

# Low Voltage Compandor

## SA575

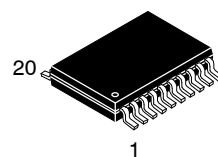
The SA575 is a precision dual gain control circuit designed for low voltage applications. The SA575's channel 1 is an expander, while channel 2 can be configured either for expander, compressor, or automatic level controller (ALC) application.

### Features

- Operating Voltage Range from 3.0 V to 7.0 V
- Reference Voltage of 100 mV<sub>RMS</sub> = 0 dB
- One Dedicated Summing Op Amp Per Channel and Two Extra Uncommitted Op Amps
- 600  $\Omega$  Drive Capability
- Single or Split Supply Operation
- Wide Input/Output Swing Capability
- These Devices are Pb-Free, Halogen Free/BFR Free and are RoHS Compliant

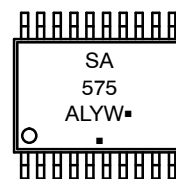
### Applications

- Portable Communications
- Cellular Radio
- Cordless Telephone
- Consumer Audio
- Portable Broadcast Mixers
- Wireless Microphones
- Modems
- Electric Organs
- Hearing Aids



TSSOP-20  
DTB SUFFIX  
CASE 948E

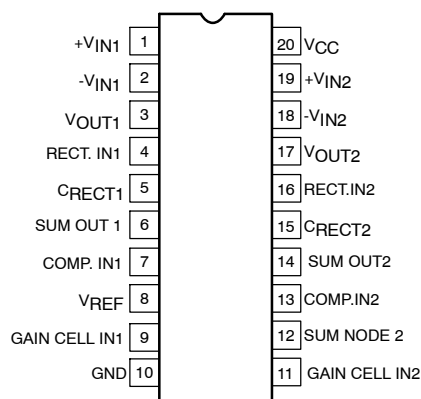
### MARKING DIAGRAM



A = Assembly Location  
 WL, L = Wafer Lot  
 YY, Y = Year  
 WW, W = Work Week  
 ■ = Pb-Free Package

(Note: Microdot may be in either location)

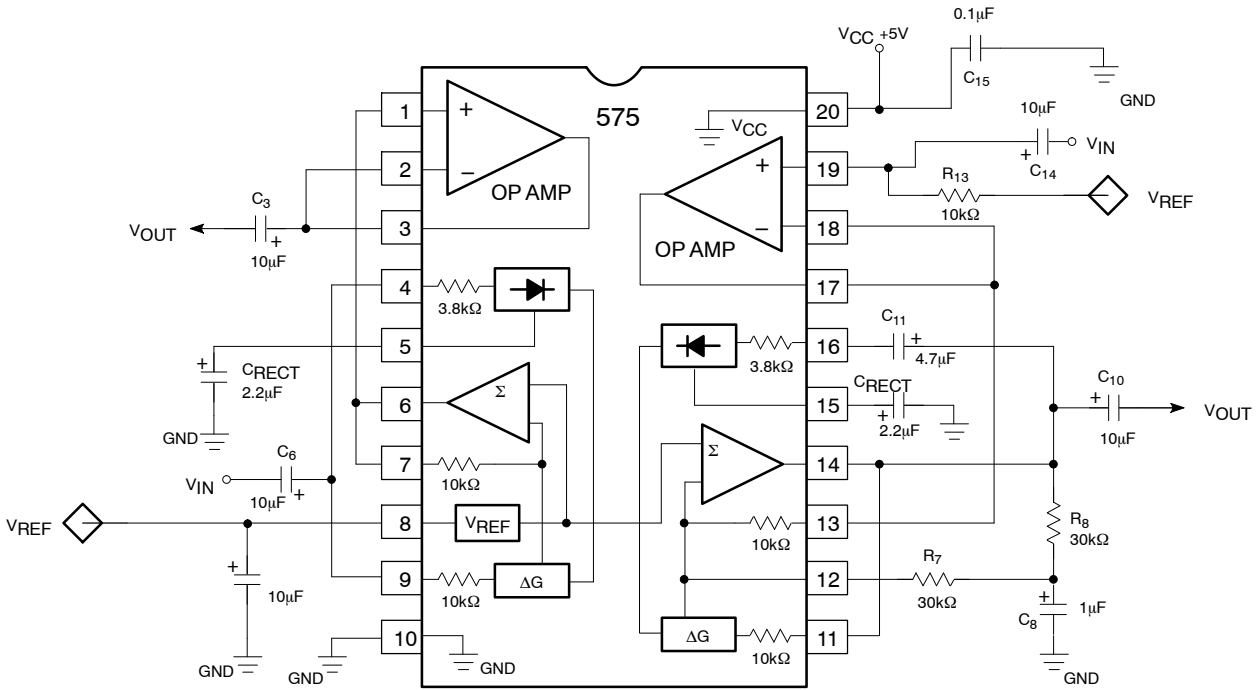
### PIN CONNECTIONS



### ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 12 of this data sheet.

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**Figure 1. Block Diagram and Test Circuit**

## PIN FUNCTION DESCRIPTION

| Pin | Symbol        | Description                               |
|-----|---------------|-------------------------------------------|
| 1   | $+V_{IN1}$    | Non-Inverted Input 1                      |
| 2   | $-V_{IN1}$    | Inverted Input 1                          |
| 3   | $V_{OUT}$     | Output                                    |
| 4   | RECT. IN1     | Rectifier 1 Input                         |
| 5   | $C_{RECT1}$   | External Capacitor Pinout for Rectifier 1 |
| 6   | SUM OUT1      | Summation Output 1                        |
| 7   | COMP. IN1     | Compensator Pin                           |
| 8   | $V_{REF}$     | Voltage Reference                         |
| 9   | GAIN CELL IN1 | Variable Gain Cell Input 1                |
| 10  | GND           | Ground                                    |
| 11  | GAIN CELL IN2 | Variable Gain Cell Input 2                |
| 12  | SUM NODE 2    | Summation Node 2                          |
| 13  | COMP. IN2     | Compensator Pin                           |
| 14  | SUM OUT2      | Summation Output 2                        |
| 15  | $C_{RECT2}$   | External Capacitor Pinout for Rectifier 2 |
| 16  | RECT. IN2     | Rectifier 2 Input                         |
| 17  | $V_{OUT2}$    | Output 2                                  |
| 18  | $-V_{IN2}$    | Inverted Input 2                          |
| 19  | $+V_{IN2}$    | Non-Inverted Input 2                      |
| 20  | $V_{CC}$      | Positive Power Supply                     |

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## MAXIMUM RATINGS

| Rating                              | Symbol        | Value                      | Unit |
|-------------------------------------|---------------|----------------------------|------|
| Single Supply Voltage               | $V_{CC}$      | -0.3 to 8.0                | V    |
| Voltage Applied to Any Other Pin    | $V_{IN}$      | -0.3 to ( $V_{CC} + 0.3$ ) | V    |
| Operating Ambient Temperature Range | $T_A$         | -40 to +85                 | °C   |
| Operating Junction Temperature      | $T_J$         | 150                        | °C   |
| Storage Temperature Range           | $T_{STG}$     | 150                        | °C   |
| Thermal Impedance                   | $\theta_{JA}$ | 124                        | °C/W |
| Maximum Power Dissipation           | $P_D$         | 1068                       | mW   |

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

**DC ELECTRICAL CHARACTERISTICS** Typical values are at  $T_A = 25^\circ\text{C}$ . Minimum and Maximum values are for the full operating temperature range: -40 to +85°C for SA575, except SSOP package is tested at +25°C only.  $V_{CC} = 5.0\text{ V}$ , unless otherwise stated. Both channels are tested in the Expandor mode (see Test Circuit).

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|----------------|--------|-----------------|-----|-----|-----|------|
|----------------|--------|-----------------|-----|-----|-----|------|

### FOR COMPANDOR, INCLUDING SUMMING AMPLIFIER

|                                 |           |                                                                      |      |      |     |               |
|---------------------------------|-----------|----------------------------------------------------------------------|------|------|-----|---------------|
| Supply Voltage (Note 1)         | $V_{CC}$  | –                                                                    | 3.0  | 5.0  | 7.0 | V             |
| Supply Current                  | $I_{CC}$  | No Signal                                                            | 3.0  | 4.2  | 5.5 | mA            |
| Reference Voltage (Note 2)      | $V_{REF}$ | $V_{CC} = 5.0\text{ V}$                                              | 2.4  | 2.5  | 2.6 | V             |
| Summing Amp Output Load         | $R_L$     | –                                                                    | 10   | –    | –   | k $\Omega$    |
| Total Harmonic Distortion       | THD       | 1.0 kHz, 0 dB, BW = 3.5 kHz                                          | –    | 0.12 | 1.5 | %             |
| Output Voltage Noise            | $E_{NO}$  | BW = 20 kHz, $R_S = 0\ \Omega$                                       | –    | 6.0  | 30  | $\mu\text{V}$ |
| Unity Gain Level                | 0dB       | 1.0 kHz                                                              | -1.5 | –    | 1.5 | dB            |
| Output Voltage Offset           | $V_{OS}$  | No Signal                                                            | -150 | –    | 150 | mV            |
| Output DC Shift                 |           | No Signal to 0 dB                                                    | -100 | –    | 100 | mV            |
| Tracking Error Relative to 0 dB |           | Gain Cell Input = 0 dB, 1.0 kHz<br>Rectifier Input = 6.0 dB, 1.0 kHz | -1.0 | –    | 1.0 | dB            |
|                                 |           | Gain Cell Input = 0 dB, 1.0 kHz<br>Rectifier Input = -30 dB, 1.0 kHz | -1.0 | –    | 1.0 | dB            |
| Crosstalk                       |           | 1.0 kHz, 0 dB, $C_{REF} = 220\ \mu\text{F}$                          | –    | -80  | -65 | dB            |

### FOR OPERATIONAL AMPLIFIER

|                              |           |                                         |              |          |          |                  |
|------------------------------|-----------|-----------------------------------------|--------------|----------|----------|------------------|
| Output Swing                 | $V_O$     | $R_L = 10\text{ k}\Omega$               | $V_{CC}-0.4$ | $V_{CC}$ | –        | V                |
| Output Load                  | $R_L$     | 1.0 kHz                                 | 600          | –        | –        | $\Omega$         |
| Input Common-Mode Range      | CMR       | –                                       | 0            | –        | $V_{CC}$ | V                |
| Common-Mode Rejection Ratio  | CMRR      | –                                       | 60           | 80       | –        | dB               |
| Input Bias Current           | $I_B$     | $V_{IN} = 0.5\text{ V to }4.5\text{ V}$ | -1.0         | –        | 1.0      | $\mu\text{A}$    |
| Input Offset Voltage         | $V_{OS}$  | –                                       | –            | 3.0      | –        | mV               |
| Open-Loop Gain               | $A_{VOL}$ | $R_L = 10\text{ k}\Omega$               | –            | 80       | –        | dB               |
| Slew Rate                    | SR        | Unity Gain                              | –            | 1.0      | –        | V/ $\mu\text{s}$ |
| Bandwidth                    | GBW       | Unity Gain                              | –            | 3.0      | –        | MHz              |
| Input Voltage Noise          | $E_{NI}$  | BW = 20 kHz                             | –            | 2.5      | –        | $\mu\text{V}$    |
| Power Supply Rejection Ratio | PSRR      | 1.0 kHz, 250 mV                         | –            | 60       | –        | dB               |

1. Operation down to  $V_{CC} = 2.0\text{ V}$  is possible, but performance is reduced. See curves in Figures 6 and 7.
2. Reference voltage,  $V_{REF}$  is typically at  $1/2\ V_{CC}$ .

## Functional Description

This section describes the basic subsystems and applications of the SA575 Compressor. More theory of operation on compressors can be found in AND8159 and AND8160. The typical applications of the SA575 low voltage compressor in an Expander (1:2), Compressor (2:1) and Automatic Level Control (ALC) function are explained. These three circuit configurations are shown in Figures 2, 3, and 4 respectively.

The SA575 has two channels for a complete compressing system. The left channel, A, can be configured as a 1:2 Expander while the right channel, B, can be configured as either a 2:1 Compressor, a 1:2 Expander or an ALC. Each channel consists of the basic compressing building blocks of rectifier cell, variable gain cell, summing amplifier and  $V_{REF}$  cell. In addition, the SA575 has two additional high performance uncommitted op amps which can be utilized for application such as filtering, pre-emphasis/de-emphasis or buffering.

Figure 5 shows the complete schematic for the applications demo board. Channel A is configured as an expander while channel B is configured so that it can be used either as a compressor or as an ALC circuit. The switch,  $S_1$ , toggles the circuit between compressor and ALC mode. Jumpers  $J_1$  and  $J_2$  can be used to either include the additional op amps for signal conditioning or exclude them from the signal path. Bread boarding space is provided for  $R_1$ ,  $R_2$ ,  $C_1$ ,  $C_2$ ,  $R_{10}$ ,  $R_{11}$ ,  $C_{10}$  and  $C_{11}$  so that the response can be tailored for each individual need. The components as specified are suitable for the complete audio spectrum from 20 Hz to 20 kHz.

The most common configuration is as a unity gain non-inverting buffer where  $R_1$ ,  $C_1$ ,  $C_2$ ,  $R_{10}$ ,  $C_{10}$  and  $C_{11}$  are eliminated and  $R_2$  and  $R_{11}$  are shorted. Capacitors  $C_3$ ,  $C_5$ ,  $C_8$ , and  $C_{12}$  are for DC blocking. In systems where the inputs and outputs are AC coupled, these capacitors and resistors can be eliminated. Capacitors  $C_4$  and  $C_9$  are for setting the attack and release time constant.

$C_6$  is for decoupling and stabilizing the voltage reference circuit. The value of  $C_6$  should be such that it will offer a very low impedance to the lowest frequencies of interest. Too small a capacitor will allow supply ripple to modulate the audio path. The better filtered the power supply, the smaller this capacitor can be.  $R_{12}$  provides DC reference voltage to the amplifier of channel B.  $R_6$  and  $R_7$  provide a DC feedback path for the summing amp of channel B, while  $C_7$  is a short-circuit to ground for signals.  $C_{14}$  and  $C_{15}$  are for power supply decoupling.  $C_{14}$  can also be eliminated if the power supply is well regulated with very low noise and ripple.

## Demonstrated Performance

The applications demo board was built and tested for a frequency range of 20 Hz to 20 kHz with the component values as shown in Figure 5 and  $V_{CC} = 5.0$  V. In the expander mode, the typical input dynamic range was from -34 dB to +12 dB where 0 dB is equal to 100 mV<sub>RMS</sub>. The typical unity gain level measured at 0 dB @ 1.0 kHz input was  $\pm 0.5$  dB and the typical tracking error was  $\pm 0.1$  dB for input range of -30 to +10 dB.

In the compressor mode, the typical input dynamic range was from -42 dB to  $\pm 18$  dB with a tracking error  $\pm 0.1$  dB and the typical unity gain level was  $\pm 0.5$  dB.

In the ALC mode, the typical input dynamic range was from -42 dB to +8.0 dB with typical output deviation of  $\pm 0.2$  dB about the nominal output of 0 dB. For input greater than +9.0 dB in ALC configuration, the summing amplifier sometimes exhibits high frequency oscillations. There are several solutions to this problem. The first is to lower the values of  $R_6$  and  $R_7$  to 20 k $\Omega$  each. The second is to add a current limiting resistor in series with  $C_{12}$  at Pin 13. The third is to add a compensating capacitor of about 22 to 30 pF between the input and output of summing amplifier (Pins 12 and 14). With any one of the above recommendations, the typical ALC mode input range increased to +18 dB yielding a dynamic range of over 60 dB.

### Expander

The typical expander configuration is shown in Figure 2. The variable gain cell and the rectifier cell are in the signal input path. The  $V_{REF}$  is always  $1/2 V_{CC}$  to provide the maximum headroom without clipping. The 0 dB ref is 100 mV<sub>RMS</sub>. The input is AC coupled through  $C_5$ , and the output is AC coupled through  $C_3$ . If in a system the inputs and outputs are AC coupled, then  $C_3$  and  $C_5$  can be eliminated, thus requiring only one external component,  $C_4$ . The variable gain cell and rectifier cell are DC coupled so any offset voltage between Pins 4 and 9 will cause small offset error current in the rectifier cell. This will affect the

accuracy of the gain cell. This can be improved by using an extra capacitor from the input to Pin 4 and eliminating the DC connection between Pins 4 and 9.

The expander gain expression and the attack and release time constant is given by Equation 1 and Equation 2, respectively.

$$\text{Expander gain} = \left( \frac{4V_{IN(\text{avg})}}{3.8 \text{ k}\Omega \times 100 \mu\text{A}} \right)^2 \quad (\text{eq. 1})$$

$$\text{where } V_{IN(\text{avg})} = 0.95V_{IN(\text{RMS})}$$

$$\tau_R = \tau_A = 10 \text{ k}\Omega \times C_{RECT} = 10 \text{ k}\Omega \times C_4 \quad (\text{eq. 2})$$

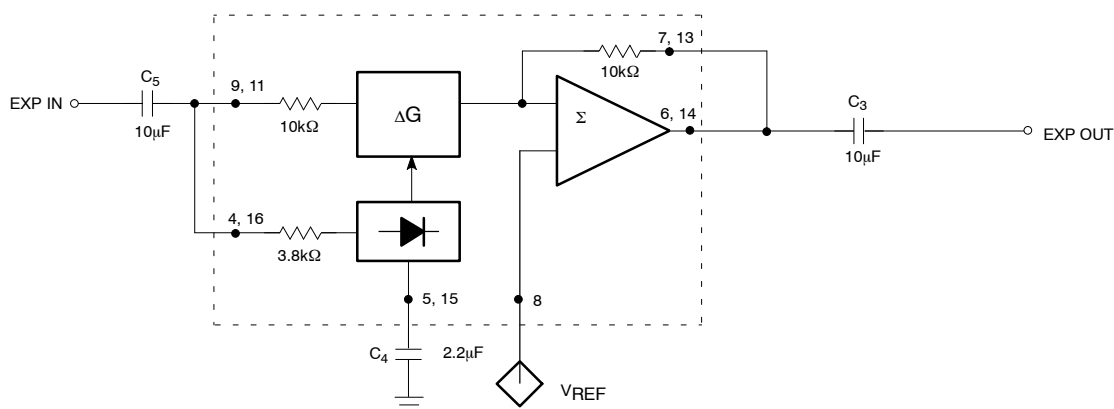


Figure 2. Typical Expander Configuration

### Compressor

The typical compressor configuration is shown in Figure 3. In this mode, the rectifier cell and variable gain cell are in the feedback path.  $R_6$  and  $R_7$  provide the DC feedback to the summing amplifier. The input is AC coupled through  $C_{12}$  and output is AC coupled through  $C_8$ . In a system with inputs and outputs AC coupled,  $C_8$  and  $C_{12}$  could be eliminated and only  $R_6$ ,  $R_7$ ,  $C_7$ , and  $C_{13}$  would be required. If the external components  $R_6$ ,  $R_7$  and  $C_7$  are eliminated, then the output of the summing amplifier will motor-boat in absence of signals or at extremely low signals. This is because there is no DC feedback path from

the output to input. In the presence of an AC signal this phenomenon is not observed and the circuit will appear to function properly.

The compressor gain expression and the attack and release time constant is given by Equation 3 and Equation 4, respectively.

$$\text{Compressor gain} = \left[ \frac{3.8 \text{ k}\Omega \times 100 \text{ }\mu\text{A}}{4V_{IN(\text{avg})}} \right]^{1/2} \quad (\text{eq. 3})$$

$$\text{where } V_{IN(\text{avg})} = 0.95V_{IN(\text{RMS})}$$

$$\tau_R = \tau_A = 10 \text{ k}\Omega \times C_{\text{RECT}} = 10 \text{ k}\Omega \times C_4 \quad (\text{eq. 4})$$

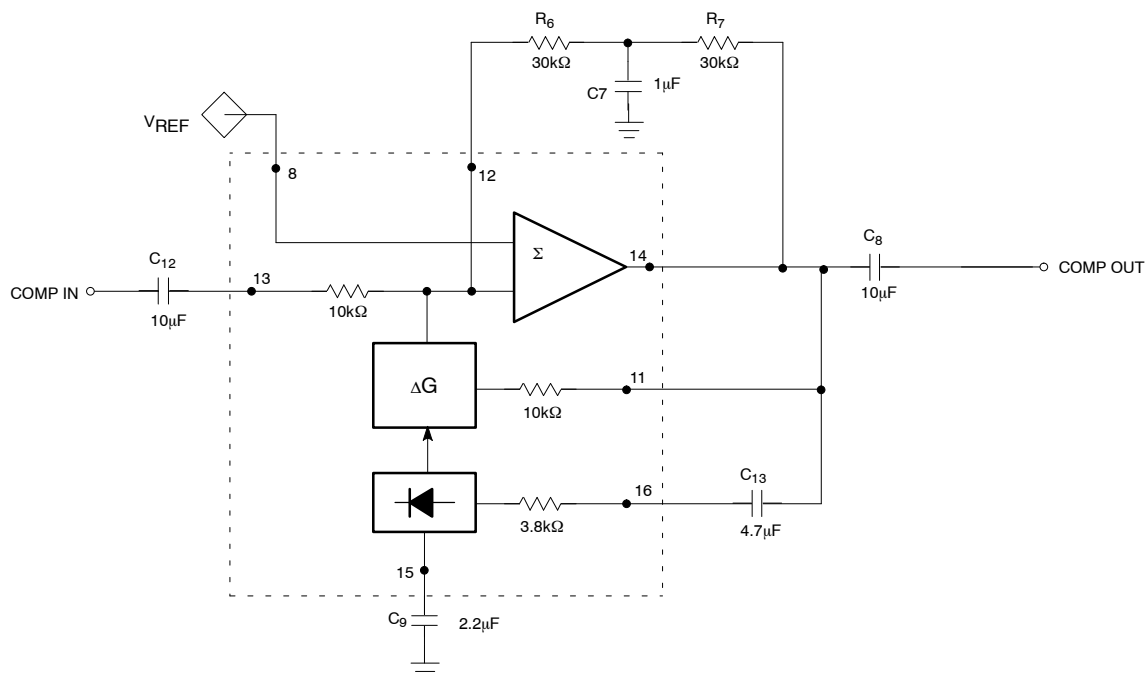


Figure 3. Typical Compressor Configuration

### Automatic Level Control

The typical Automatic Level Control circuit configuration is shown in Figure 4. It can be seen that it is quite similar to the compressor schematic except that the input to the rectifier cell is from the input path and not from the feedback path. The input is AC coupled through  $C_{12}$  and  $C_{13}$  and the output is AC coupled through  $C_8$ . Once again, as in the previous cases, if the system input and output signals are already AC coupled, then  $C_{12}$ ,  $C_{13}$  and  $C_8$  could be eliminated. Concerning the compressor, removing  $R_6$ ,  $R_7$  and  $C_7$  will cause motor-boating in

absence of signals.  $C_{COMP}$  is necessary to stabilize the summing amplifier at higher input levels. This circuit provides an input dynamic range greater than 60 dB with the output within  $\pm 0.5$  dB typical. The necessary design expressions are given by Equation 5 and Equation 6, respectively.

$$\text{ALC gain} = \frac{3.8 \text{ k}\Omega \times 100 \text{ }\mu\text{A}}{4V_{IN(\text{avg})}} \quad (\text{eq. 5})$$

$$\tau_R = \tau_A = 10 \text{ k}\Omega \times C_{RECT} = 10 \text{ k}\Omega \times C_9 \quad (\text{eq. 6})$$

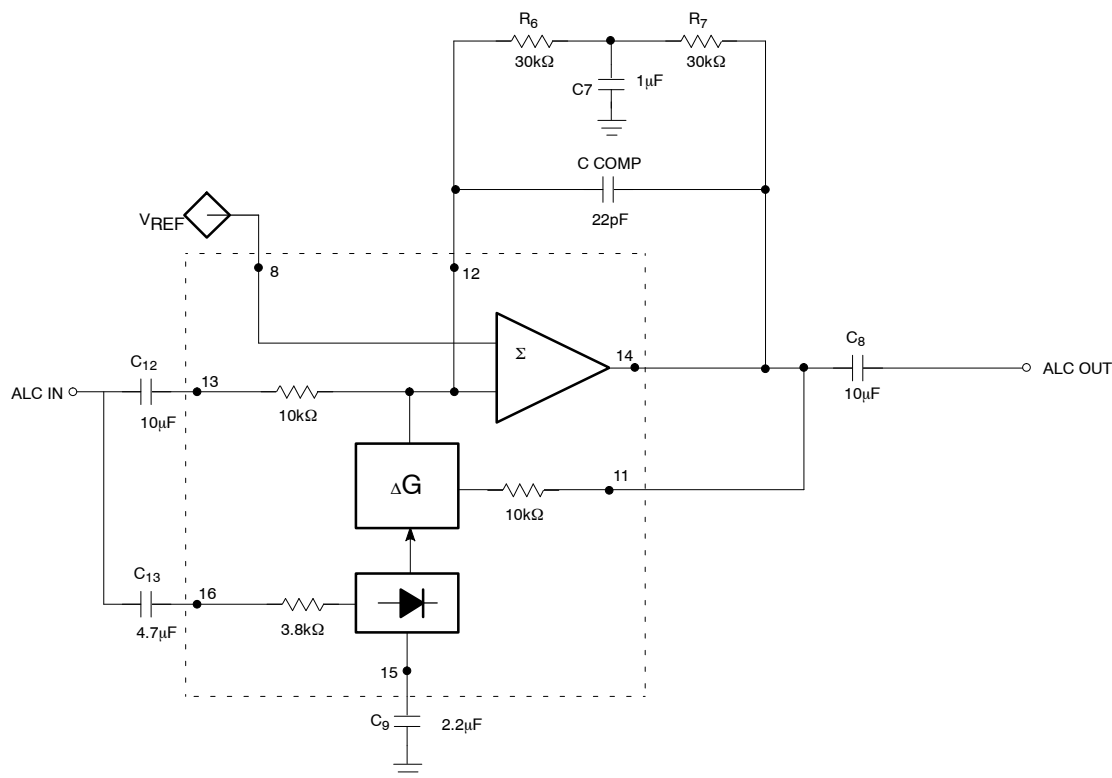


Figure 4. Typical ALC Configuration

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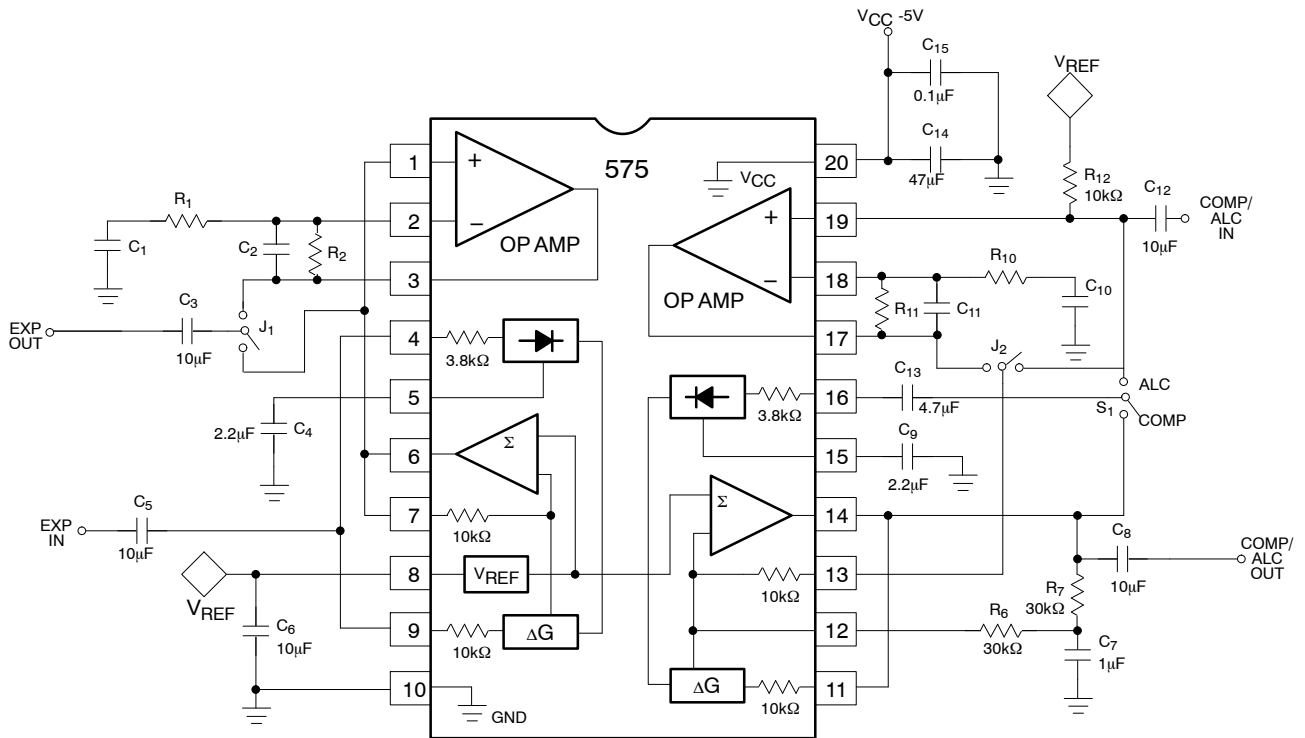


Figure 5. SA575 Low Voltage Expander/Compressor/ALC Demo Board

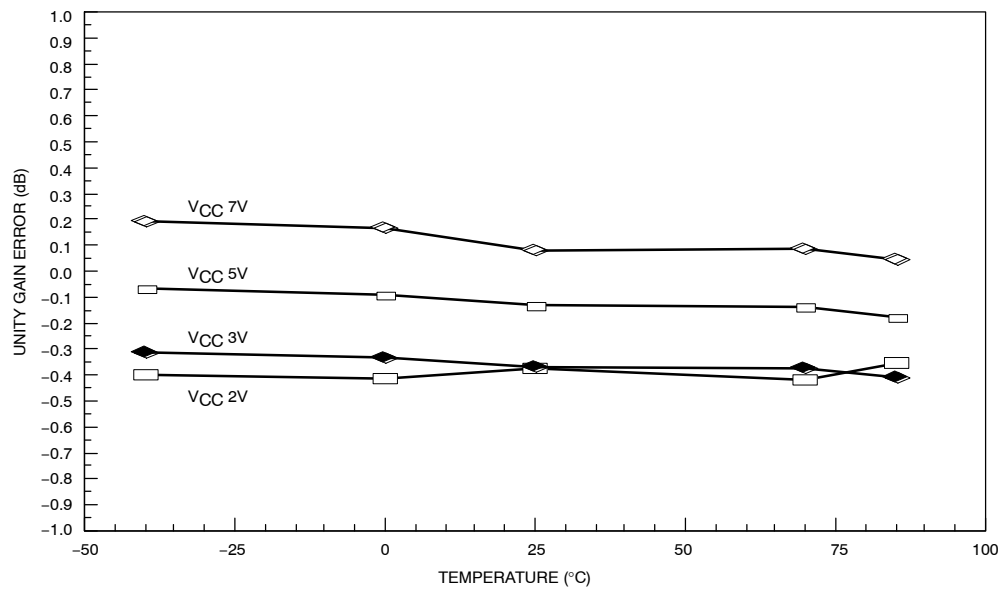


Figure 6. Unity Gain Error vs. Temperature and  $V_{CC}$

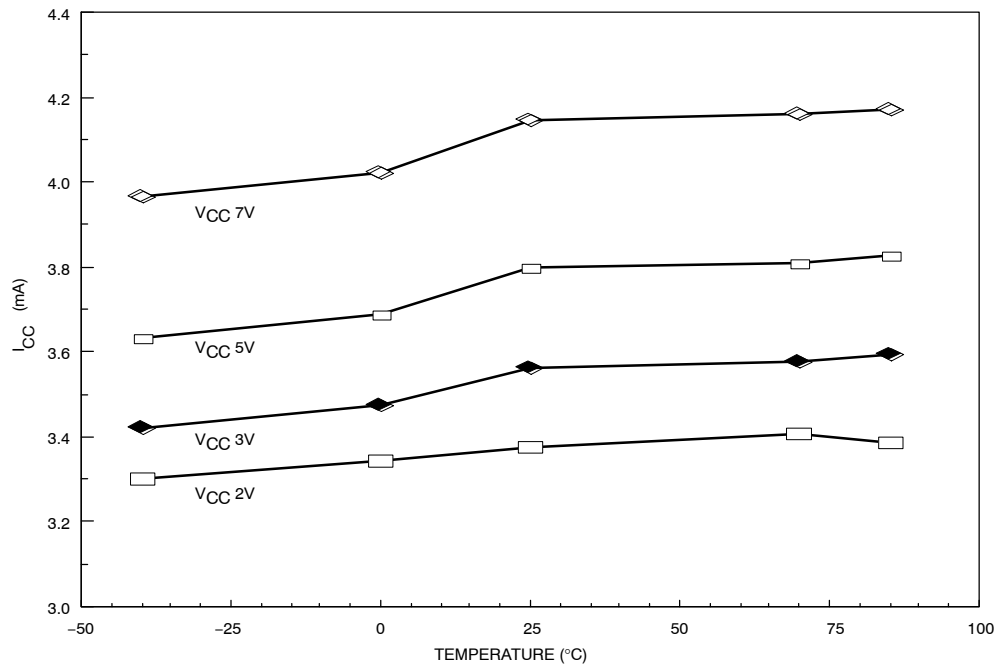


Figure 7.  $I_{CC}$  vs. Temperature and  $V_{CC}$

## TYPICAL PERFORMANCE CHARACTERISTICS

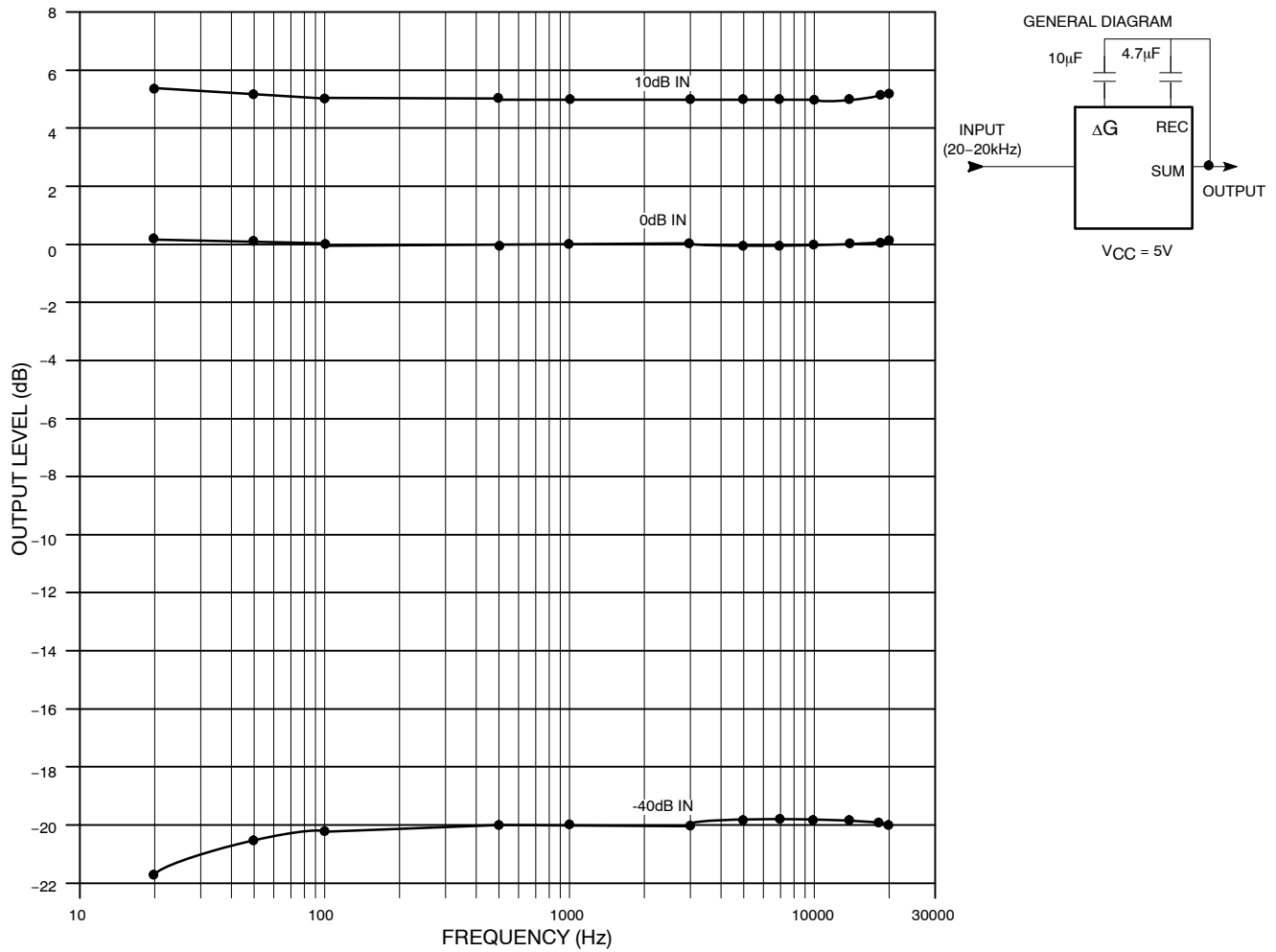


Figure 8. Compressor Output Frequency Response

## TYPICAL PERFORMANCE CHARACTERISTICS

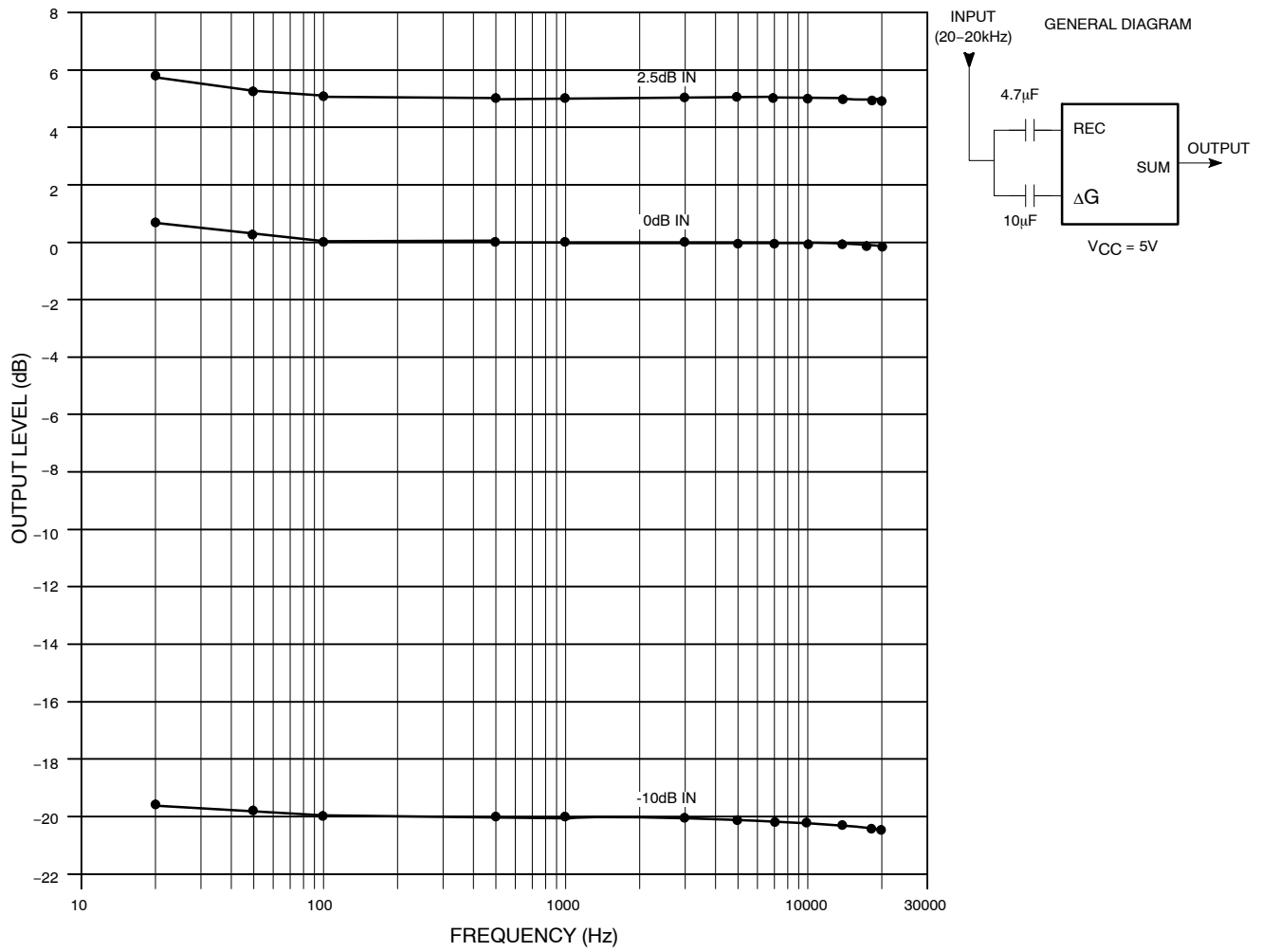
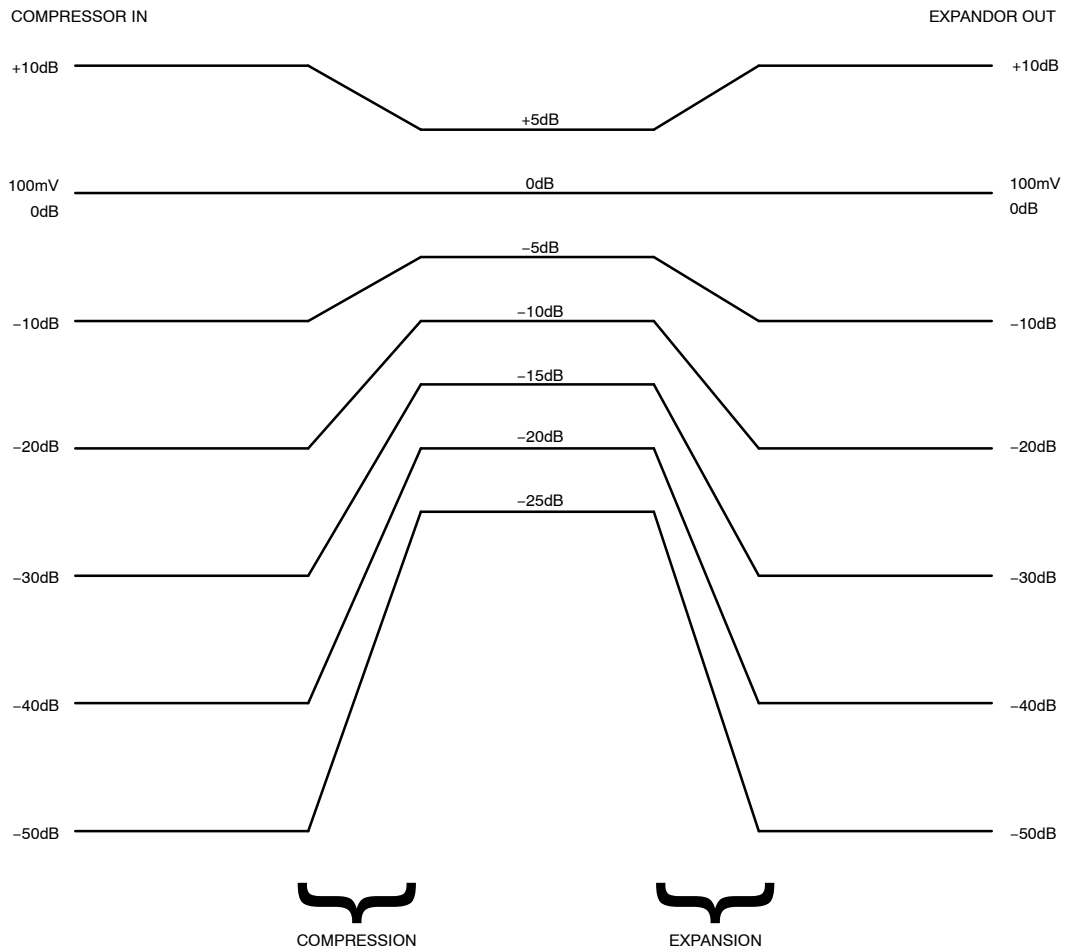


Figure 9. Expander Output Frequency Response

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**Figure 10. The Companding Function**

## ORDERING INFORMATION

| Device      | Package               | Temperature Range | Shipping†          |
|-------------|-----------------------|-------------------|--------------------|
| SA575DTBR2G | TSSOP-20<br>(Pb-Free) | -40 to +85°C      | 2500 / Tape & Reel |

† For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specification Brochure, [BRD8011/D](#).

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