

## DIFFERENTIAL VARIABLE GAIN AMPLIFIER

- LOW NOISE :  $4.6\text{nV}/\sqrt{\text{Hz}}$
- LOW DISTORTION
- HIGH SLEW RATE :  $90\text{V}/\mu\text{s}$
- WIDE BANDWIDTH :  $52\text{MHz}$  @  $-3\text{dB}$  &  $18\text{dB}$  gain
- GAIN PROGRAMMABLE from  $-9\text{dB}$  to  $+30\text{dB}$  with  $3\text{dB}$  STEPS
- POWER DOWN FUNCTION

### DESCRIPTION

The TS652 is a differential digitally controled variable gain amplifier featuring a high slew rate of  $90\text{V}/\mu\text{s}$ , a large bandwidth, a very low distortion and a very low current and voltage noise.

The gain can be set from  $-9\text{dB}$  to  $+30\text{dB}$  through a 4bit digital word, with  $3\text{dB}$  steps.

The gain monotonicity is guaranteed by design.

This device is particularly intended for applications such as preamplification in telecommunication systems using multiple carriers.

### APPLICATION

- Preamplifier and automatic gain control for Assymetric Digital Subscriber Line (ADSL).

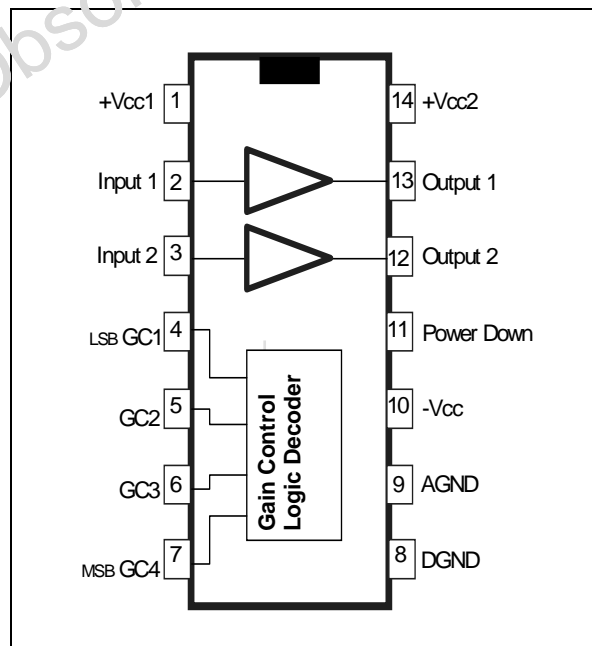
### ORDER CODE

| Part Number | Temperature Range          | Package |
|-------------|----------------------------|---------|
|             |                            | D       |
| TS652ID     | $-40, +85^{\circ}\text{C}$ | •       |

D = Small Outline Package (SO) - also available in Tape & Reel (DT)



### PIN CONNECTIONS (top view)



**ABSOLUTE MAXIMUM RATINGS**

| Symbol     | Parameter                                    | Value       | Unit |
|------------|--|-------------|------|
| $V_{CC}$   | Supply voltage <sup>1)</sup>                 | 14          | V    |
| $V_i$      | Input Voltage <sup>2)</sup>                  | 0 to 14     | V    |
| $T_{oper}$ | Operating Free Air Temperature Range TS652ID | -40 to + 85 | °C   |
| $T_{std}$  | Storage Temperature                          | -65 to +150 | °C   |
| $T_j$      | Maximum Junction Temperature                 | 150         | °C   |
| $R_{thjc}$ | Thermal Resistance Junction to Case          | 22          | °C/W |
| $R_{thja}$ | Thermal Resistance Junction to Ambiente Area | 125         | °C/W |
|            | Output Short Circuit Duration                | Infinite    |      |

1. All voltages values are with respect to network terminal.

2. The magnitude of input and output voltages must never exceed  $V_{CC} + 0.3V$ .

**OPERATING CONDITIONS**

| Symbol    | Parameter                 | Value      | Unit |
|-----------|---------------------------|------------|------|
| $V_{CC}$  | Supply Voltage            | 5 to 12    | V    |
| $V_{icm}$ | Common Mode Input Voltage | $V_{CC}/2$ | V    |

**ELECTRICAL CHARACTERISTICS.**  $V_{CC} = \pm 6\text{Volts}$ ,  $T_{amb} = 25^\circ\text{C}$  (unless otherwise specified).

| Symbol                      | Parameter  | Test Condition  | Min.          | Typ.               | Max | Unit                   |
|-----------------------------|--|---|---------------|--------------------|-----|------------------------|
| <b>DC PERFORMANCE</b>       |  |   |               |                    |     |                        |
| $V_i$                       | Voltage on the Input Pin   |   |               | 0                  |     | V                      |
| $I_{CC}$                    | Total Supply Current   | No load, $V_{out} = 0$  |               | 28                 |     | mA                     |
| $\Delta V_{OFFSET}$         | Differential Input Offset Voltage  | $V_{in} = 0$ , $A_V = 30\text{dB}$  |               |                    | 6   | mV                     |
| SVR                         | Supply Voltage Rejection Ratio   | $A_V = 0\text{dB}$  | 50            | 80                 |     | dB                     |
| <b>POWER DOWN MODE</b>      |  |   |               |                    |     |                        |
| $V_{pdw}$                   | Thershold Voltage for Power Down Mode (high level active)                          | Low Level   |               | 0                  | 0.8 | V                      |
|                             |  | High Level  | 2             | 3.3                |     | V                      |
| $I_{ccpdw}$                 | Power Down Total Consumption   | Power Down Mode   |               |                    | 150 | $\mu\text{A}$          |
| $Z_{out}$                   | Power Down Output Impedance  | Power Down Mode   | 100k $\Omega$ | 150k $\Omega$ /5pF |     |                        |
| <b>AC PERFORMANCE</b>       |  |   |               |                    |     |                        |
| $Z_{in}$                    | Input Impedance  |   |               | 100k $\Omega$ /5pF |     |                        |
| $V_{OH}$                    | High Level Output Voltage<br>$R_L$ connected to GND                                | $R_L = 500\Omega$   | 4             | 4.5                |     | V                      |
| $V_{OL}$                    | Low Level Output Voltage<br>$R_L$ connected to GND                                 | $R_L = 500\Omega$   |               | -4.5               | -4  | V                      |
| $A_V$                       | Voltage Gain   | $F = 1\text{MHz}$   | -9            |                    | 30  | dB                     |
|                             | Gain monotonicity guaranteed by design   |   |               |                    |     |                        |
| $P_{AV}$                    | Precision of the Voltage Gain  | $F = 1\text{MHz}$   | -1            |                    | 1   | dB                     |
| $A_{Vstep}$                 | Step Value   | $F = 1\text{MHz}$   | 2.4           | 3                  | 3.6 | dB                     |
| $A_{vmin}$                  | Gain Mismatch between Both Channels  | $F = 1\text{MHz}$   |               |                    | 1   | dB                     |
| $B_w$                       | Bandwidth @ -3dB<br>$R_L = 500\Omega$<br>$C_L = 15\text{pF}$                       | $A_V = -9\text{dB}$   | 55            | 110                | 200 | MHz                    |
|                             |  | $A_V = 0\text{dB}$  | 32            | 69                 | 132 |                        |
|                             |  | $A_V = +18\text{dB}$  | 26            | 52                 | 100 |                        |
|                             |  | $A_V = +30\text{dB}$  | 10            | 18                 | 36  |                        |
| $R_{bw}$                    | Bandwidth Roll-off   | $A_V = +30\text{dB}$ , $F = 1\text{MHz}$  |               | 0.08               |     | dB                     |
| $I_o$                       | Bandwidth @ -3dB<br>$R_L = 500\Omega$ , $C_L = 15\text{pF}$                        | Source  | 17            | 28                 |     | mA                     |
|                             |  | Sink  | 17            | 22                 |     |                        |
| SR                          | Slew Rate (gain independent)   | $V_o = 2\text{Vpeak}$   | 50            | 100                |     | V/ $\mu\text{s}$       |
| <b>NOISE AND DISTORTION</b> |  |   |               |                    |     |                        |
| $i_n$                       | Equivalent Input Noise Current   | $F = 100\text{kHz}$   |               | 1.5                |     | pA/ $\sqrt{\text{Hz}}$ |
| $e_n$                       | Equivalent Input Noise Voltage   | $F = 100\text{kHz}$<br>$A_V = 30\text{dB}$                                      |               | 4.6                |     | nV/ $\sqrt{\text{Hz}}$ |
| THD30                       | Harmonic Distorsion  | 1Vpeak, $F = 150\text{kHz}$ ,<br>$A_V = +30\text{dB}$ , $R_L = 500\Omega$ /15pF |               |                    |     | dBc                    |
|                             |  | H2  |               | -70                |     |                        |
|                             |  | H3  |               | -93                |     |                        |
|                             |  | H4  |               | -98                |     |                        |
|                             |  | H5  |               | -99                |     |                        |
| IM3                         | Third Order Intermodulation Product<br>$F1 = 180\text{kHz}$ , $F2 = 280\text{kHz}$ | $V_{out} = 1\text{Vpeak}$ , $A_V = +30\text{dB}$<br>$R_L = 500\Omega$ /15pF     |               |                    |     | dBc                    |
|                             |  | @ 80kHz   |               | -77                |     |                        |
|                             |  | @ 380kHz  |               | -85                |     |                        |
|                             |  | @ 640kHz  |               | -86                |     |                        |
|                             |  | @ 740kHz  |               | -87                |     |                        |
| IM3                         | Third Order Intermodulation Product<br>$F1 = 70\text{kHz}$ , $F2 = 80\text{kHz}$   | $V_{out} = 1\text{Vpeak}$ , $A_V = +30\text{dB}$<br>$R_L = 500\Omega$ /15pF     |               |                    |     | dBc                    |
|                             |  | @ 60kHz   |               | -77                |     |                        |
|                             |  | @ 90kHz   |               | -79                |     |                        |
|                             |  | @ 220kHz  |               | -83                |     |                        |
|                             |  | @ 230kHz  |               | -84                |     |                        |

## DIGITAL INPUTS

| Symbol                | Parameter  | Min. | Typ. | Max. | Unit |
|-----------------------|------------|------|------|------|------|
| GC1, GC2, GC3 and GC4 | Low Level  |      | 0    | 0.8  | V    |
|                       | High Level | 2    | 3.3  |      |      |

## SIMPLIFIED SCHEMATIC

The TS652 consists of two independent channels.

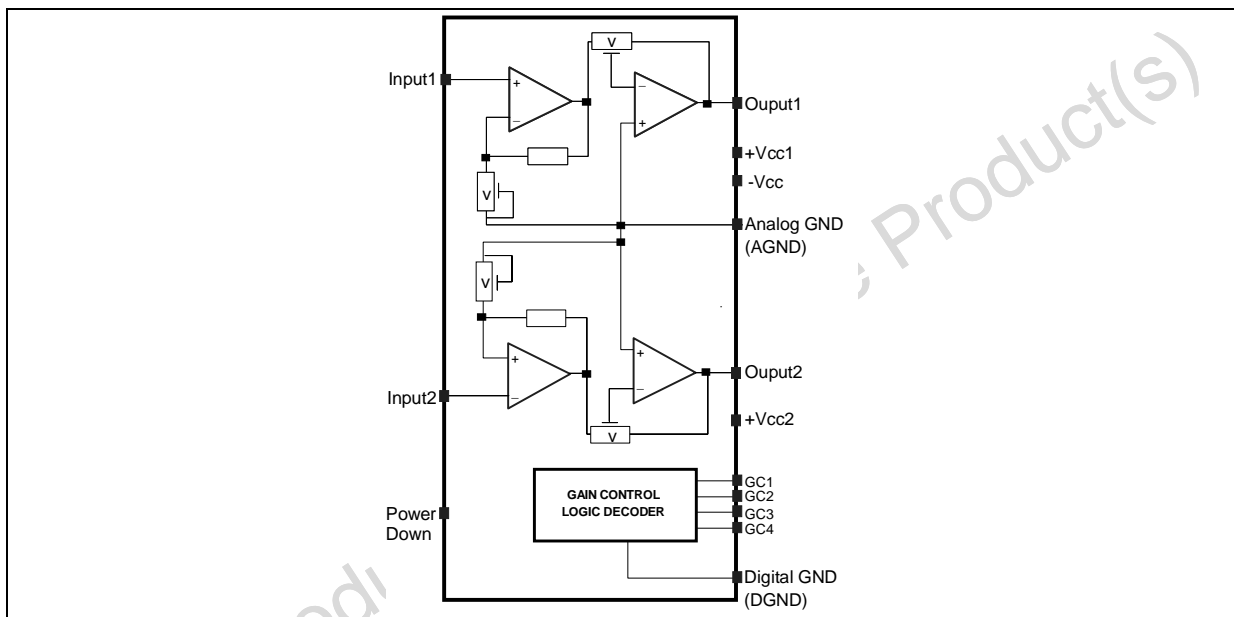
Each channel has two stages. The first is a very low noise digitally controlled variable gain amplifier (range 0 to 18dB).

The TS652 features a high input impedance and a low noise current. To minimize the overall noise figure, the source impedance must be less than 3k $\Omega$ .

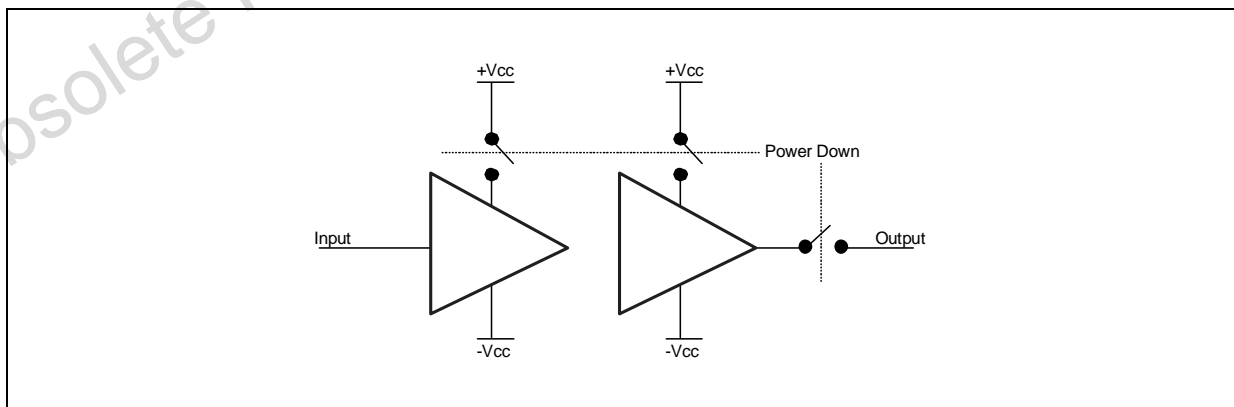
This value gives an equal contribution of voltage and current noises.

The second stage is a gain/attenuation stage (+12dB to -9dB) featuring a low output impedance.

This output stage can drive loads as low as 500 $\Omega$ .



## POWER DOWN MODE POSITION



## BANDWIDTH

The small signal bandwidth is almost constant for gains between +18dB to 0dB and is in the order of 52MHz to 70MHz respectively. For 30dB gain the bandwidth is around 18MHz.

The power bandwidth is typically equal to 30MHz for 2V peak to peak signals.

## MAXIMUM INPUT LEVEL

The input level must not exceed the following values :

negative peak value: must be greater than  $-V_{CC} + 1.5V$

positive peak value: must be less than  $+V_{CC} - 1.5V$

For example, if a  $\pm 6V$  power supply is used, the input signal can swing between -4.5V and +4.5V.

These values are due to common mode input range limitations of the input stage of the first amplifier.

Some other limitations may occur, due to the slew rate of the first operational amplifier (typically in the order of 300V/ $\mu s$ ). This means that the maximum input signal decreases at high frequency.

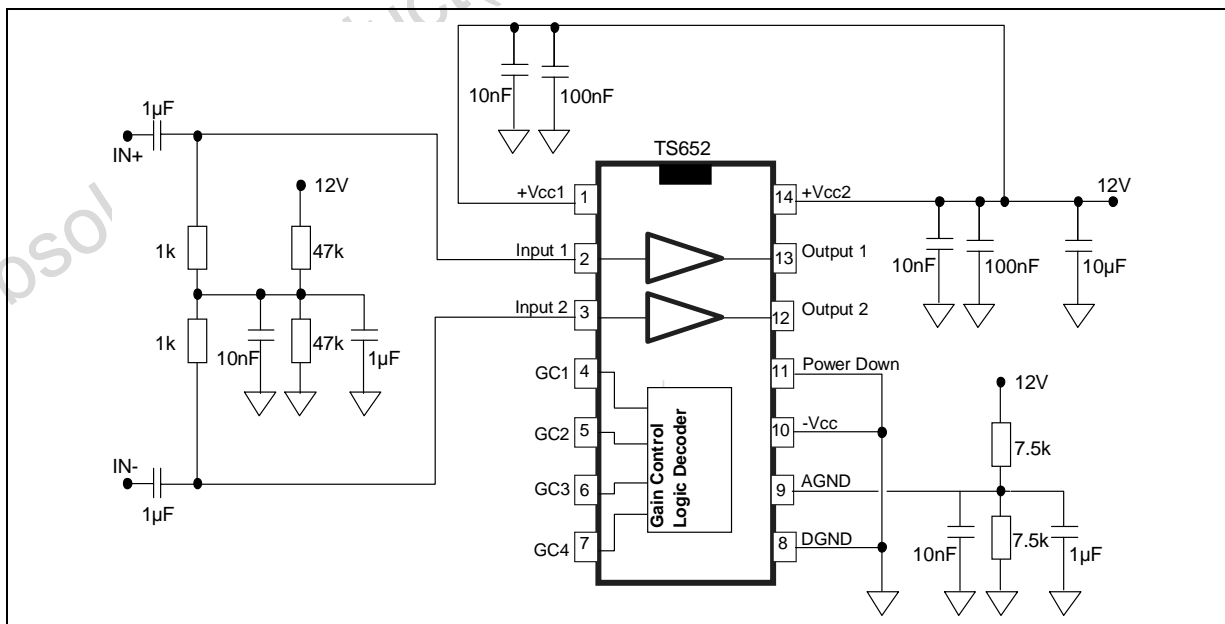
## SINGLE SUPPLY OPERATION

The incoming signal is AC coupled to the inputs.

The TS652 can be used either with a dual or a single supply. If a single supply is used, the inputs are biased to the mid supply voltage ( $+V_{CC/2}$ ). This bias network must be carefully designed, in order to reject any noise present on the supply rail.

The AGND pin (9) must be connected to  $+V_{CC/2}$ . The bias current of the second stage (inverting structure) is 8 $\mu A$  for both amplifiers. A resistor divider structure can be used. Two resistances should be chosen by considering 8 $\mu A$  as the 1% of the total current through these resistances. For a single +12V supply voltage, two resistances of 7.5k $\Omega$  can be used. The differential input consists of a high pass circuit, formed by the 1 $\mu F$  capacitor and a 1k $\Omega$  resistance and gives a break frequency of 160Hz.

## SINGLE +12V SUPPLY OF THE TS652



## GAIN CONTROL

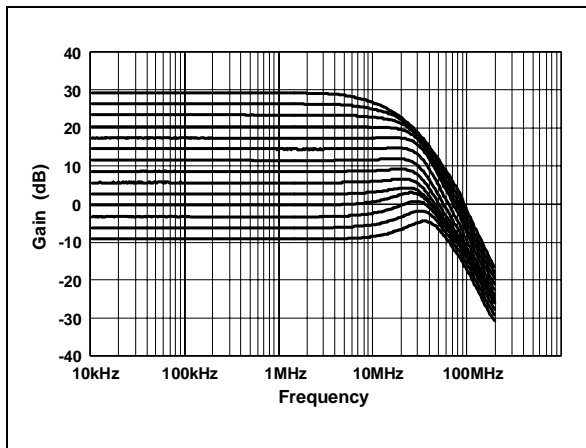
The gain and the power down mode is programmed with a 4 bit digital word :

| Digital Control<br>GC4....GC1<br>MSB LSB | Total Gain<br>(dB) | First Stage<br>Gain<br>(dB) | Second Stage<br>Gain<br>(dB) | Maximum<br>Input Level | Bandwidth<br>Small Signal | Eq. Input<br>Noise<br>(nV/√Hz) |
|--|--------------------|-----------------------------|------------------------------|------------------------|---------------------------|--------------------------------|
| \$0000                                   | -9                 | 0                           | -9                           | 2.8Vrms                | 110mHZ                    | 29                             |
| \$0001                                   | -6                 | 0                           | -6                           | 2.8Vrms                | 100MHz                    | 26                             |
| \$0010                                   | -3                 | 0                           | -3                           | 2.8Vrms                | 85MHz                     | 23                             |
| \$0011                                   | 0                  | 0                           | 0                            | 2.8Vrms                | 69MHz                     | 22                             |
| \$0100                                   | 3                  | 3                           | 0                            | 2Vrms                  | 63MHz                     | 16                             |
| \$0101                                   | 6                  | 6                           | 0                            | 1.4Vrms                | 58MHz                     | 12                             |
| \$0110                                   | 9                  | 9                           | 0                            | 1Vrms                  | 56MHz                     | 9                              |
| \$0111                                   | 12                 | 12                          | 0                            | 0.7Vrms                | 55MHz                     | 7                              |
| \$1000                                   | 15                 | 15                          | 0                            | 0.5Vrms                | 54MHz                     | 6                              |
| \$1001                                   | 18                 | 18                          | 0                            | 0.35Vrms               | 52MHz                     | 4.8                            |
| \$1010                                   | 21                 | 21                          | 3                            | 0.25Vrms               | 42MHz                     | 4.7                            |
| \$1011                                   | 24                 | 24                          | 6                            | 175mVrms               | 30MHz                     | 4.7                            |
| \$1100                                   | 27                 | 27                          | 9                            | 125mVrms               | 24MHz                     | 4.6                            |
| \$1101                                   | 30                 | 30                          | 12                           | 88mVrms                | 18MHz                     | 4.6                            |
| \$1110                                   | 30                 | 30                          | 12                           | 88mVrms                | 18MHz                     | 4.6                            |
| \$1111                                   | 30                 | 30                          | 12                           | 88mVrms                | 18MHz                     | 4.6                            |

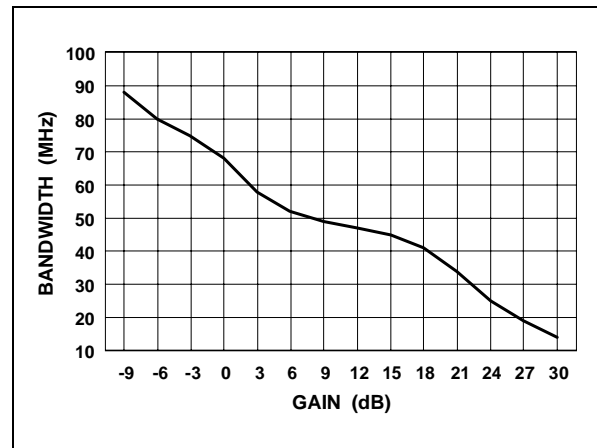
The gain is the same for both channels.

The digital inputs are CMOS compatible. The supply voltage of the logic decoder used to transcode the digital word can be either 3.3V or 5V or  $V_{CC}$ .

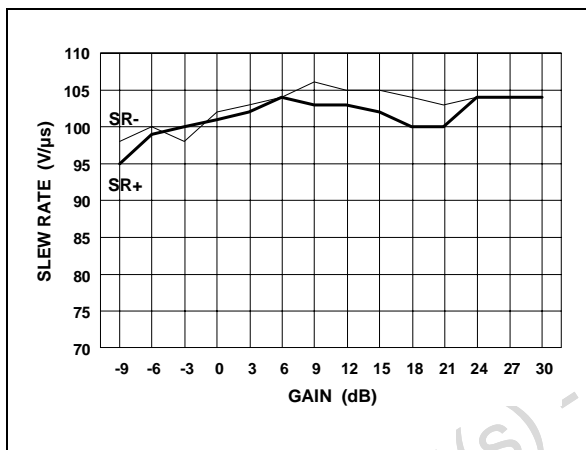
Closed Loop Gain vs Frequency



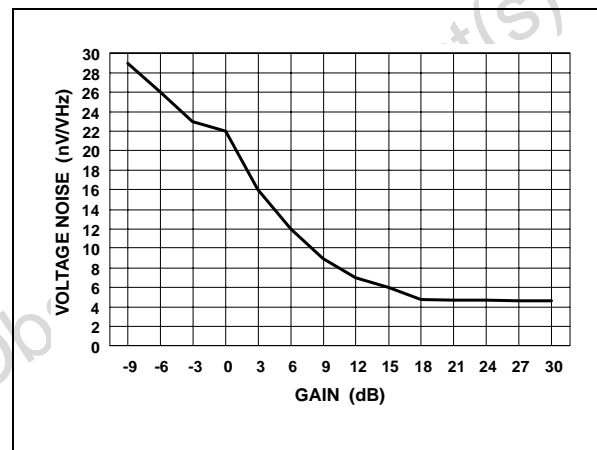
Bandwidth vs Gain



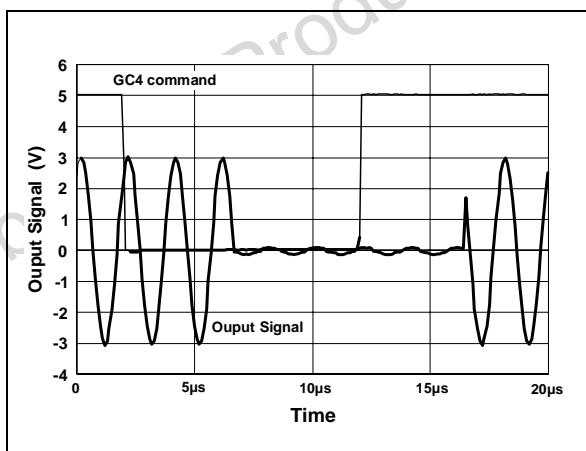
Negative &amp; Positive Slew Rate vs Gain



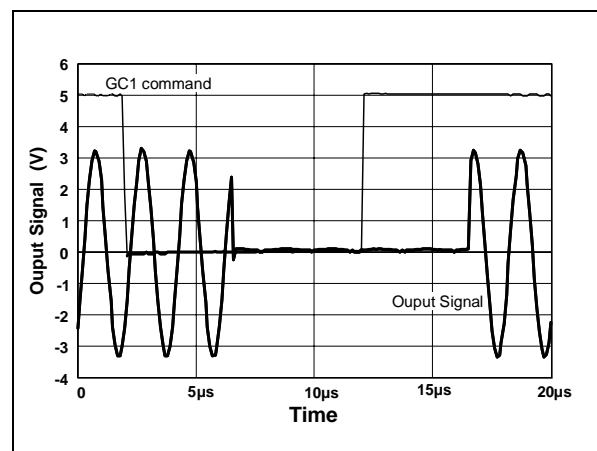
Equivalent Input Voltage Noise vs Gain



Gain Switching (+15dB to -9dB)

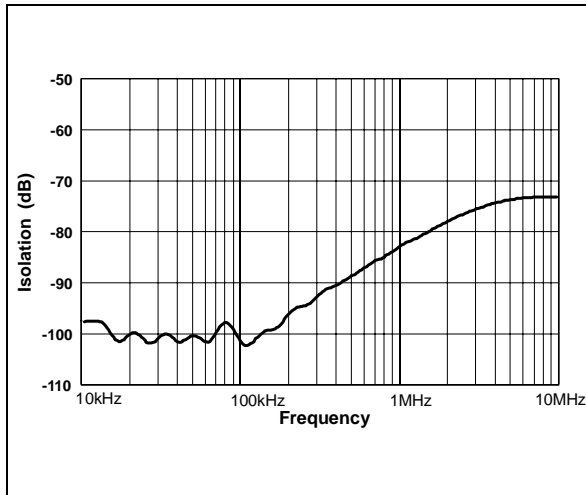


Gain Switching (+30dB to +9dB)

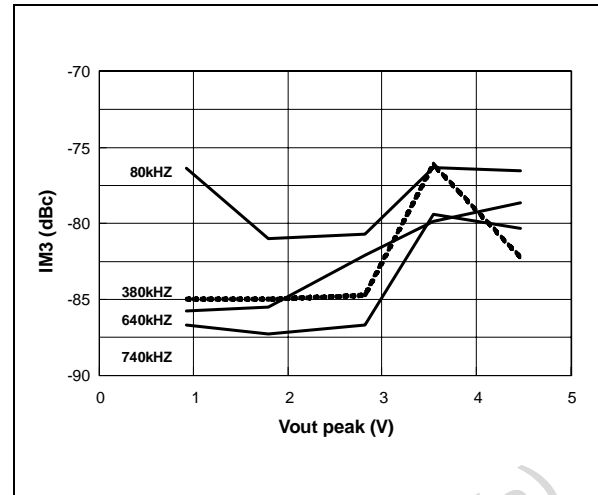


measurement conditions:  $V_{CC} = \pm 6V$ ,  $R_{load} = 500\Omega$ ,  $T_{amb} = 25^\circ C$

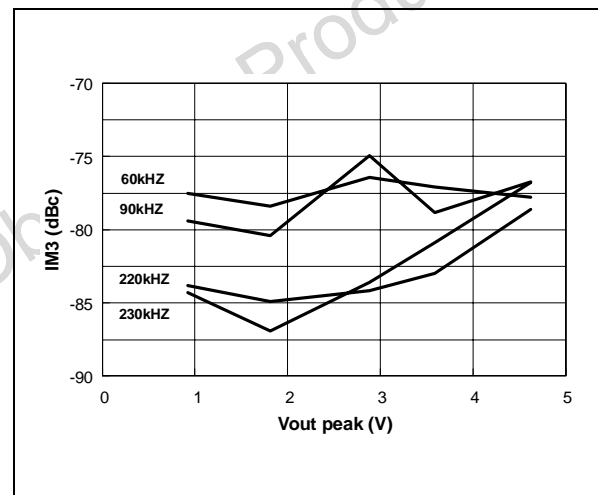
### Output/Input Isolation in Power Down Mode vs Frequency



### 3rd Order Intermodulation (2 tones : 180kHz and 280kHz)

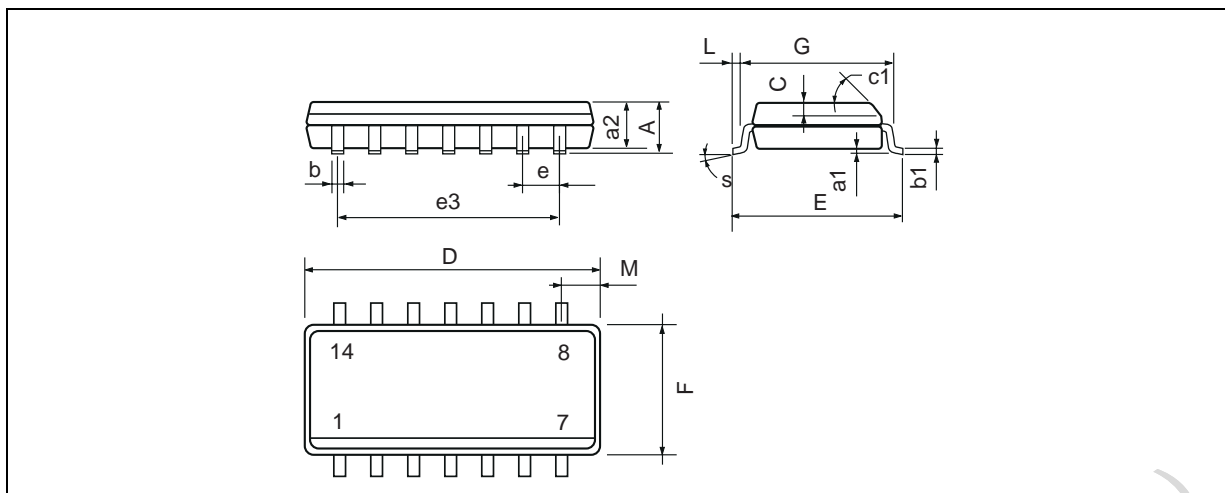


### 3rd Order Intermodulation (2 tones : 180kHz and 280kHz)



measurement conditions:  $V_{cc}=\pm 6V$ ,  $R_{load}=500\Omega$ ,  $T_{amb}=25^{\circ}C$



**PACKAGE MECHANICAL DATA****14 PINS - PLASTIC MICROPACKAGE (SO)**

| Dimensions | Millimeters |      |      | Inches |       |       |
|------------|-------------|------|------|--------|-------|-------|
|            | Min.        | Typ. | Max. | Min.   | Typ.  | Max.  |
| A          |             |      | 1.75 |        |       | 0.069 |
| a1         | 0.1         |      | 0.2  | 0.004  |       | 0.008 |
| a2         |             |      | 1.6  |        |       | 0.063 |
| b          | 0.35        |      | 0.46 | 0.014  |       | 0.018 |
| b1         | 0.19        |      | 0.25 | 0.007  |       | 0.010 |
| C          |             | 0.5  |      |        | 0.020 |       |
| c1         | 45° (typ.)  |      |      |        |       |       |
| D (1)      | 8.55        |      | 8.75 | 0.336  |       | 0.344 |
| E          | 5.8         |      | 6.2  | 0.228  |       | 0.244 |
| e          |             | 1.27 |      |        | 0.050 |       |
| e3         |             | 7.62 |      |        | 0.300 |       |
| F (1)      | 3.8         |      | 4.0  | 0.150  |       | 0.157 |
| G          | 4.6         |      | 5.3  | 0.181  |       | 0.208 |
| L          | 0.5         |      | 1.27 | 0.020  |       | 0.050 |
| M          |             |      | 0.68 |        |       | 0.027 |
| S          | 8° (max.)   |      |      |        |       |       |

Note : (1) D and F do not include mold flash or protrusions - Mold flash or protrusions shall not exceed 0.15mm (.066 inc) ONLY FOR DATA BOOK.

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