | 1-SD&<br>3-SD | 9MHz<br>36MHz  | MSOP-10<br>TSSOP-14 |
| TPF136   | Low power 3 channel, 6th-order<br>36MHz HD video filter and 3 channel                            | 3-SD&<br>3-HD | 9MHz<br>36MHz  | TSSOP-20            |

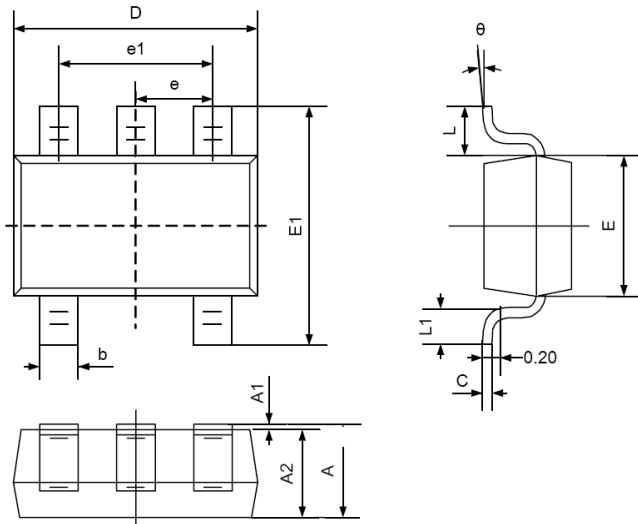


**TPF111/TPF111U**  
**Ultra-low Power, 1-Channel 6<sup>th</sup>-Order SD Video Filter Driver**

|        |                                                                                               |                |               |                     |
|--------|-----------------------------------------------------------------------------------------------|----------------|---------------|---------------------|
|        | SD video filter                                                                               |                |               |                     |
| TPF143 | Low power 3 channel, 6th-order<br>72MHz Full HD video filter                                  | 3-FHD          | 72MHz         | SO-8                |
| TPF144 | Low power 3 channel, 6th-order<br>72MHz Full HD video filter and 1<br>channel SD video filter | 1-SD&<br>3-FHD | 9MHz<br>72MHz | MSOP-10<br>TSSOP-14 |
| TPF146 | Low power 3 channel, 6th-order<br>72MHz Full HD video filter and 3<br>channel SD video filter | 3-SD&<br>3-FHD | 9MHz<br>72MHz | TSSOP-20            |
| TPF153 | Low power 3 channel, 6th-order<br>220MHz Full HD video filter                                 | 3-CH           | 220MHz        | SO-8                |

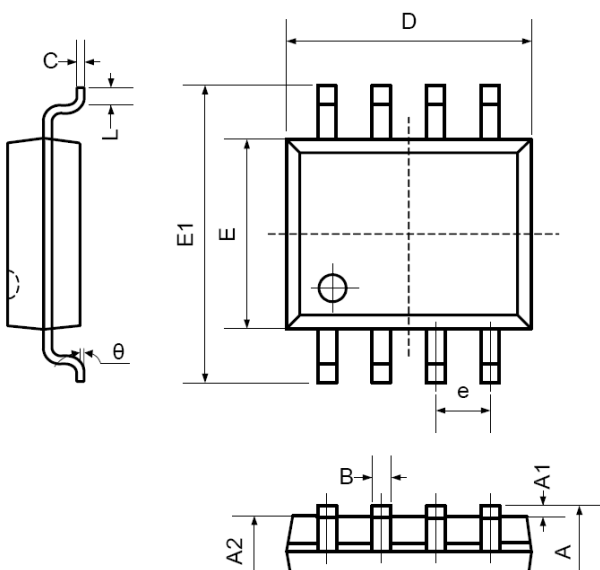
## Package Outline Dimensions

SC70-5 /SOT-353



| Symbol | Dimensions<br>In Millimeters |       | Dimensions In<br>Inches |       |
|--------|------------------------------|-------|-------------------------|-------|
|        | Min                          | Max   | Min                     | Max   |
| A      | 0.900                        | 1.100 | 0.035                   | 0.043 |
| A1     | 0.000                        | 0.100 | 0.000                   | 0.004 |
| A2     | 0.900                        | 1.000 | 0.035                   | 0.039 |
| b      | 0.150                        | 0.350 | 0.006                   | 0.014 |
| C      | 0.080                        | 0.150 | 0.003                   | 0.006 |
| D      | 2.000                        | 2.200 | 0.079                   | 0.087 |
| E      | 1.150                        | 1.350 | 0.045                   | 0.053 |
| E1     | 2.150                        | 2.450 | 0.085                   | 0.096 |
| e      | 0.650TYP                     |       | 0.026TYP                |       |
| e1     | 1.200                        | 1.400 | 0.047                   | 0.055 |
| L      | 0.525REF                     |       | 0.021REF                |       |
| L1     | 0.260                        | 0.460 | 0.010                   | 0.018 |
| θ      | 0°                           | 8°    | 0°                      | 8°    |

SO-8



| Symbol | Dimensions<br>In Millimeters |       | Dimensions In<br>Inches |       |
|--------|------------------------------|-------|-------------------------|-------|
|        | Min                          | Max   | Min                     | Max   |
| A      | 1.350                        | 1.750 | 0.053                   | 0.069 |
| A1     | 0.100                        | 0.250 | 0.004                   | 0.010 |
| A2     | 1.350                        | 1.550 | 0.053                   | 0.061 |
| B      | 0.330                        | 0.510 | 0.013                   | 0.020 |
| C      | 0.190                        | 0.250 | 0.007                   | 0.010 |
| D      | 4.780                        | 5.000 | 0.188                   | 0.197 |
| E      | 3.800                        | 4.000 | 0.150                   | 0.157 |
| E1     | 5.800                        | 6.300 | 0.228                   | 0.248 |
| e      | 1.270TYP                     |       | 0.050TYP                |       |
| L1     | 0.400                        | 1.270 | 0.016                   | 0.050 |
| θ      | 0°                           | 8°    | 0°                      | 8°    |

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