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# HA12155NT/HA12157NT

Audio Signal Processor for Cassette Deck (Dolby B/C-type NR  
with Recording System)

## HITACHI

ADE-207-115C (Z)

4th Edition  
June 1997

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### Description

HA12155NT/HA12157NT is silicon monolithic bipolar IC providing Dolby noise reduction system\*, electrical volume system, REC equalizer system and level meter system in one chip.

### Functions

- REC equalizer           × 2 channel
- Dolby B/C NR           × 2 channel
- Electronic volume     × 2 channel
- Level Meter            × 2 channel

### Features

- Inductor less REC equalizer is adjustable of its characteristics by external resistor
- Rec level is adjustable automatically with electrical volume which is built-in
- 3 type of input selection is available (one is by way of electrical volume)
- Separate input selection SW and REC/PB SW
- Dolby noise reduction with dubbing cassette decks  
(Unprocessed signal output available from recording out terminals during PB mode)
- Log-compressed level meter output is range from 0 V to 5 V  
(Usable as music search switchable gain of 0 dB and 20 dB respectively)
- Normal-speed/high-speed (Double), normal/metal/chrome fully electronic control switching built-in
- NR-ON/OFF, Dolby B/C, MPX ON/OFF fully electronic control switching built-in  
(Controllable from micro-controller directly)
- Reduction of number of pin by transfered serial data to electronic volume control switching and another control switching  
(Controllable from micro-controller directly)
- Low external parts count

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# HA12155NT/HA12157NT

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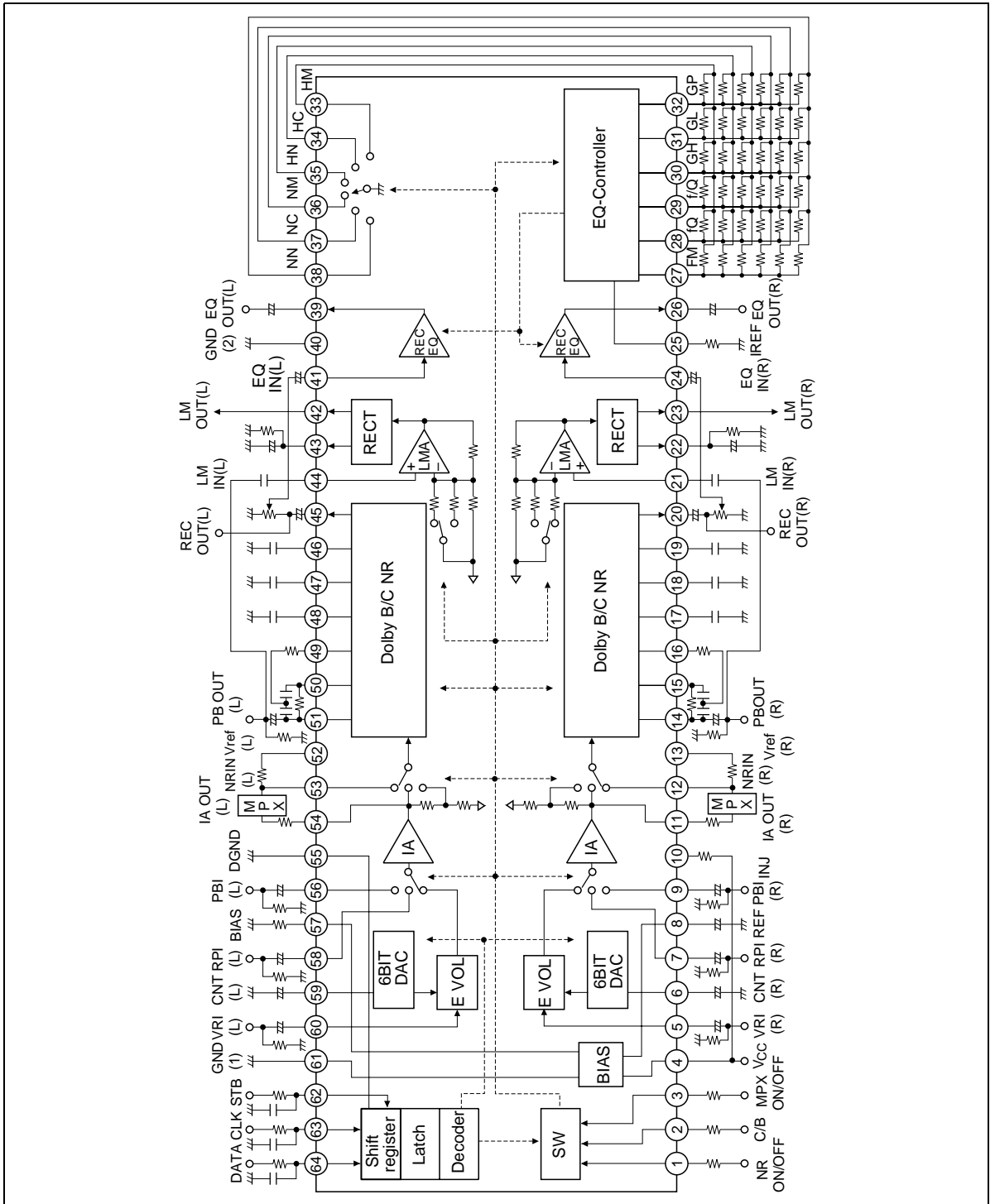
\* Dolby is a trademark of Dolby Laboratories Licensing Corporation.  
A license from Dolby Laboratories Licensing Corporation is required for the use of this IC.

## Ordering Information

| Type      | Package | Dolby Level | REC-OUT Level | PB-OUT Level | Operating voltage |      |
|-----------|---------|-------------|---------------|--------------|-------------------|------|
|           |         |             |               |              | Min               | Max  |
| HA12155NT | DP-64S  | 300 mVrms   | 300 mVrms     | 580 mVrms    | 9.5 V             | 16 V |
| HA12157NT |         |             |               | 775 mVrms    | 12 V              | 16 V |

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Block Diagram



# HA12155NT/HA12157NT

## Absolute Maximum Ratings

| Item                  | Symbol    | Ratings     | Unit |
|-----------------------|-----------|-------------|------|
| Supply voltage        | $V_{CC}$  | 16          | V    |
| Power dissipation*1   | $P_d$     | 770         | mW   |
| Operating temperature | $T_{opr}$ | -30 to +75  | °C   |
| Storage temperature   | $T_{stg}$ | -55 to +125 | °C   |

Note: 1. Value at  $T_a \leq 75^\circ\text{C}$

## Electrical Characteristics ( $T_a = 25^\circ\text{C}$ $V_{CC} = 14\text{ V}$ Dolby level 300 mVrms)

| Item                      | Symbol                            | Min       | Typ   | Max   | Unit | Test conditions  | Notes                                       |
|---------------------------|-----------------------------------|-----------|-------|-------|------|--|---|
| Quiescent current         | $I_Q$                             | —         | 29.0  | 37.0  | mA   | no signal  |   |
| Input amp gain            | $G_{VIA}$ RPI                     | 18.5      | 20.0  | 21.5  | dB   | $V_{in} = 0\text{ dB}$ , $f = 1\text{ kHz}$              |   |
|                           | $G_{VIA}$ PBI                     | 18.5      | 20.0  | 21.5  |      |  |   |
| B-type NR Encode Boost    | B-ENC-2K                          | 2.8       | 4.3   | 5.8   | dB   | $V_{in} = -20\text{ dB}$ , $f = 2\text{ kHz}$            |   |
|                           | B-ENC-5K                          | 1.7       | 3.2   | 4.7   |      | $V_{in} = -20\text{ dB}$ , $f = 5\text{ kHz}$            |   |
| C-type NR Encode Boost    | C-ENC-1K(1)                       | 3.9       | 5.9   | 7.9   | dB   | $V_{in} = -20\text{ dB}$ , $f = 1\text{ kHz}$            |   |
|                           | C-ENC-1K(2)                       | 18.1      | 19.6  | 21.6  |      | $V_{in} = -60\text{ dB}$ , $f = 1\text{ kHz}$            |   |
|                           | C-ENC-700                         | 9.8       | 11.8  | 13.8  |      | $V_{in} = -30\text{ dB}$ , $f = 700\text{ Hz}$           |   |
| Signal handling           | $V_{omax}$                        | 12.0      | 13.0  | —     | dB   | $f = 1\text{ kHz}$ , THD = 1%,<br>$V_{CC} = 12\text{ V}$ | *1  |
| Signal to noise ratio     | S/N                               | 60.0      | 63.0  | —     | dB   | $R_g = 5.1\text{ k}\Omega$ , CCIR/ARM                    |   |
| Total harmonic distortion | THD                               | —         | 0.08  | 0.3   | %    | $V_{in} = 0\text{ dB}$ , $f = 1\text{ kHz}$              |   |
| Crosstalk                 | $C_T$ (R $\leftrightarrow$ L)     | —         | -85.0 | -79.0 | dB   | $V_{in} = 0\text{ dB}$ , $f = 1\text{ kHz}$              |   |
|                           | $C_T$ (RPI $\leftrightarrow$ PBI) | —         | -80.0 | -74.0 |      |  |   |
|                           | $C_T$ (VRI $\leftrightarrow$ RPI) | —         | -77.0 | -71.0 |      |  |   |
| Control voltage           | Hi level                          | $V_{cH}$  | 3.5   | —     | 5.3  | V  | MPX ON/OFF, NR                              |
|                           | Lo level                          | $V_{cL}$  | -0.2  | —     | 1.0  |  |   |
| Serial data voltage       | Hi level                          | $V_{sH}$  | 3.5   | —     | 5.3  | V  | CLK, DATA, STB                              |
|                           | Lo level                          | $V_{sL}$  | -0.2  | —     | 1.0  |  |   |
| PB-out level              | HA12155                           | $V_{out}$ | 500   | 580   | 670  | mVrms  | $V_{in} = 0\text{ dB}$ , $f = 1\text{ kHz}$ |
|                           | HA12157                           |           | 665   | 775   | 900  |  |   |
| PB-offset                 | $V_{ofs}$                         | -100      | 0.0   | +100  | mV   | no signal  |   |
| Channel balance           | $\Delta G_V$                      | -1.0      | 0.0   | 1.0   | dB   | $V_{in} = 0\text{ dB}$ , $f = 1\text{ kHz}$              |   |
| Volume gain               | $G_{VVR(MAX)}$                    | 17.5      | 19.3  | 21.5  | dB   | $V_{in} = 100\text{ mVrms}$ , $f = 1\text{ kHz}$         |   |
|                           | $G_{VVR(MIN)}$                    | —         | —     | -55.0 |      | $V_{in} = 3\text{ Vrms}$ , $f = 1\text{ kHz}$            |   |

**Electrical Characteristics** ( $T_a = 25^\circ\text{C}$   $V_{cc} = 14\text{ V}$  Dolby level 300 mVrms) (cont)

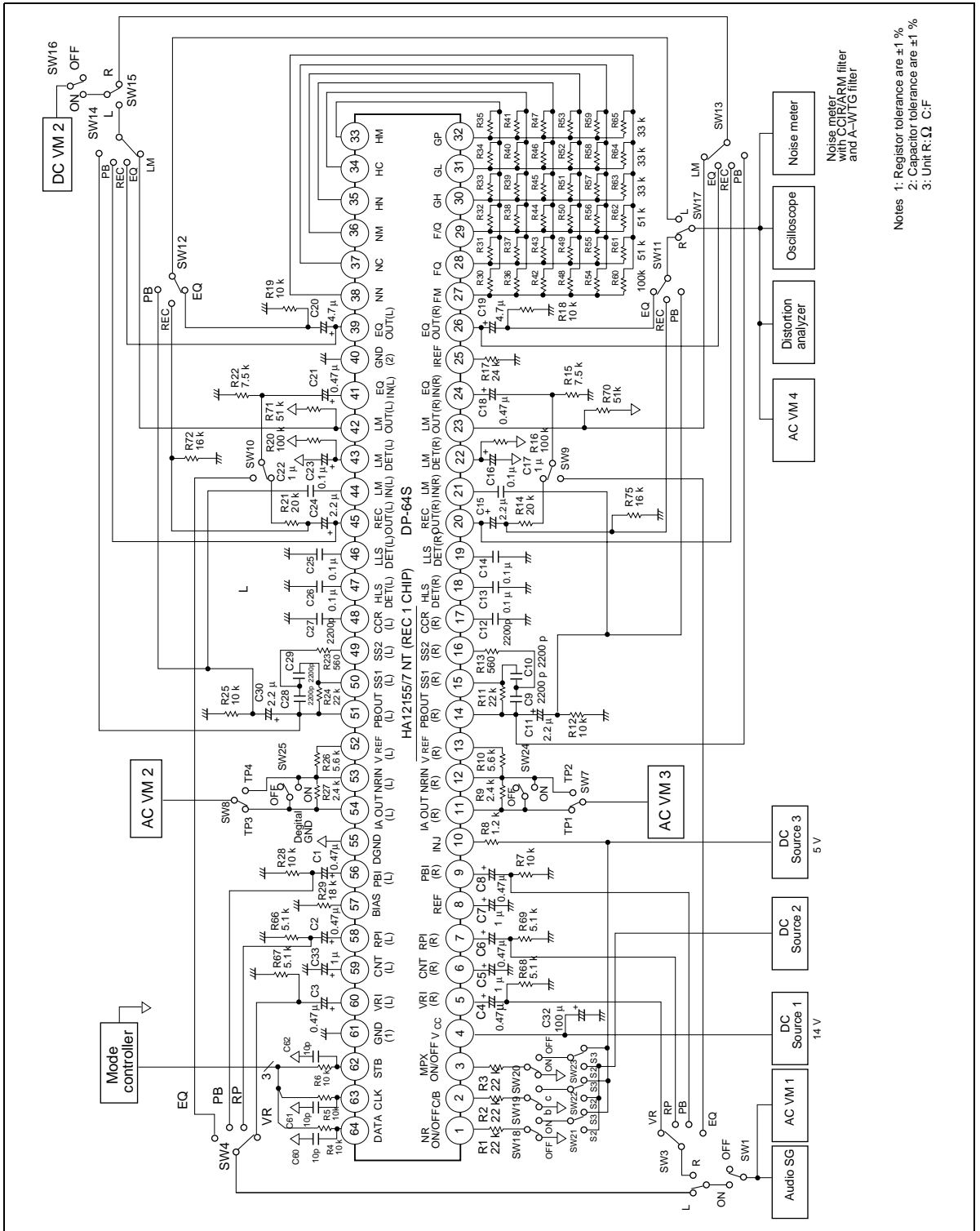
| Item                      | Symbol              | Min  | Typ  | Max   | Unit | Test conditions   | Notes |
|---------------------------|---------------------|------|------|-------|------|---|-------|
| Volume mute               | $G_{VVR(MUT)}$      | —    | —    | -80.0 | dB   | $V_{in} = 3\text{ Vrms}$ , $f = 1\text{ kHz}$                   |       |
| Max-input level to volume | $V_{in\ max}\ (VR)$ | 11.0 | 12.6 | —     | dBs  | $f = 1\text{ kHz}$ , THD = 1%,<br>$V_{cc} = 12\text{ V}$        |       |
| Volume S/N                | S/N (VR)            | 78.0 | 84.0 | —     | dB   | $V_{in} = 100\text{ mVrms}$ , $f = 1\text{ kHz}$ , A-WTG        |       |
| Volume THD                | THD (VR)            | —    | 0.04 | 0.3   | %    | $V_{in} = 100\text{ mVrms}$ , $f = 1\text{ kHz}$                |       |
| Equalizer gain            | $G_{VEQ(500)}$      | 13.0 | 15.0 | 17.0  | dB   | $V_{in} = 77.5\text{ mVrms}$ ,<br>$f = 500\text{ Hz}$           |       |
|                           | $G_{VEQ(1K)}$       | 13.0 | 15.0 | 17.0  |      | $V_{in} = 77.5\text{ mVrms}$ ,<br>$f = 1\text{ kHz}$            |       |
|                           | $G_{VEQ(5K)}$       | 14.5 | 16.5 | 18.5  |      | $V_{in} = 77.5\text{ mVrms}$ ,<br>$f = 5\text{ kHz}$            |       |
|                           | $G_{VEQ(10K)}$      | 18.5 | 20.5 | 22.5  |      | $V_{in} = 77.5\text{ mVrms}$ ,<br>$f = 10\text{ kHz}$           |       |
|                           | $G_{VEQ(20K)}$      | 29.5 | 32.0 | 34.5  |      | $V_{in} = 77.5\text{ mVrms}$ ,<br>$f = 20\text{ kHz}$           |       |
| Equalizer maximum input   | $V_{in\ max}\ (EQ)$ | -8.0 | -7.0 | —     | dBs  | $f = 1\text{ kHz}$ , THD = 1%,<br>$V_{cc} = 12\text{ V}$        | *1    |
| Equalizer S/N             | S/N (EQ)            | 57.0 | 62.0 | —     | dB   | $R_g = 5.1\text{ k}\Omega$ , A-WTG                              |       |
| Equalizer THD             | THD (EQ)            | —    | 0.2  | 0.5   | %    | $V_{in} = 77.5\text{ mVrms}$ ,<br>$f = 1\text{ kHz}$            |       |
| Equalizer offset          | Vofs (EQ)           | -400 | 0.0  | +400  | mV   | no signal   |       |
| Level meter output        | LM (0 dB)           | 2.60 | 2.85 | 3.10  | V    | $V_{in} = 0\text{ dB}$ , $f = 1\text{ kHz}$                     | *2    |
|                           | LM (12 dB)          | 3.60 | 3.90 | 4.20  | V    | $V_{in} = 12\text{ dB}$ , $f = 1\text{ kHz}$                    |       |
| Level meter output        | LM (-20 dB)1        | 0.80 | 1.10 | 1.40  | V    | $V_{in} = -20\text{ dB}$ , $f = 1\text{ kHz}$                   | *2    |
|                           | LM (-20 dB)2        | 2.55 | 3.0  | 3.15  | V    | $V_{in} = -20\text{ dB}$ , $f = 1\text{ kHz}$ ,<br>-20 dB range |       |
| Level meter offset        | LMofs 1             | —    | 150  | 300   | mV   | no signal   |       |
|                           | LMofs 2             | —    | 200  | 350   |      | no signal, -20 dB range   |       |

 Notes: 1. HA12155  $V_{cc} = 9.5\text{ V}$ , HA12157  $V_{cc} = 12\text{ V}$ 

2. 0 dB = PB-OUT level

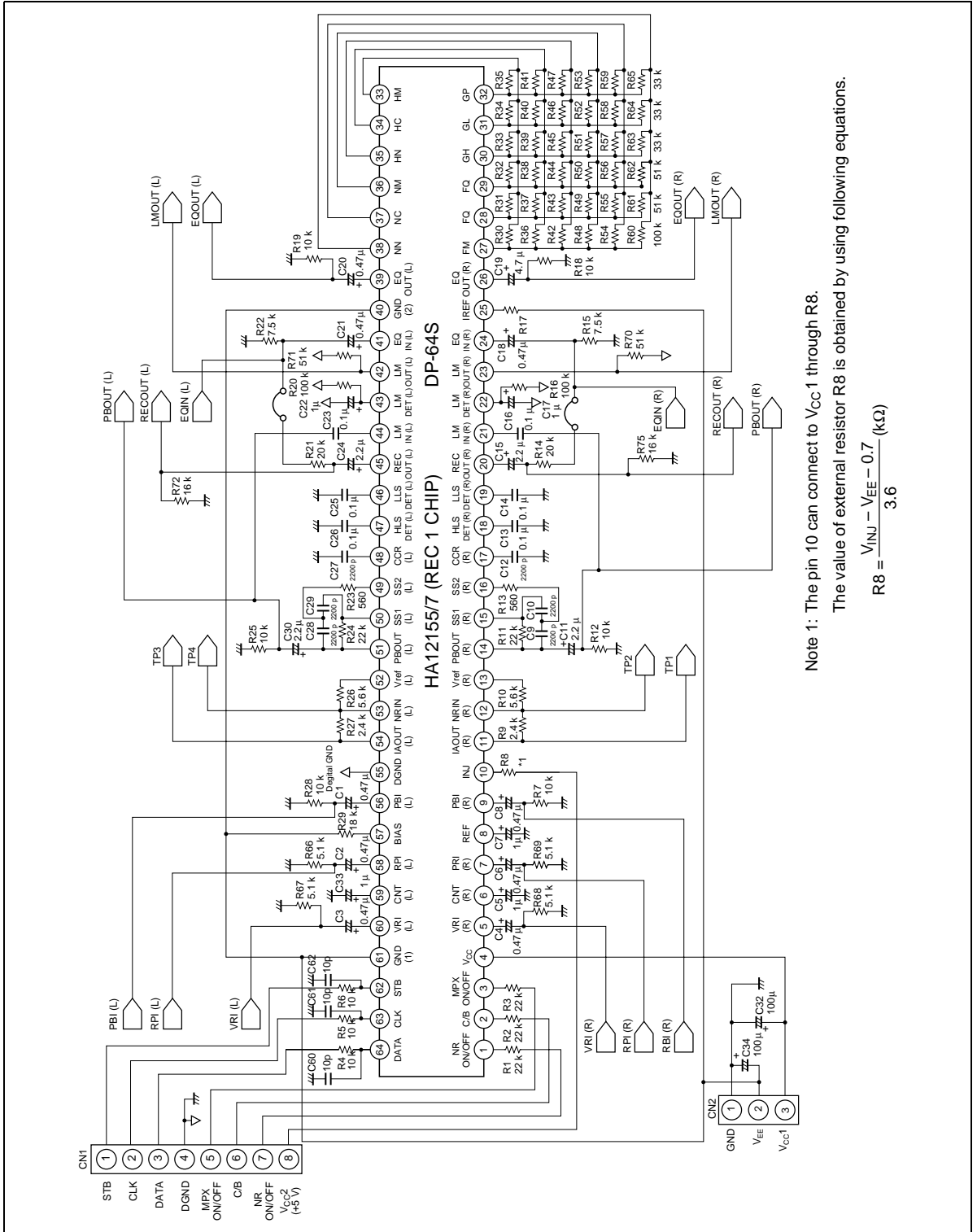
# HA12155NT/HA12157NT

## Test Circuit



Notes 1: Resistor tolerance are  $\pm 1\%$   
 2: Capacitor tolerance are  $\pm 1\%$   
 3: Unit R:  $\Omega$  C: F

Example of Split Supply Circuit

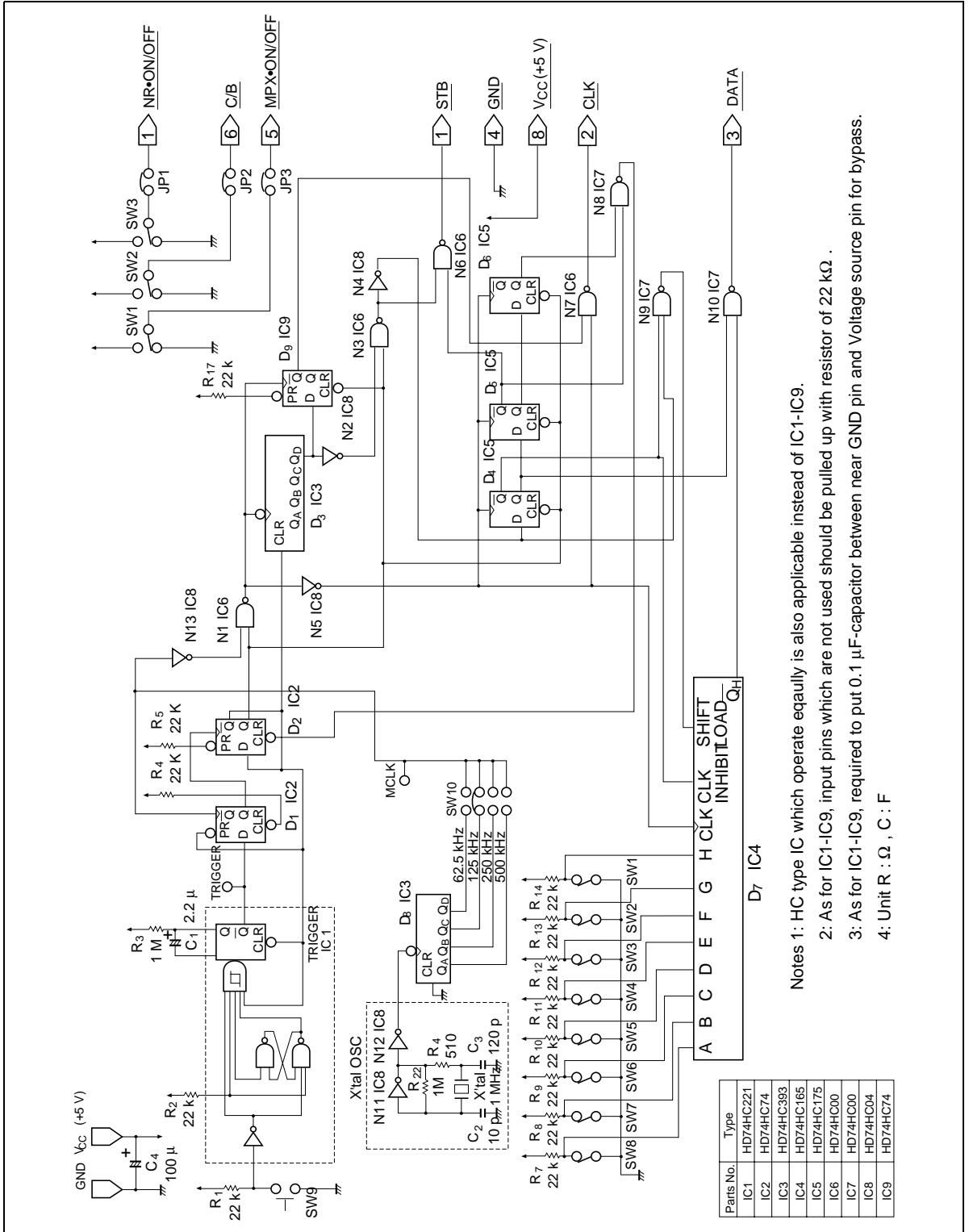


Note 1: The pin 10 can connect to  $V_{CC1}$  through R8.  
 The value of external resistor R8 is obtained by using following equations.  

$$R8 = \frac{V_{INJ} - V_{EE} - 0.7}{3.6} \text{ (k}\Omega\text{)}$$

# HA12155NT/HA12157NT

## Mode Controller

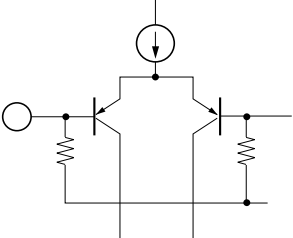
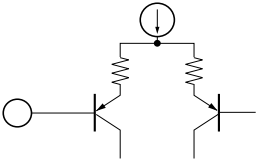
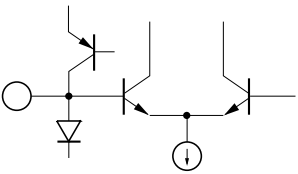


- Notes 1: HC type IC which operate equally is also applicable instead of IC1-IC9.  
 2: As for IC1-IC9, input pins which are not used should be pulled up with resistor of 22 kΩ .  
 3: As for IC1-IC9, required to put 0.1 μF-capacitor between near GND pin and Voltage source pin for bypass.  
 4: Unit R : Ω , C : F

| Parts No. | Type      |
|-----------|-----------|
| IC1       | HD74HC221 |
| IC2       | HD74HC74  |
| IC3       | HD74HC393 |
| IC4       | HD74HC175 |
| IC5       | HD74HC175 |
| IC6       | HD74HC00  |
| IC7       | HD74HC00  |
| IC8       | HD74HC04  |
| IC9       | HD74HC74  |

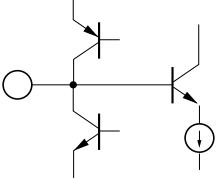
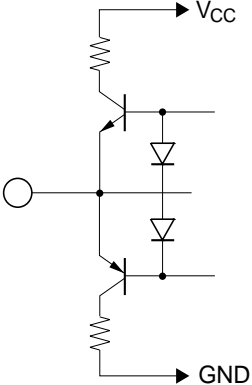


**Pin Description** ( $V_{CC} = 14\text{ V}$ ,  $T_a = 25^\circ\text{C}$ , No signal, the value in the table show typical value)

| Pin No. | Terminal | DC                           | Equivalent circuit  | Description                |
|---------|----------|------------------------------|---|----------------------------|
| 7       | RPI      | $100\text{ k}\Omega$         | $V_{CC}/2$  | Recording input            |
| 58      |          |                              |    |                            |
| 9       | PBI      |                              |   | Play back input            |
| 56      |          |                              |   |                            |
| 21      | LM IN    | HA12155<br>---75 k $\Omega$  |   | Level meter input          |
| 44      |          | HA12157<br>---100 k $\Omega$ |   |                            |
| 24      | EQ IN    | $100\text{ k}\Omega$         |   | Equalyzer input            |
| 41      |          |                              |   |                            |
| 5       | VRI      | $100\text{ k}\Omega$         | $V_{CC}/2$  | Volume input               |
| 60      |          |                              | +0.7 V  |                            |
| 4       | $V_{CC}$ | —                            | $V_{CC}$  | Power supply               |
| 8       | REF      | —                            | $V_{CC}/2$  | Ripple filter              |
| 12      | NR IN    | —                            | $V_{CC}/2$  | NR processor input         |
| 53      |          |                              |  |                            |
| 15      | SS 1     | —                            | $V_{CC}/2$  | Spectral skewing amp input |
| 50      |          |                              |  |                            |

# HA12155NT/HA12157NT

**Pin Description** ( $V_{CC} = 14\text{ V}$ ,  $T_a = 25^\circ\text{C}$ , No signal, the value in the table show typical value) (cont)

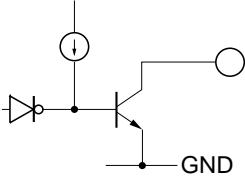
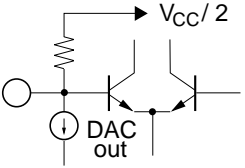
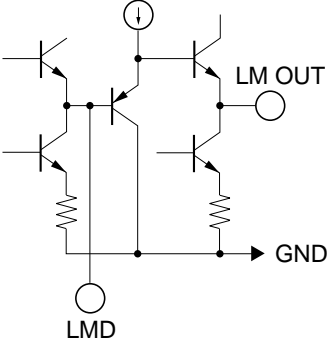
| Pin No. | Terminal | DC  | Equivalent circuit   | Description                        |
|---------|----------|-----|--|------------------------------------|
| DP-64S  | name     | Zin | voltage  |                                    |
| 17      | CCR      | —   | $V_{CC}/2$   | Current controlled resistor output |
| 48      |          |     |   |                                    |
| 11      | IA OUT   | —   | $V_{CC}/2$   | Input amp output                   |
| 54      |          |     |  |                                    |
| 13      | VREF     |     |  | Reference voltage                  |
| 52      |          |     |  | buffer output                      |
| 14      | PB OUT   |     |  | Play back (Decode) output          |
| 51      |          |     |  | output                             |
| 16      | SS 2     |     |  | Spectral skewing amp. output       |
| 49      |          |     |  | amp. output                        |
| 20      | REC OUT  |     |  | Recording (Encode) output          |
| 45      |          |     |  | output                             |
| 26      | EQ OUT   |     |  | Equalizer output                   |
| 39      |          |     |  |                                    |

**Pin Description** ( $V_{CC} = 14\text{ V}$ ,  $T_a = 25^\circ\text{C}$ , No signal, the value in the table show typical value) (cont)

| Pin No.  | Terminal | DC  | Equivalent circuit | Description                      |
|----------|----------|-----|--------------------|----------------------------------|
| DP-64S   | name     | Zin | voltage            |                                  |
| 18<br>47 | HLS DET  | —   | 2.3 V              | Time constant pin for rectifier  |
|          |          |     |                    |                                  |
| 19<br>46 | LLS DET  |     |                    |                                  |
| 57       | BIAS     | —   | 0.28 V             | Dolby NR Reference current input |
|          |          |     |                    |                                  |
| 25       | IREF     | —   | 1.2 V              | EQ Reference current input       |
|          |          |     |                    |                                  |
| 27       | FM       |     |                    | EQ Parameter current             |
| 28       | fQ       |     |                    | input                            |
| 29       | f/Q      |     |                    |                                  |
| 30       | GH       |     |                    |                                  |
| 31       | GL       |     |                    |                                  |
| 32       | GP       |     |                    |                                  |

# HA12155NT/HA12157NT

**Pin Description** ( $V_{CC} = 14\text{ V}$ ,  $T_a = 25^\circ\text{C}$ , No signal, the value in the table show typical value) (cont)

| Pin No. | Terminal name | Zin    | DC voltage                             | Equivalent circuit  | Description                       |
|---------|---------------|--------|--|---|-----------------------------------|
| 33      | HM            | —      | —                                      |    | EQ Parameter selector             |
| 34      | HC            |        |  |   |                                   |
| 35      | HN            |        |  |   |                                   |
| 36      | NM            |        |  |   |                                   |
| 37      | NC            |        |  |   |                                   |
| 38      | NN            |        |  |   |                                   |
| 6       | CNT           | 5.2 kΩ | $V_{CC}/2$ -<br>1.5 V to<br>$V_{CC}/2$ |    | DAC output Volume control input   |
| 22      | LMD           | —      | 0.2 V                                  |   | Time constant Pin for level meter |
| 43      |               |        |  |  |                                   |
| 23      | LM OUT        | —      | 0.2 V                                  |   | Level meter output                |
| 42      |               |        |  |   |                                   |

**Pin Description** ( $V_{CC} = 14\text{ V}$ ,  $T_a = 25^\circ\text{C}$ , No signal, the value in the table show typical value) (cont)

| Pin No. | Terminal name | Zin            | DC voltage | Equivalent circuit | Description                        |
|---------|---------------|----------------|------------|--------------------|------------------------------------|
| 1       | NR ON/OFF     | 100 k $\Omega$ | —          |                    | Mode control input                 |
| 2       | C/B           |                |            |                    |                                    |
| 3       | MPX ON/OFF    |                |            |                    |                                    |
| 62      | STB           |                |            |                    |                                    |
| 63      | CLK           |                |            |                    |                                    |
| 64      | DATA          |                |            |                    |                                    |
| 10      | INJ           | —              | 0.7 V      | —                  | Injection current input for $I^2L$ |
| 55      | D-GND         | —              | 0.0 V      | —                  | Digital (Logic) ground             |
| 40      | GND           | —              | 0.0 V      | —                  | Ground                             |
| 61      |               |                |            |                    |                                    |

### Application Note

#### Power Supply Range

HA12155NT/HA12157NT are designed to operate on either single supply or split supply.

The operating range of the supply voltage is shown in table 1.

**Table 1 Supply Voltage**

| Type No.  | Single supply | Split supply            |
|-----------|---------------|-------------------------|
| HA12155NT | 9.5 V to 16 V | $\pm 6\text{ V}$ to 8 V |
| HA12157NT | 12 V to 16 V  | $\pm 6\text{ V}$ to 8 V |

The lower limit of supply voltage depends on the line output reference level.

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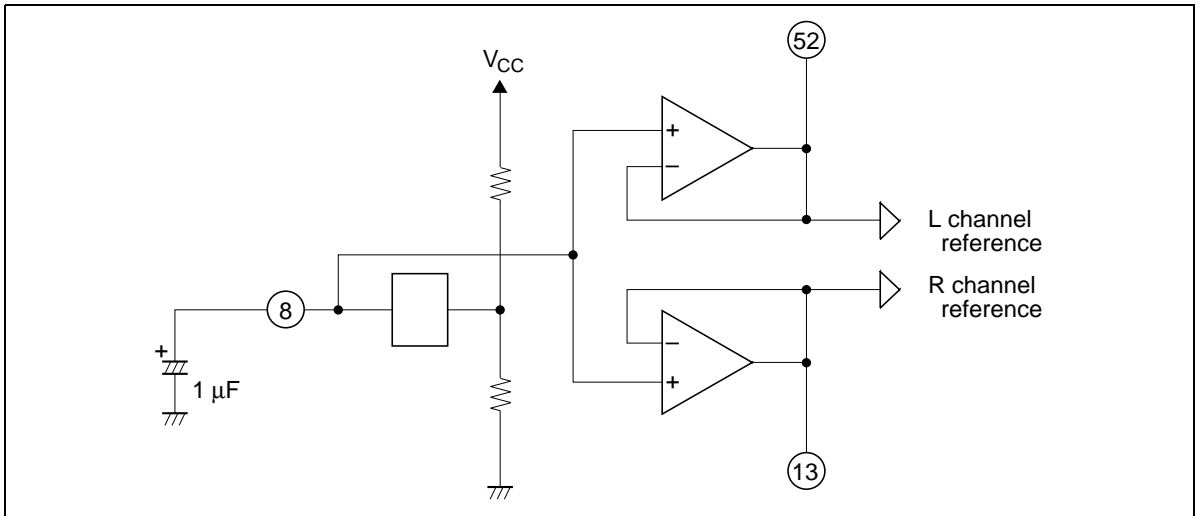
## HA12155NT/HA12157NT

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The minimum value of the headroom margin is specified as 12 dB by Dolby Laboratories. HA12155 series are provided with two line output level, which will permit an optimum headroom margin for power supply conditions.

### Reference Voltage

For the single supply operation these devices provide the reference voltage of half the supply voltage that is the signal grounds. As the peculiarity of these devices, the capacitor for the ripple filter is very small about 1/100 compared with their usual value. The Reference voltage are provided for the left channel and the right channel separately. The block diagram is shown as figure 1.



**Figure 1 The Block Diagram of Reference Voltage Supply**

### Operating Mode Control

HA12155NT/HA12157NT provides fully electronic switching circuits. NR-ON/OFF, C/B, and MPX ON/OFF switches are controlled by parallel data (DC voltage) and other switches are controlled by serial data.

**Table 2** Threshold Voltage ( $V_{TH}$ )

| Pin No.    | Lo          | Hi         | Unit |
|------------|-------------|------------|------|
| 1, 2, 3    | -0.2 to 1.0 | 3.5 to 5.3 | V    |
| 62, 63, 64 | -0.2 to 1.0 | 3.5 to 5.3 | V    |

Notes: 1. Voltages shown above are determined by internal circuits of LSI when take pin 55 (DGND pin) as reference pin. On split supply use, same  $V_{TH}$  can be offered by connecting DGND pin to GND pin.

This means that it can be controlled directly by micro processor.

2. Each pins are on pulled down with 100 k $\Omega$  internal resistor.

Therefore, it will be low-level when each pins ar open.

3. Note on serial data inputting

(a) The clock frequency on CLK must be less than 500 kHz.

(b) Over shoot level and under shoot level of input signal must be the value shown below.

(c) The serial input pins (pins 62, 63, and 64) are extremely sensitive to undershoot, overshoot, ringing, and noise. This can result in malfunctions due to problems with the wiring pattern. We recommend attaching capacitors in parallel with the serial input pins to ameliorate this problem.

Figure 2-b shows an example of this circuit appropriate when the clock frequency is 500 kHz. The value of the capacitor should be set in accordance with the clock frequency actually used.

4. NR Mode Switching

In actual use, pop noises may accompany NR on/off switching in C mode. To avoid these noises, use the following sequences to turn NR on and off.

From C mode NR off to C mode NR on:

(C mode, NR off)  $\rightarrow$  (B mode, NR off)  $\rightarrow$  (B mode, NR on)  $\rightarrow$  (C mode, NR on).

From C mode NR on to C mode NR off:

(C mode, NR on)  $\rightarrow$  (B mode, NR on)  $\rightarrow$  (B mode, NR off)  $\rightarrow$  (C mode, NR off).

**Table 3** Switching Truth Table

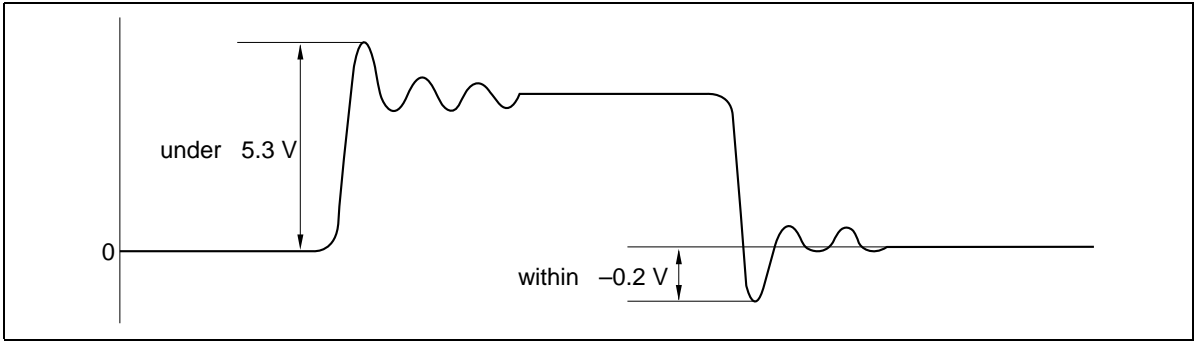
| Pin No. | Lo     | Hi      |
|---------|--------|---------|
| 1       | NR-OFF | NR-ON   |
| 2       | B-NR   | C-NR    |
| 3       | MPX-ON | MPX-OFF |

Notes: 1. Low level will be offered when each pins are open.

2. Please refer to next term as for the serial data for formatting.

When connecting microcomputer or Logic-IC with HA12155NT/HA12157NT directly, there is apprehension of rash-current under some transition timming of raising voltage or falling voltage at  $V_{CC}$  ON/OFF.

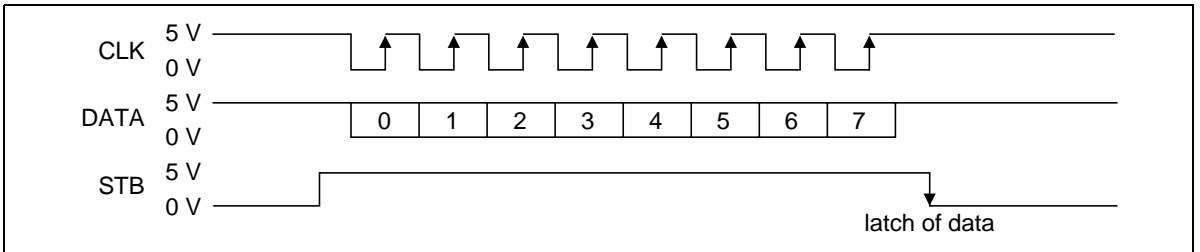
For this countermeasure, connect 10 k $\Omega$  to 20 k $\Omega$  resistor with each pins. It is shown in test circuit.



**Figure 2 Input Level**

## Serial Data Formatting

8 bit shift register is employed. CLK and DATA are stored during STB being high and data is latched when STB goes high to low. The clock frequency on CLK must be less than 500 kHz.



**Figure 3 Serial Data Timing Chart**



Table 4 Serial Data Formatting

| Bit No.   | Control register  | Volume register   |   |   |   |          |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
|-----------|-------------------|---|---|---|---|----------|---------|--------|---|---------|--------|---|---------|--|--|--|--|--|--|---|---|---|---|---|---|------|---|---|---|---|---|---|----------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|-------|--|--|--|--|--|--|-------|--|--|--|--|--|--|-------|--|--|--|--|--|--|---|---|---|---|---|---|----------|---|---|---|---|---|---|---|---|---|---|---|---|------|
| 0         | TAPE SELECT 1     | H<br>L  | DAC0  |   |   |          |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
|           |                   | <table border="1"> <tr> <td>TS1 \ TS2</td> <td>H</td> <td>L</td> </tr> <tr> <td>H</td> <td>TAPE IV</td> <td>TAPE I</td> </tr> <tr> <td>L</td> <td>TAPE II</td> <td>TAPE I</td> </tr> </table> | TS1 \ TS2   | H | L | H        | TAPE IV | TAPE I | L | TAPE II | TAPE I | <table border="1"> <tr> <th colspan="6">bit No.</th> <th></th> </tr> <tr> <td>5</td> <td>4</td> <td>3</td> <td>2</td> <td>1</td> <td>0</td> <td>gain</td> </tr> <tr> <td>L</td> <td>L</td> <td>L</td> <td>L</td> <td>L</td> <td>L</td> <td>increase</td> </tr> <tr> <td>L</td> <td>L</td> <td>L</td> <td>L</td> <td>L</td> <td>H</td> <td rowspan="2">↑</td> </tr> <tr> <td>L</td> <td>L</td> <td>L</td> <td>L</td> <td>H</td> <td>L</td> </tr> <tr> <td>L</td> <td>L</td> <td>L</td> <td>L</td> <td>H</td> <td>H</td> <td rowspan="2">↓</td> </tr> <tr> <td colspan="6">-----</td> <td></td> </tr> <tr> <td colspan="6">-----</td> <td></td> </tr> <tr> <td colspan="6">-----</td> <td></td> </tr> <tr> <td>H</td> <td>H</td> <td>H</td> <td>H</td> <td>L</td> <td>H</td> <td rowspan="2">decrease</td> </tr> <tr> <td>H</td> <td>H</td> <td>H</td> <td>H</td> <td>H</td> <td>L</td> </tr> <tr> <td>H</td> <td>H</td> <td>H</td> <td>H</td> <td>H</td> <td>H</td> <td>mute</td> </tr> </table> | bit No. |  |  |  |  |  |  | 5 | 4 | 3 | 2 | 1 | 0 | gain | L | L | L | L | L | L | increase | L | L | L | L | L | H | ↑ | L | L | L | L | H | L | L | L | L | L | H | H | ↓ | ----- |  |  |  |  |  |  | ----- |  |  |  |  |  |  | ----- |  |  |  |  |  |  | H | H | H | H | L | H | decrease | H | H | H | H | H | L | H | H | H | H | H | H | mute |
| TS1 \ TS2 | H                 | L   |   |   |   |          |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
| H         | TAPE IV           | TAPE I  |   |   |   |          |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
| L         | TAPE II           | TAPE I  |   |   |   |          |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
| bit No.   |                   |   |   |   |   |          |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 5         | 4                 | 3   | 2   | 1 | 0 | gain     |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
| L         | L                 | L   | L   | L | L | increase |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
| L         | L                 | L   | L   | L | H | ↑        |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
| L         | L                 | L   | L   | H | L |          |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
| L         | L                 | L   | L   | H | H | ↓        |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
| -----     |                   |   |   |   |   |          |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
| -----     |                   |   |   |   |   |          |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
| -----     |                   |   |   |   |   |          |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
| H         | H                 | H   | H   | L | H | decrease |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
| H         | H                 | H   | H   | H | L |          |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
| H         | H                 | H   | H   | H | H | mute     |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 1         | TAPE SELECT 2     | H<br>L  | DAC1  |   |   |          |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 2         | TAPE SPEED        | H<br>L  | High (double) speed selection<br>Normal speed selection         |   |   |          |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 3         | METER SENSITIVITY | H<br>L  | Meter sensitivity 20 dB up<br>Meter sensitivity normal          |   |   |          |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 4         | INPUT SELECT 1    | H<br>L  | DAC4  |   |   |          |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
|           |                   | <table border="1"> <tr> <td>IS1 \ IS2</td> <td>H</td> <td>L</td> </tr> <tr> <td>H</td> <td>PB I</td> <td>VR I</td> </tr> <tr> <td>L</td> <td>RP I</td> <td>VR I</td> </tr> </table>           | IS1 \ IS2   | H | L | H        | PB I    | VR I   | L | RP I    | VR I   |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
| IS1 \ IS2 | H                 | L   |   |   |   |          |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
| H         | PB I              | VR I  |   |   |   |          |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
| L         | RP I              | VR I  |   |   |   |          |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 5         | INPUT SELECT 2    | H<br>L  | DAC 5   |   |   |          |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 6         | REC/PB            | H<br>L  | PB mode selection<br>REC mode selection                         |   |   |          |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
|           |                   |   | R/L SELECT H Rch register selection<br>L Lch register selection |   |   |          |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 7         | REGISTER SELECT   | H<br>L  | Control register selection<br>Volume register selection         |   |   |          |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |
|           |                   |   | REGISTER SELECT L   |   |   |          |         |        |   |         |        |   |         |  |  |  |  |  |  |   |   |   |   |   |   |      |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |       |  |  |  |  |  |  |       |  |  |  |  |  |  |       |  |  |  |  |  |  |   |   |   |   |   |   |          |   |   |   |   |   |   |   |   |   |   |   |   |      |

\*mute is implemented when all bits are high.

Note: TAPE I: Normal tape, TAPE II: Chrome tape, TAPE IV: Metal tape

# HA12155NT/HA12157NT

## Input Block Diagram and Level Diagram

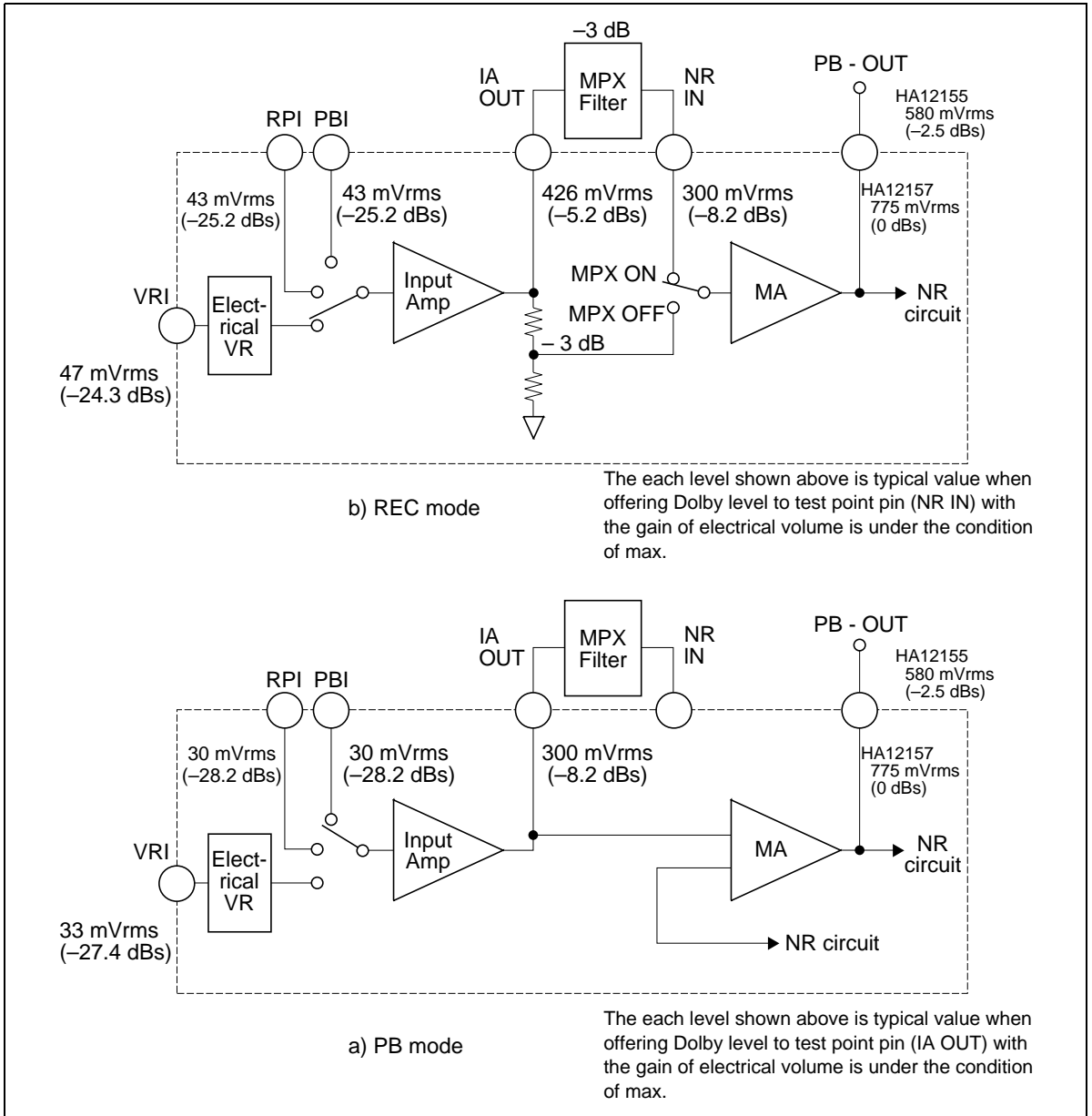
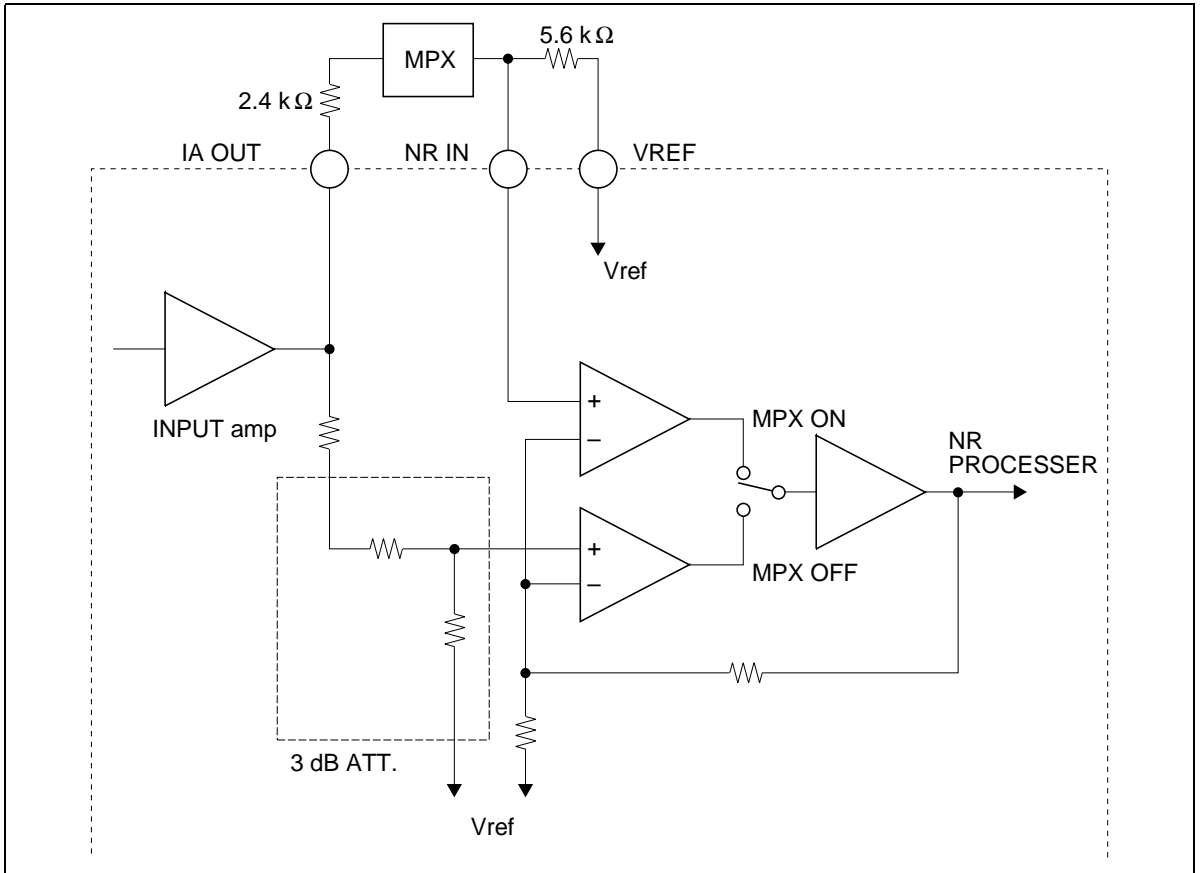


Figure 4 Input Block Diagram

**MPX ON/OFF Switch**

MPX-OFF mode means that signal from input amp doesn't go through the MPX filter, but signal goes through the SS circuit after being attenuated 3 dB by internal resistor. Refer to figure 5. For not cause any level difference between MPX-ON mode and MPX-OFF mode, it is requested to use MPX-filter which has definitely 3 dB attenuated. MPX-OFF mode offer totally flat frequency response and no bias-trap effect. And when applying other usage except figure 5, take consideration to give bias voltage to NR-IN terminal by resistor or so on because internal of NR-IN terminal has no bias resistor.



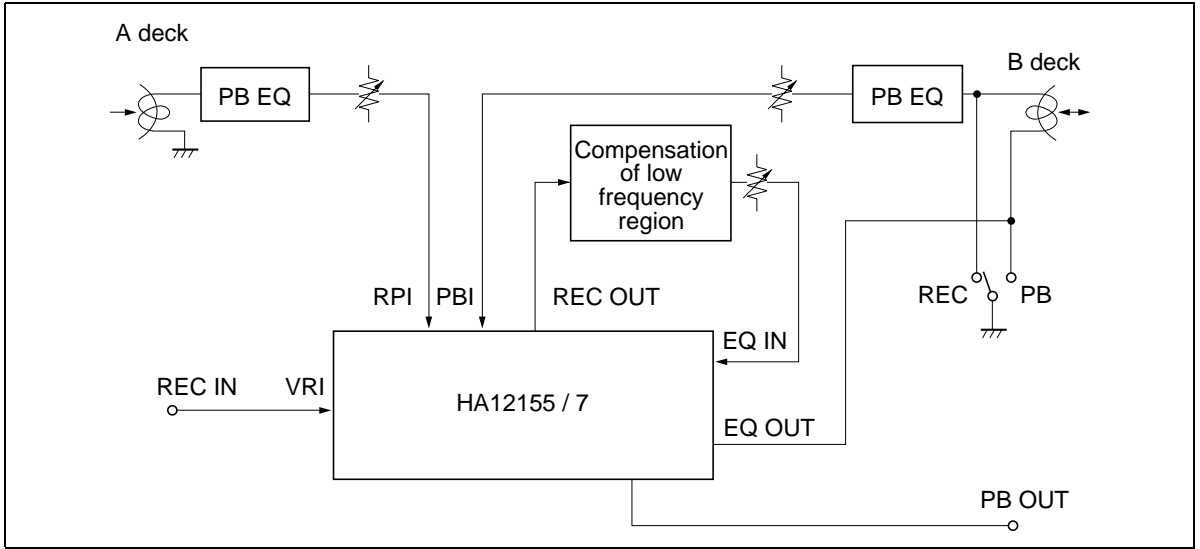
**Figure 5 MPX ON/OFF Switch Block Diagram**

Application as for the Dubbing Cassette Deck

HA12155NT/HA12157NT series has unprocessor signal from recording out terminals during playback mode. So, it is simply applied for dubbing cassette decks.

And HA12155NT/HA12157NT has three input terminal. So, it is applicable to switch the signal from PB-EQ as shown below.

# HA12155NT/HA12157NT



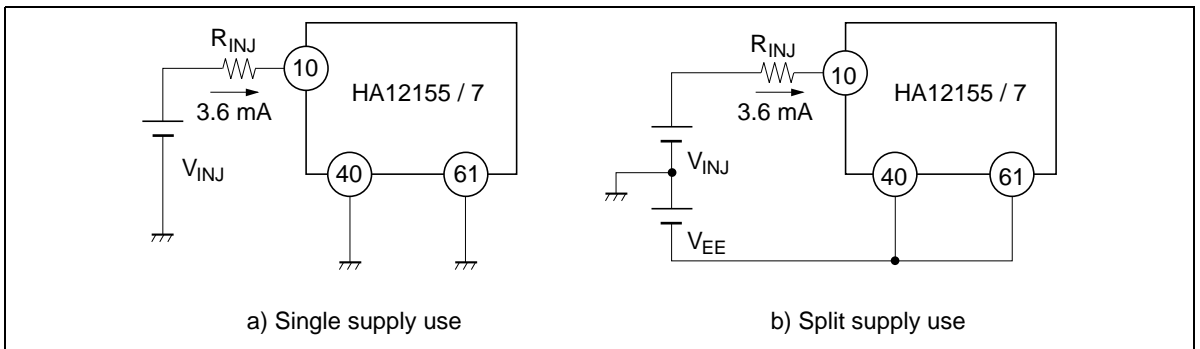
**Figure 6 Application for Dubbing Deck**

## Injector Current

HA12155NT/HA12157NT has logic circuit which is fabricated by I<sup>2</sup>L into IC. To operate this circuit, it is required enough injector current. Injector current goes into from the INJ pin (pin 10) and external resistor is required to connect to this pin for adequate current. The value of external resistor is obtained by using following equations. And put them with  $\pm 10\%$  tolerance value which is calculated.  $V_{INJ}$  can allow to connect to  $V_{CC}$  shown below. Under the condition of high temperature, the mis-operation of logic is caused by large injector current. Also, under the condition of low temperature, the stop of logic is caused by small injector current. Therefore, pay attention to have good stability of  $V_{INJ}$ .

$$R_{INJ} = \frac{V_{INJ} - 0.7}{3.6} \quad [\text{k}\Omega] \text{ ---- Single supply}$$

$$R_{INJ} = \frac{V_{INJ} + V_{EE} - 0.7}{3.6} \quad [\text{k}\Omega] \text{ ---- Split supply}$$



**Figure 7 Injector Current Application**

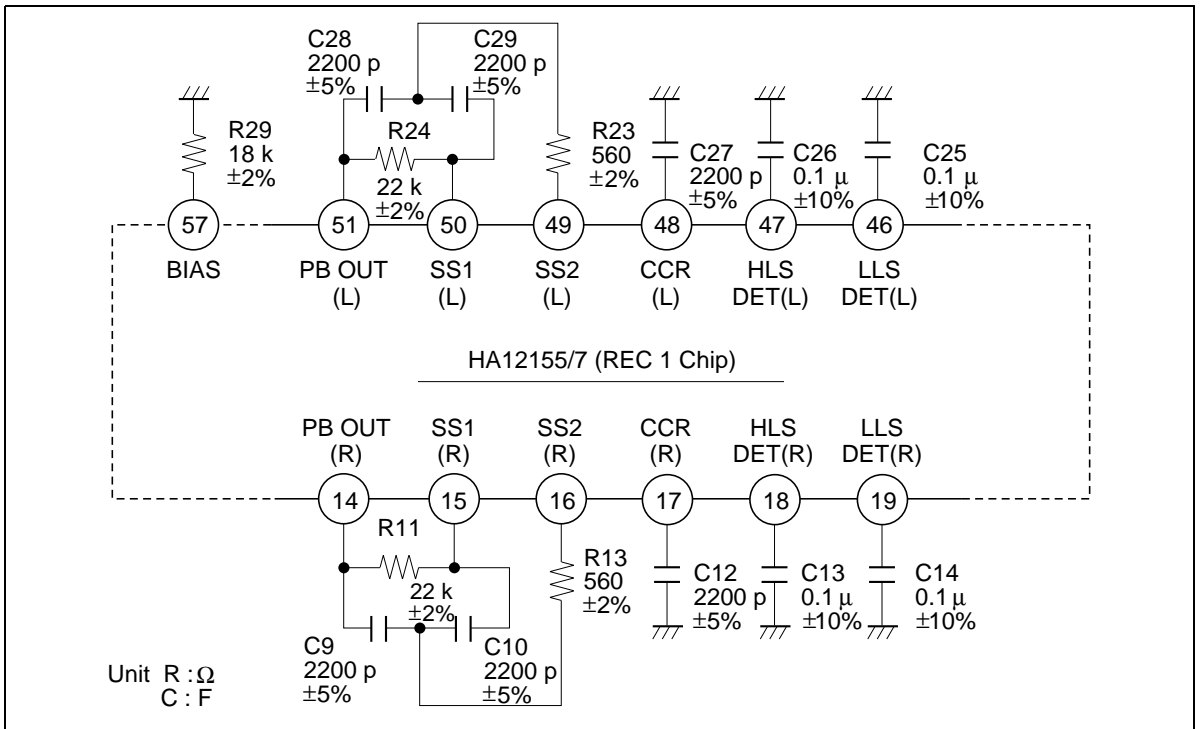
**Gain Control of Electronic Volume**

HA12155NT/HA12157NT is designed in order to change the gain by 6 bit DAC fabricated into IC. To reduce the click noise when changing volume gain instantaneously, required to connect the capacitor (CR time constant) to CNT pin (pin 6,59). These terminals are also be used as output pin of DAC. Therefore, by forcing voltage or current to these terminals, it is applicable to control volume gain directly. But, voltage forced to these terminals must be from  $V_{cc}/2 - 2\text{ V}$  to  $V_{cc}/2$  (for split supply use,  $-2\text{ V}$  to  $0\text{ V}$ ) in this case. In case of forcing the current these pins, voltage must be the value mentioned above even it is  $\pm 20\%$  distributed of internal resistor ( $5.2\text{ k}\Omega$ ) of CNT pin. And, these case, change of a gain depending on a temperature gets large.

**The Tolerances of External Components for Dolby NR-Block**

For adequate Dolby NR tracking response, take external components shown below.

For smooth capacitors of C13, C14, C25 and C26, please employ a few object of the leak, though you can be useful for an electrolytic capacitor.



**Figure 8 Tolerances of External Components**

**Level Meter**

The coupling capacitor of LMIN pin (21 pin and 44 pin).

For these capacitors please employ a small object of the leak.

# HA12155NT/HA12157NT

## The Application of Equalizer Frequency Response

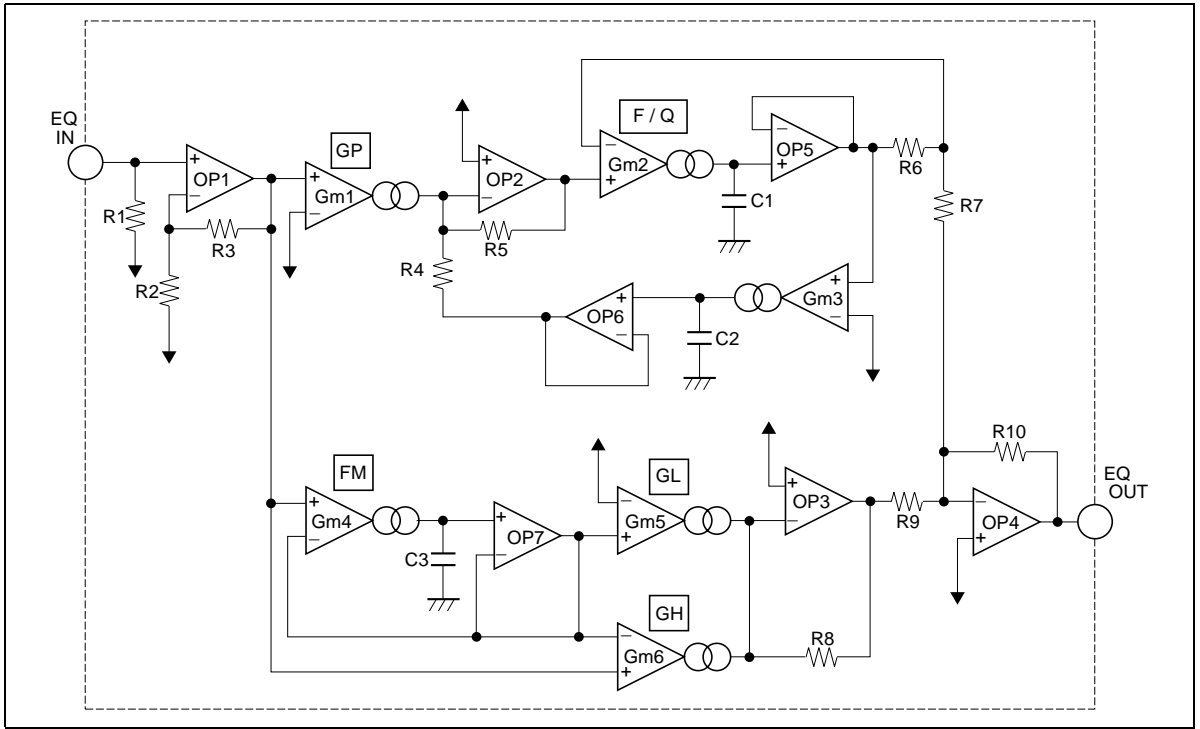


Figure 9 REC Equalizer Block Diagram

### Transfer Function:

$$\frac{V_{out}}{V_{in}} = \frac{R_2 + R_3}{R_2} \left( G_{m5} \frac{R_8 \cdot R_{10}}{R_9} \frac{1 + \frac{C_3 \cdot G_{m6}}{G_{m4} \cdot G_{m5}} S}{1 + \frac{C_3}{G_{m4}} S} + G_{m1} \frac{R_4 \cdot R_{10}}{R_6 + R_7} \frac{\frac{C_2}{G_{m3}} S}{1 + \frac{R_4}{R_5} \frac{R_7}{R_6 + R_7} \frac{C_2}{G_{m3}} S + \frac{R_4}{R_5} \frac{C_1}{G_{m2}} \frac{C_2}{G_{m3}} S^2} \right)$$

$$= \frac{4.16}{R_{REF}} \left( R_{GL} \frac{1 + 6.67 \times 10^{-10} \frac{R_{FM} \cdot R_{GH}}{R_{GL}} \cdot S}{1 + 6.67 \times 10^{-10} R_{FM} \cdot S} + R_{GP} \frac{3.0 \times 10^{-10} \cdot R_{FQ} \cdot S}{1 + 4.5 \times 10^{-11} \cdot R_{FQ} \cdot S + 2.5 \times 10^{-20} \cdot R_{FQ} \cdot R_{F/Q} S^2} \right)$$

\* $R_{REF}$ -----25 pin bias resistance

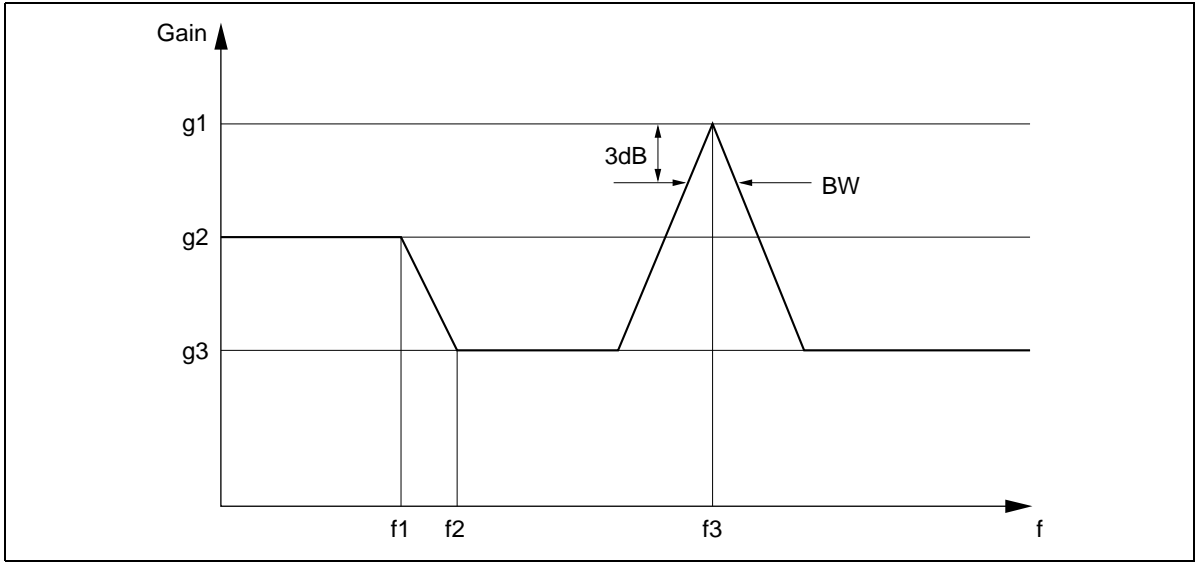


Figure 10 REC Equalizer Frequency Response

$$g1 = \frac{4.16}{R_{REF}} (6.67 \times R_{GP} + R_{GH})$$

$$g2 = \frac{4.16 \times R_{GL}}{R_{REF}}$$

$$g3 = \frac{4.16 \times R_{GH}}{R_{REF}}$$

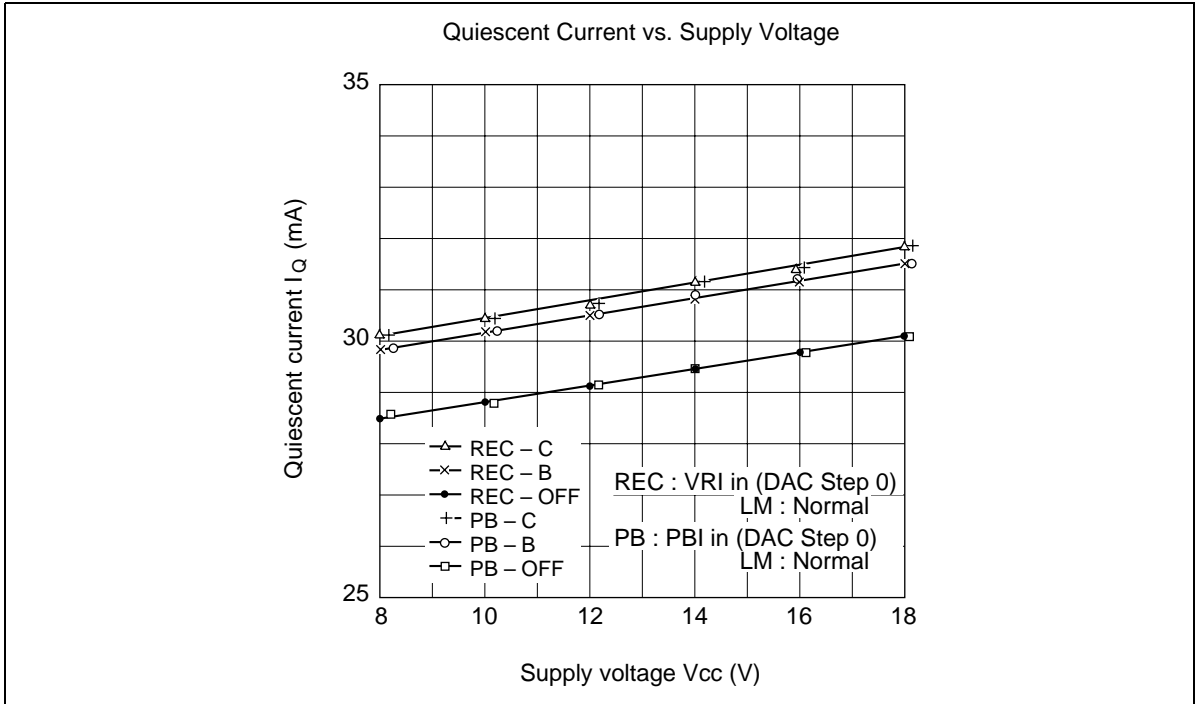
$$f1 = \frac{1}{2\pi \times 6.67 \times 10^{-10} \times R_{FM}}$$

$$f2 = \frac{R_{GL}}{2\pi \times 6.67 \times 10^{-10} \times R_{FM} \times R_{GH}}$$

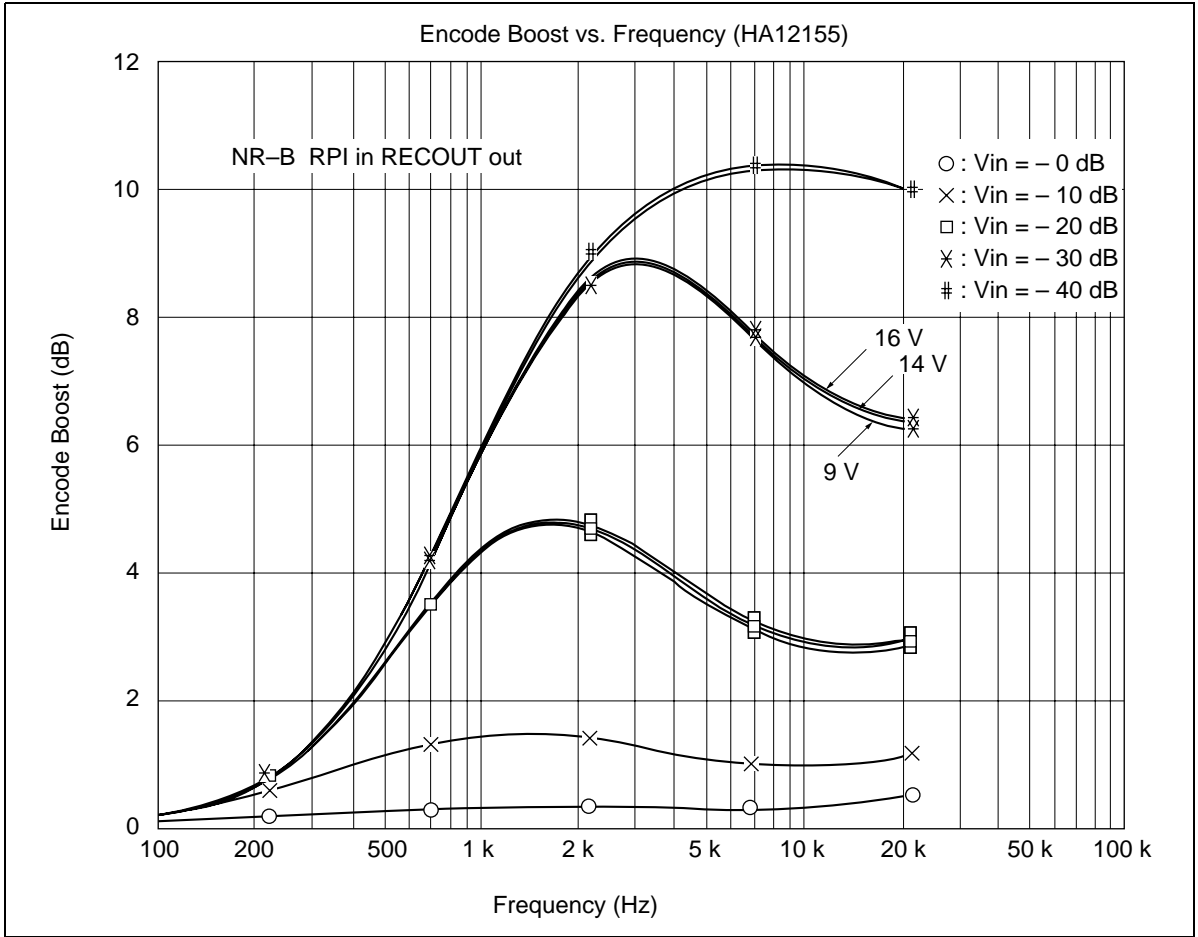
$$f3 = \frac{1}{2\pi} \cdot \frac{0.3}{\sqrt{2.25 \times 10^{-21} \times R_{FQ} \times R_{F/Q}}}$$

$$BW = \frac{1}{4\pi \times 2.78 \times 10^{-10} \times R_{F/Q}}$$

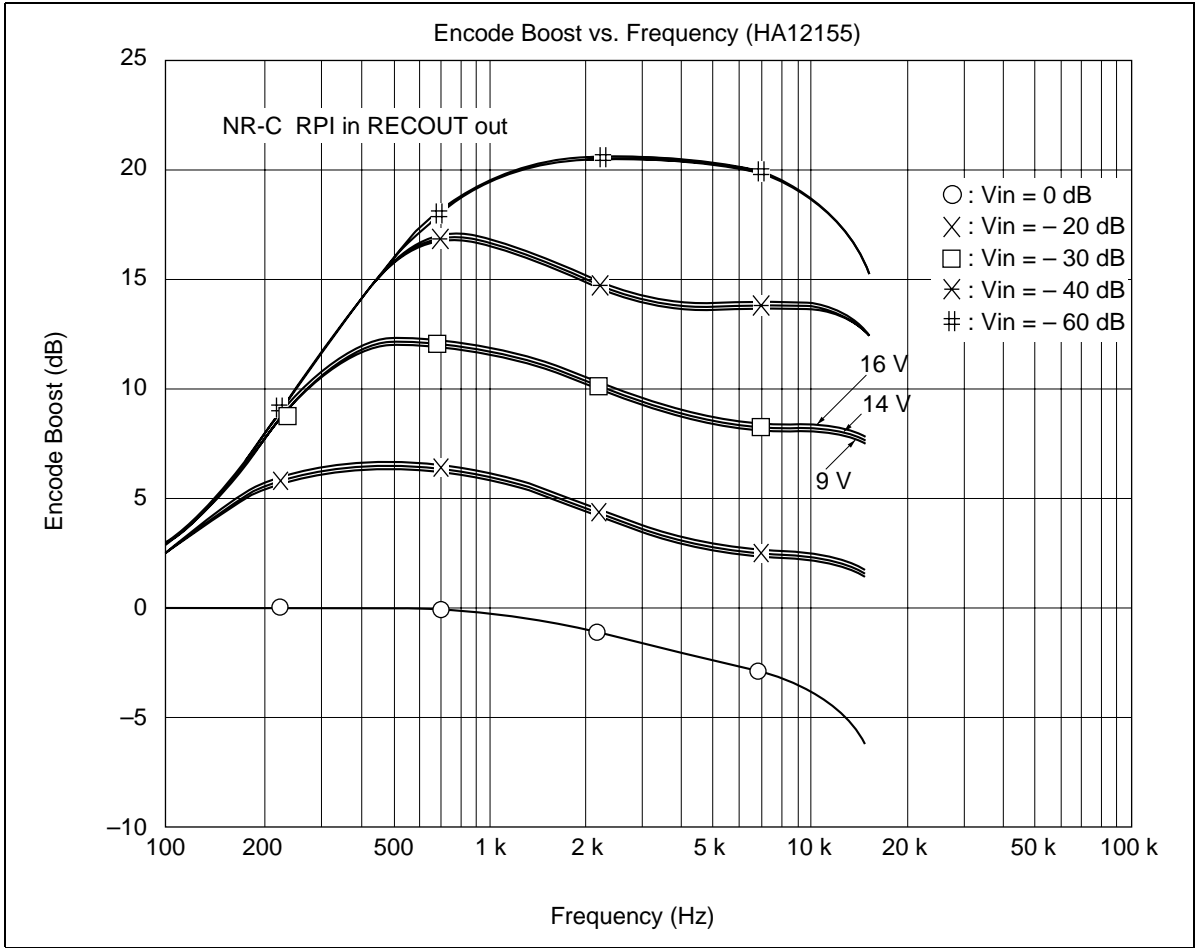
$$Q = \frac{f3}{BW} = 3.51 \times \sqrt{\frac{R_{F/Q}}{R_{F/Q}}}$$

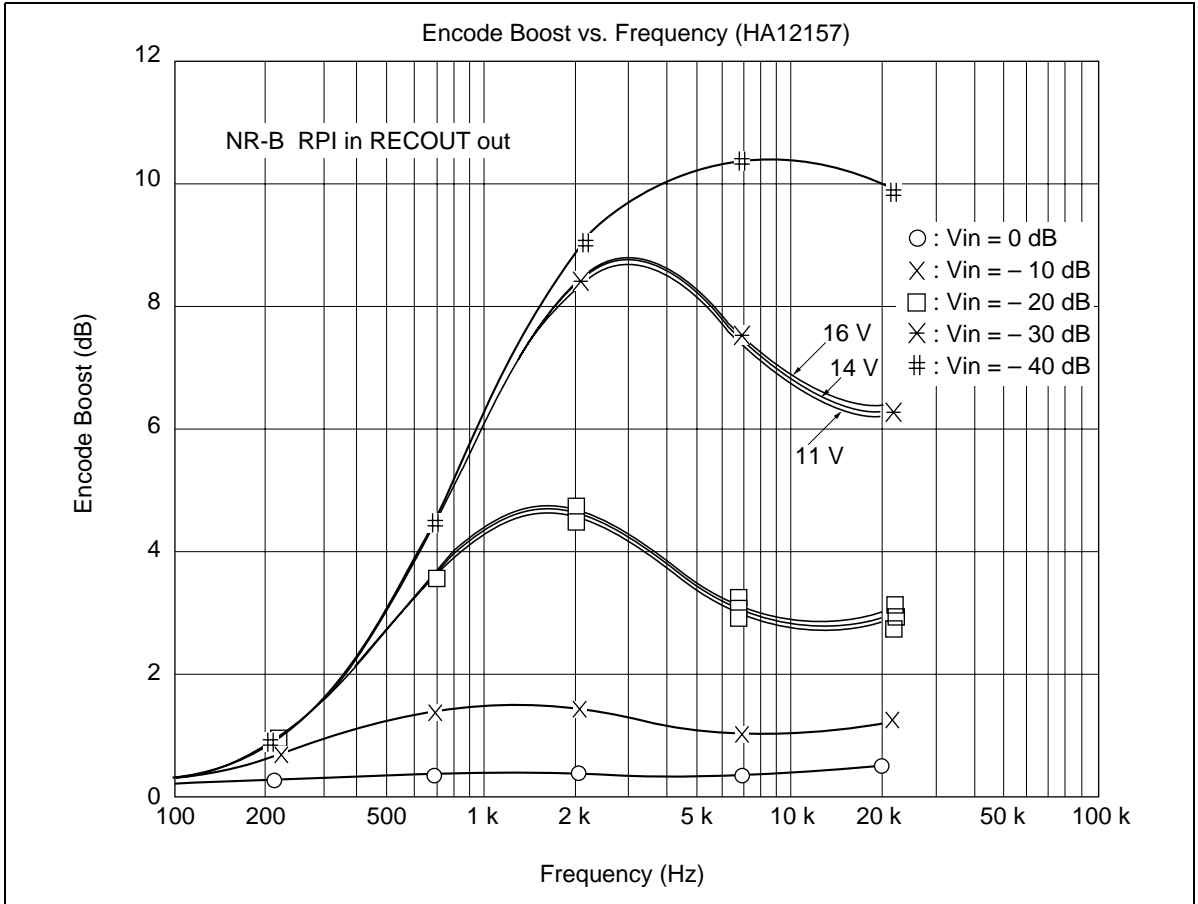




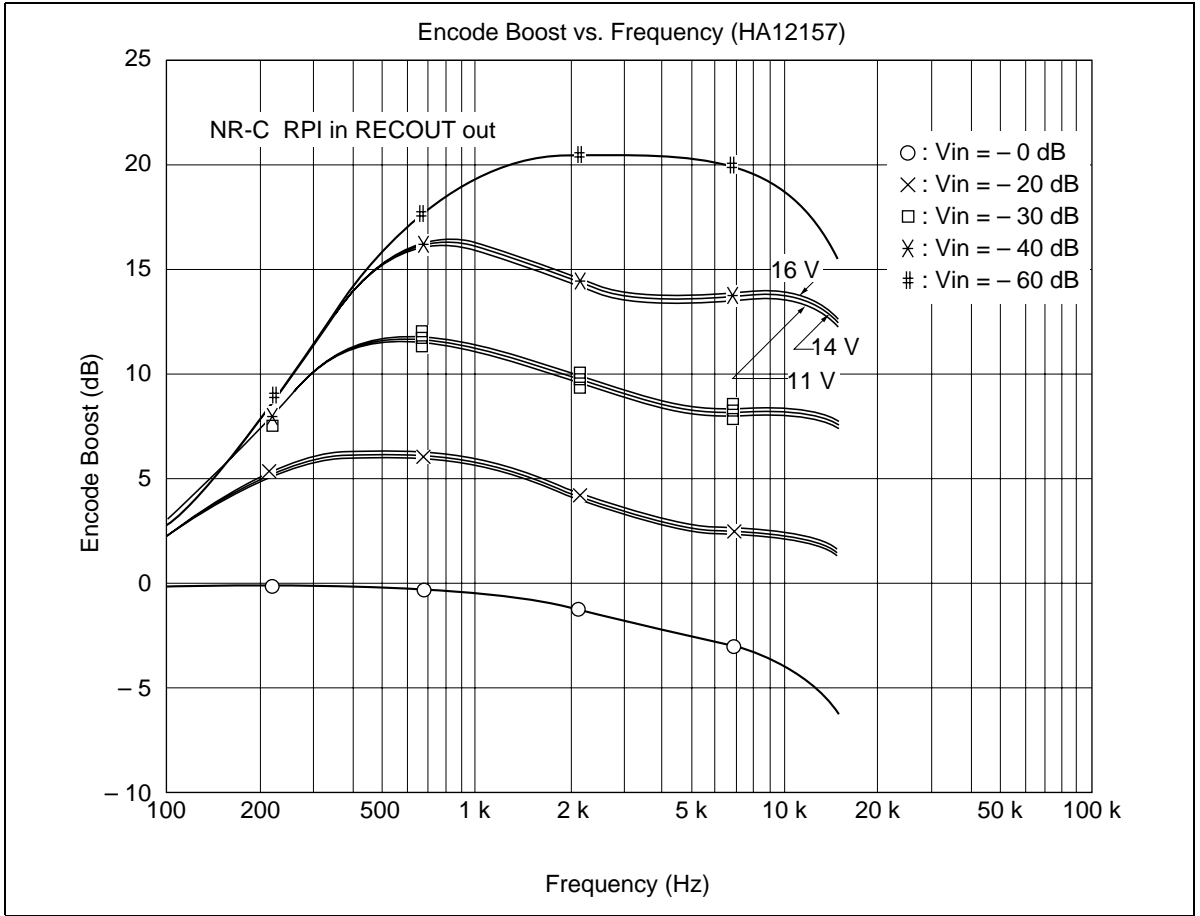


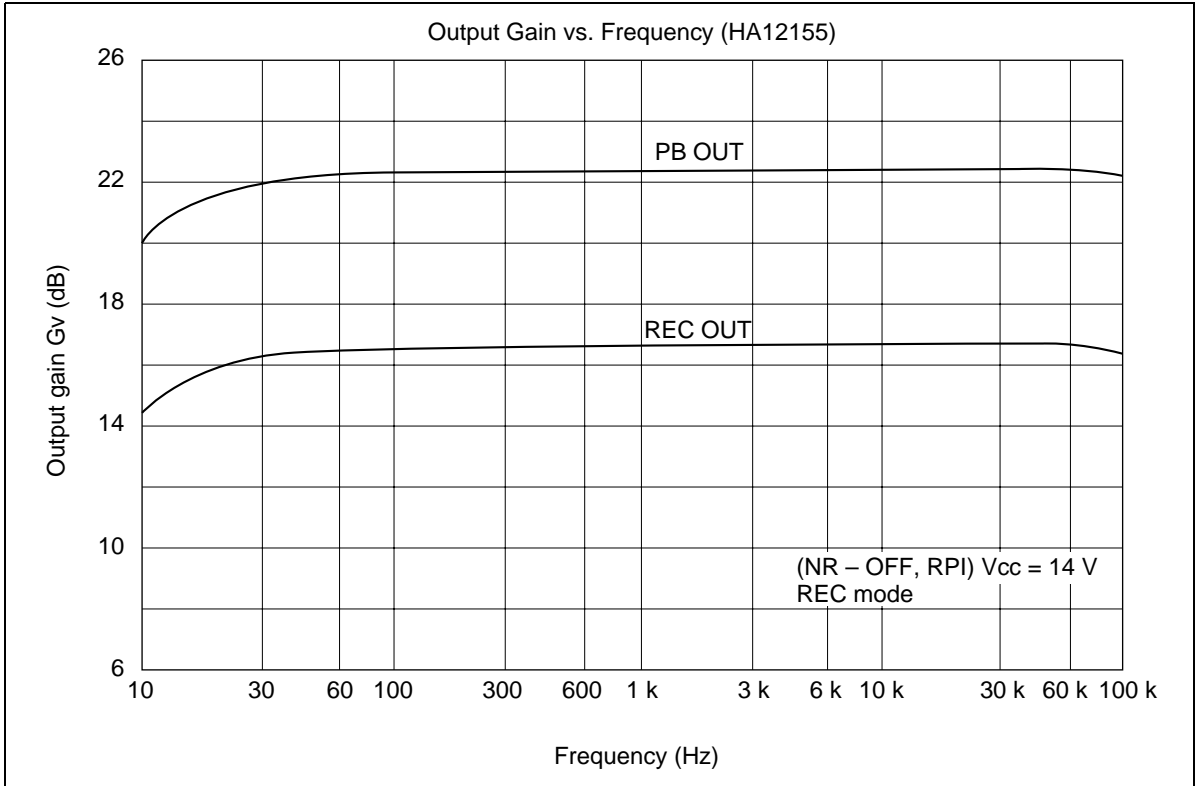
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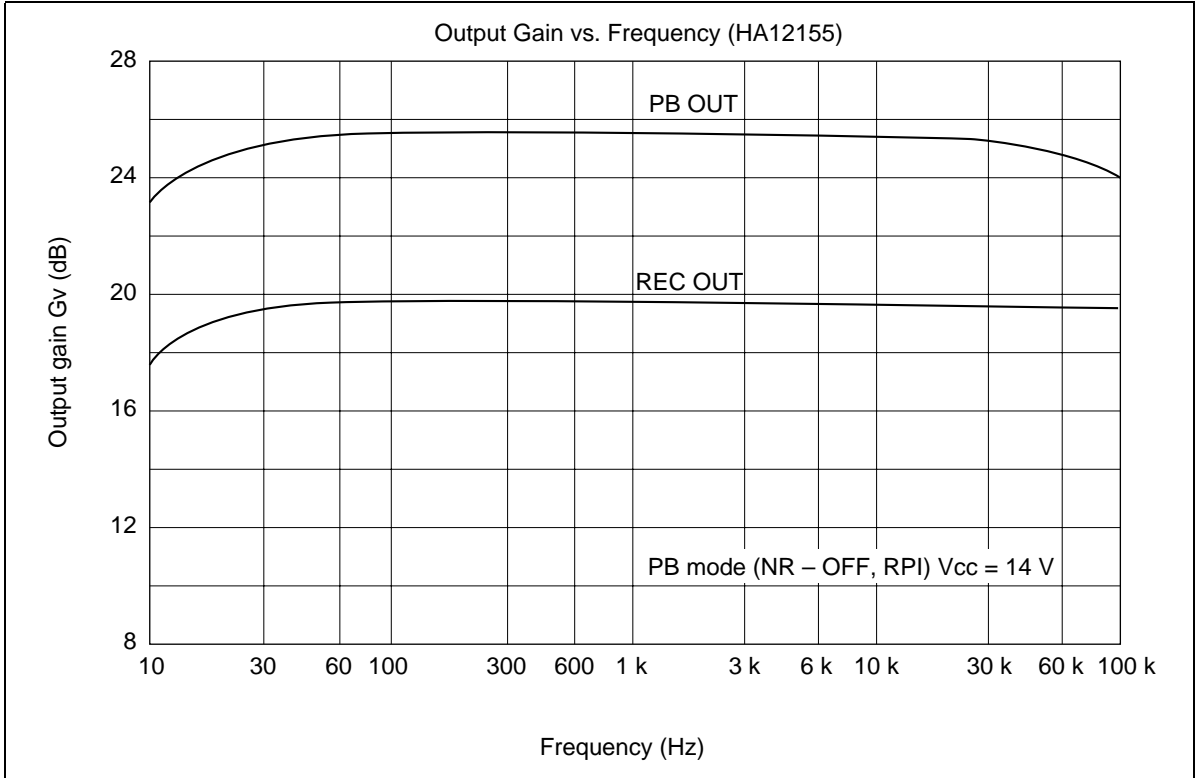


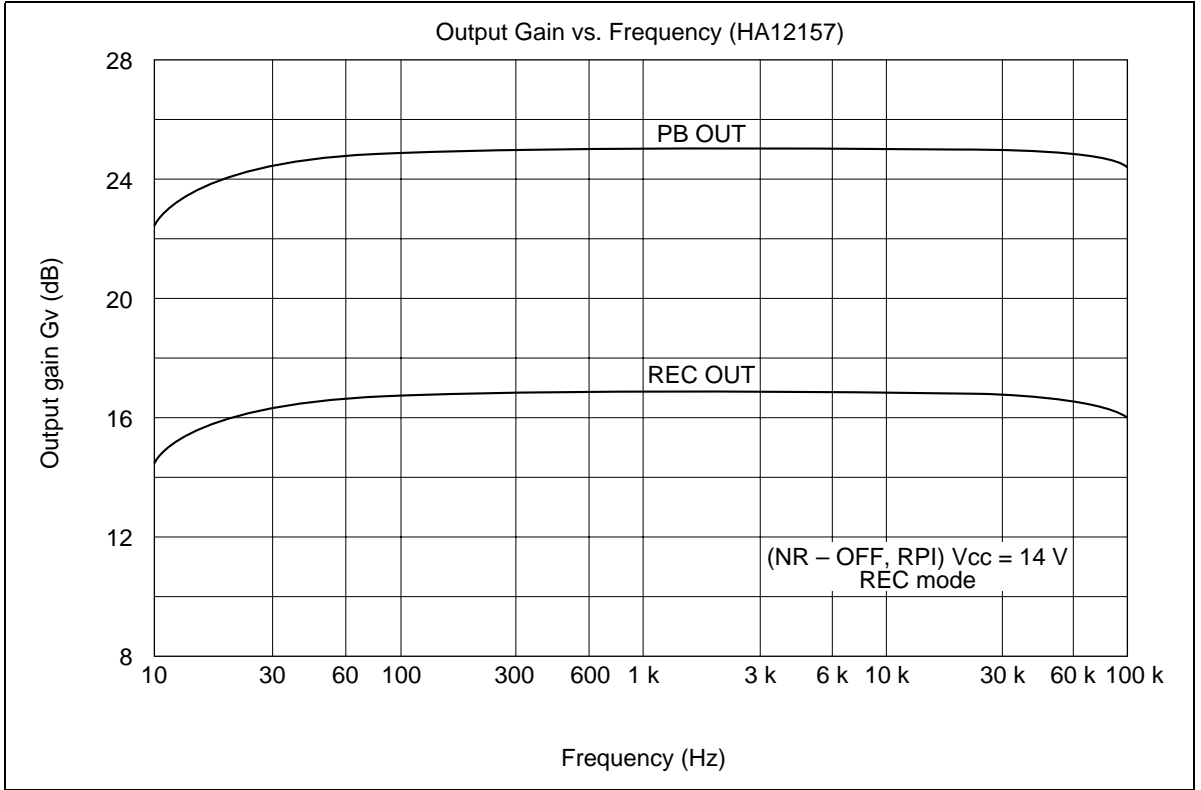
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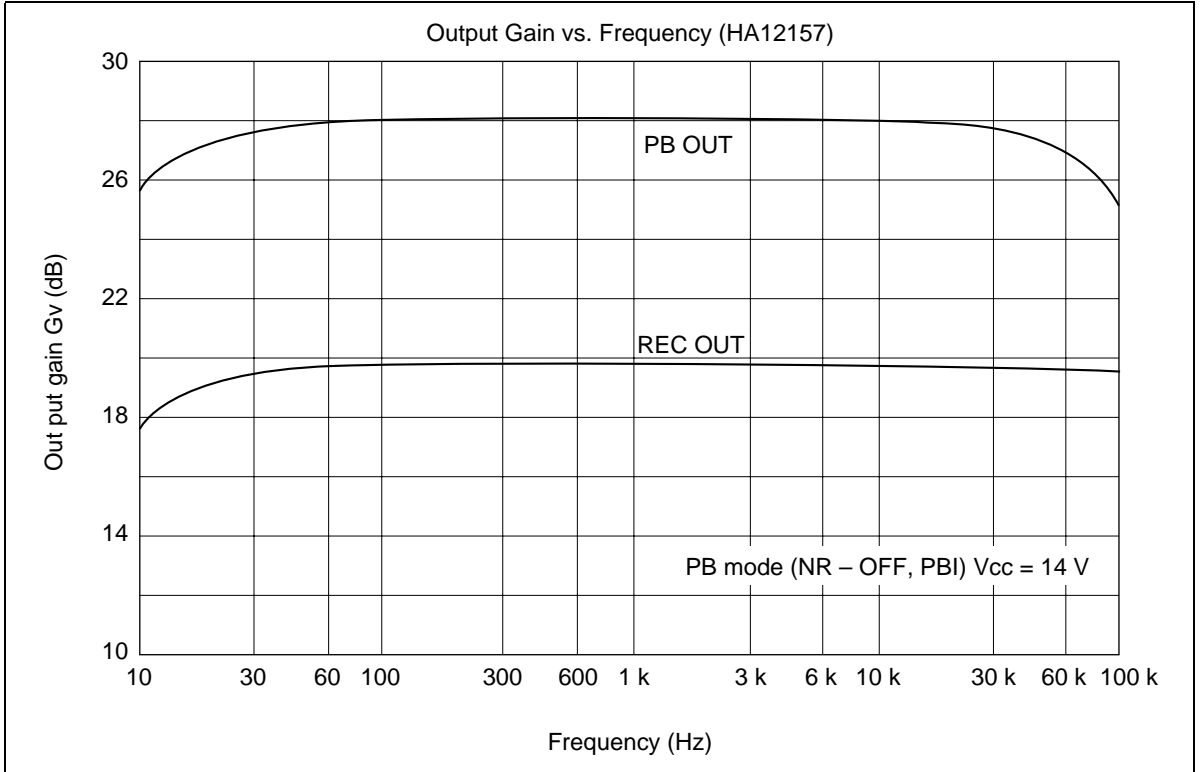


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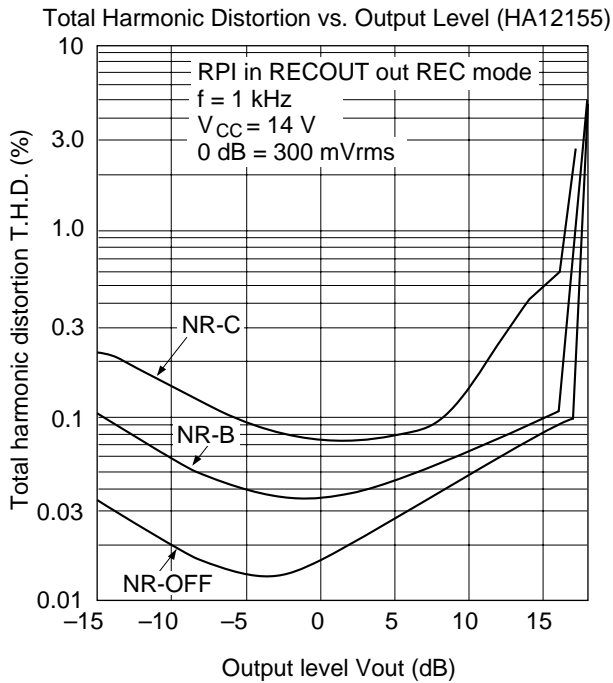
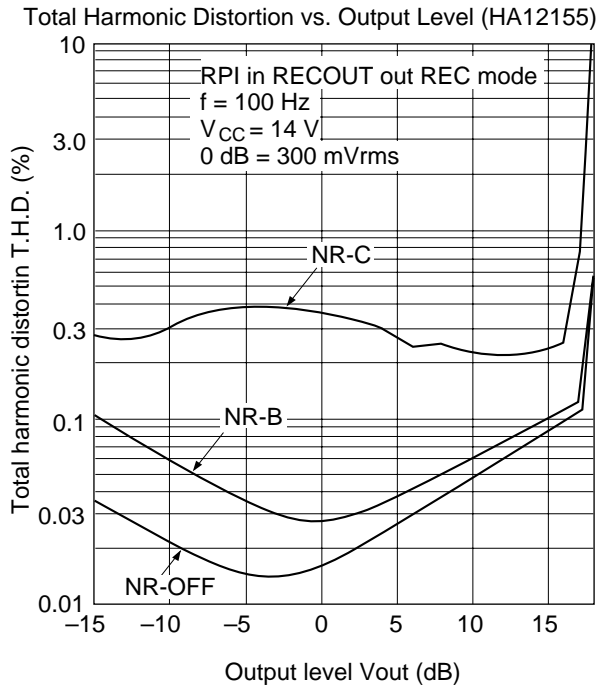




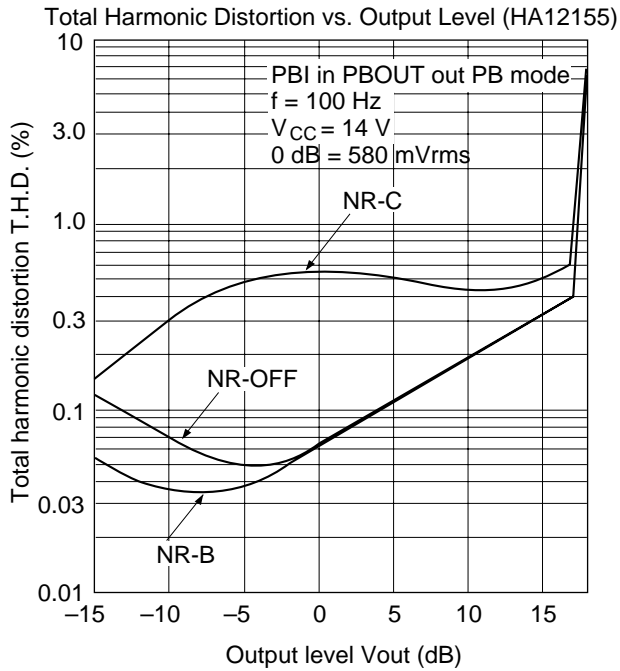
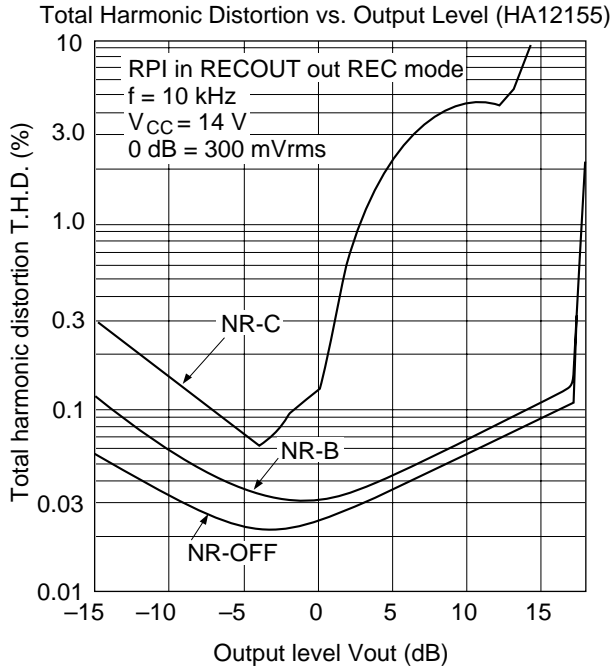
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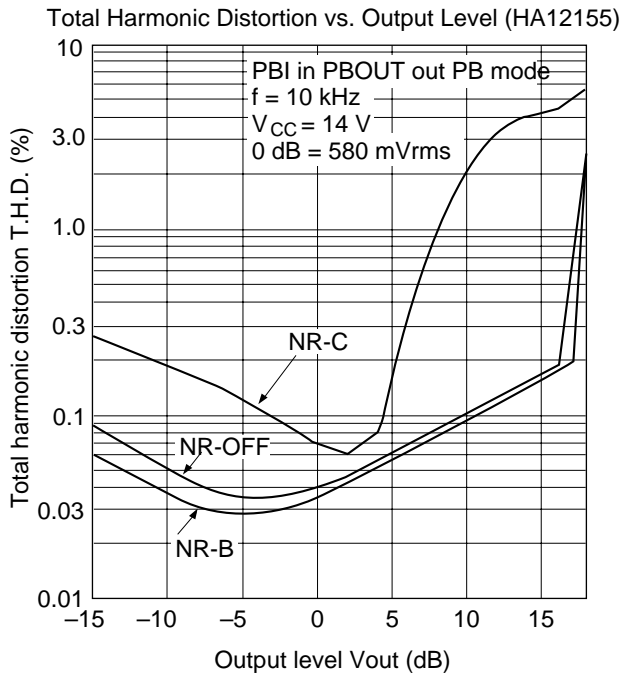
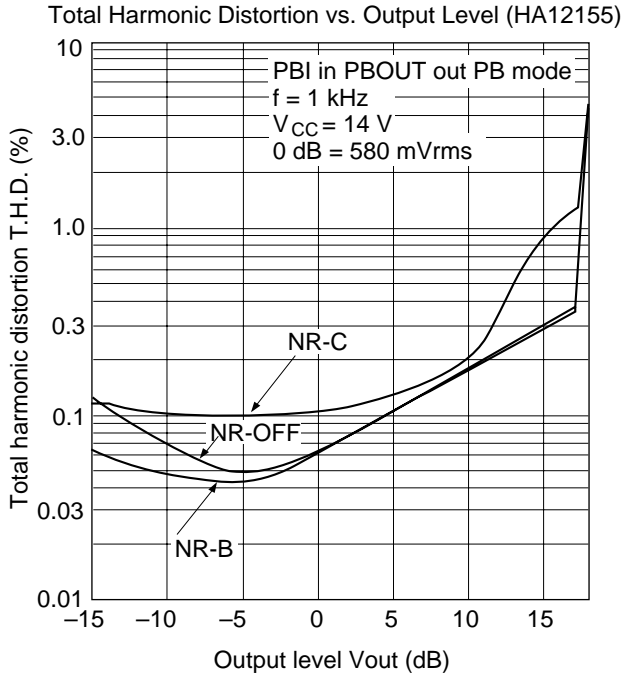


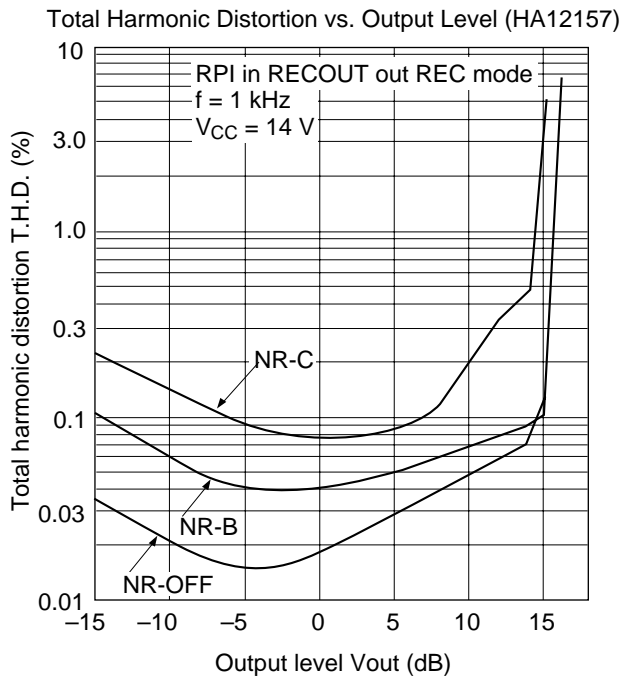
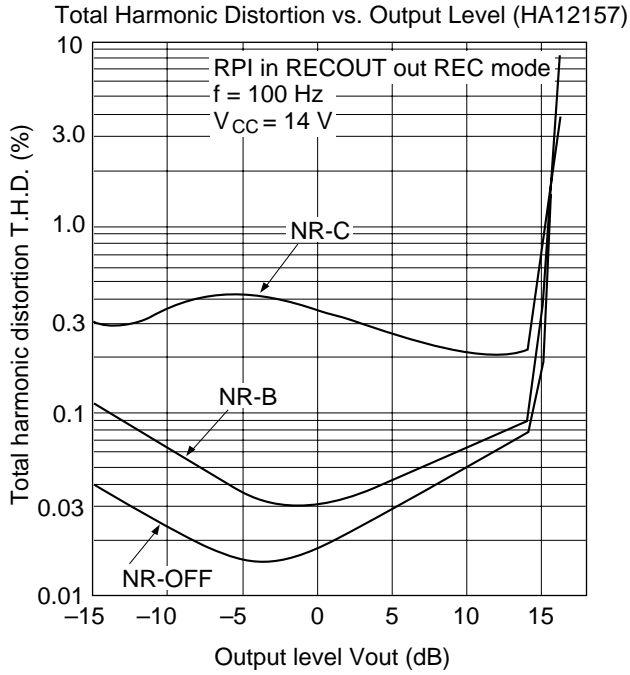


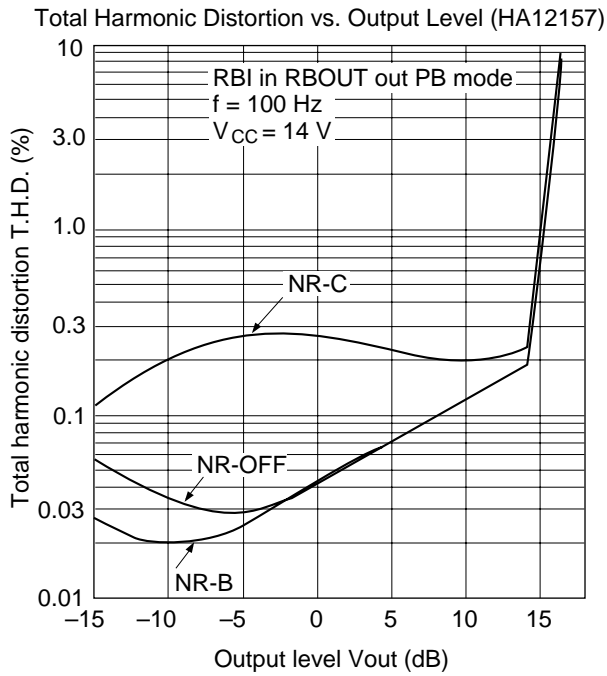
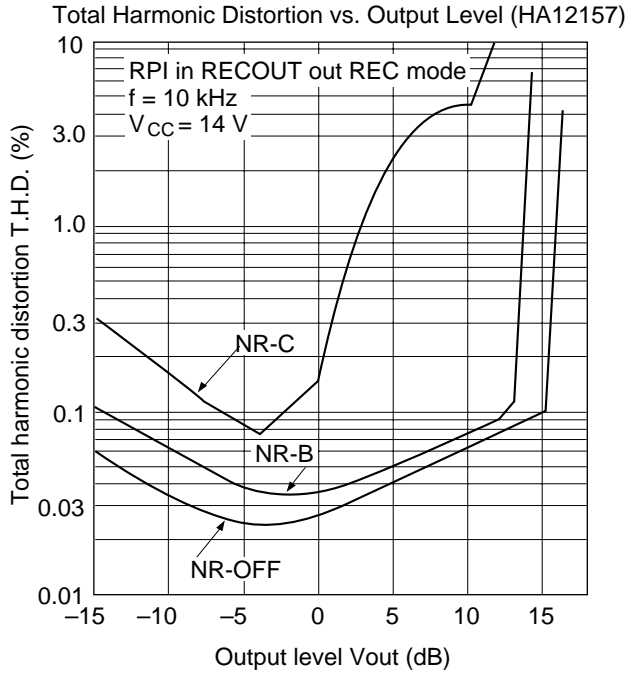


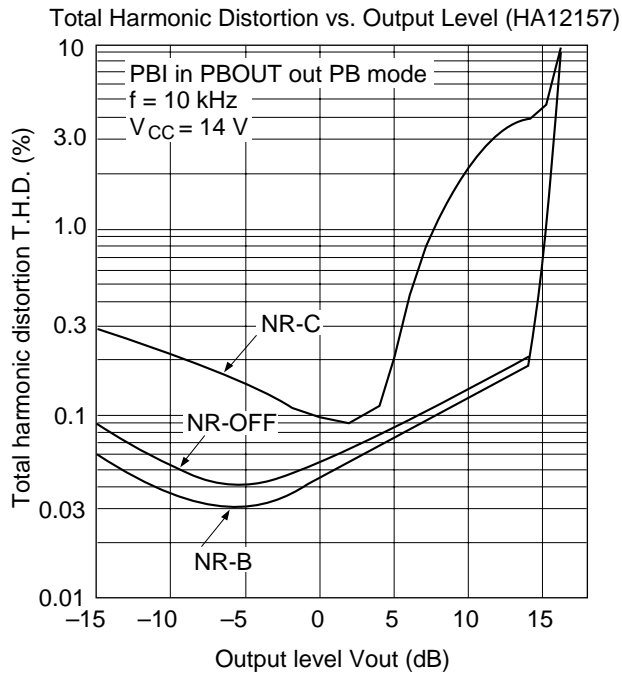
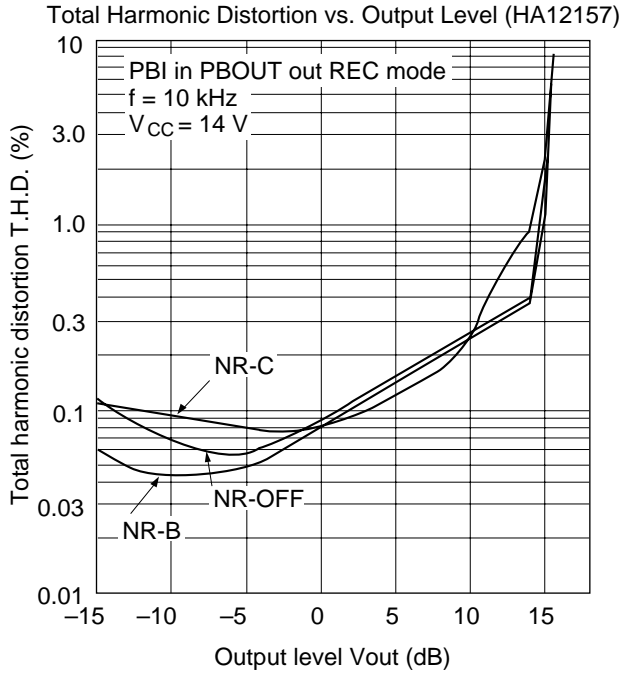
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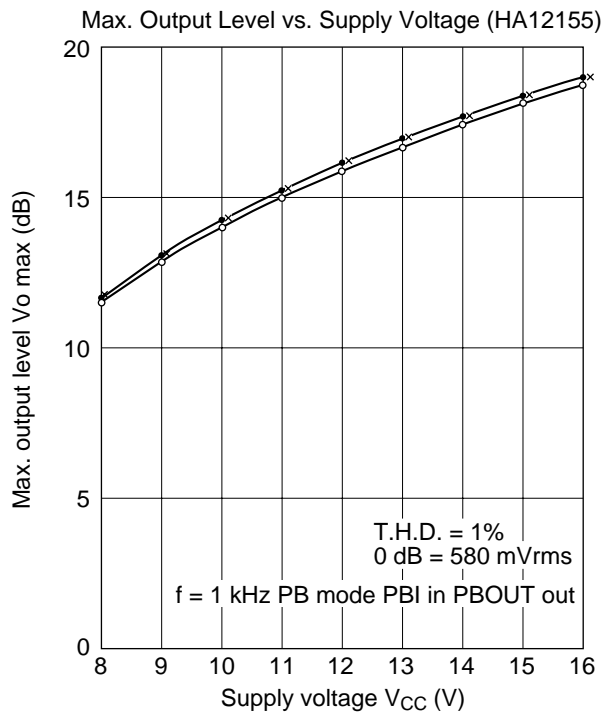
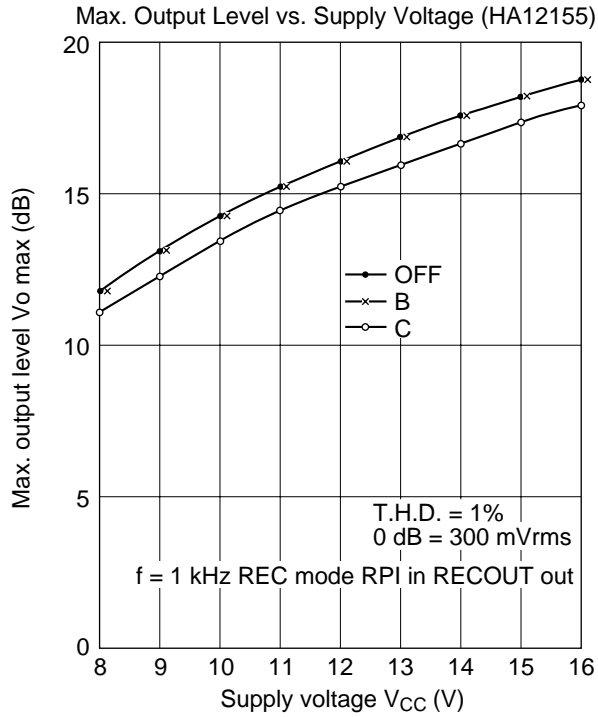






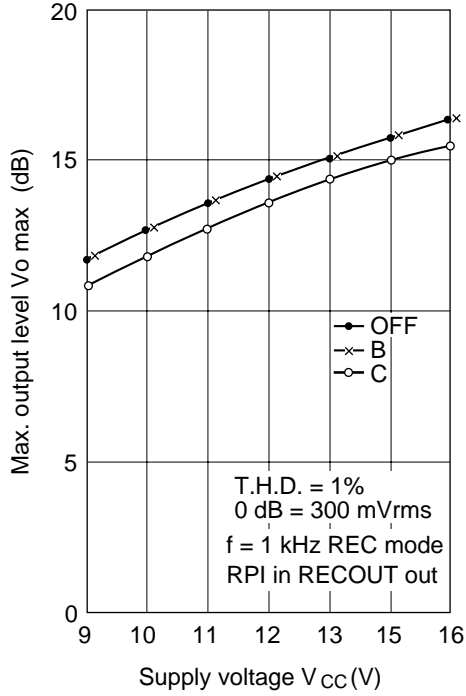




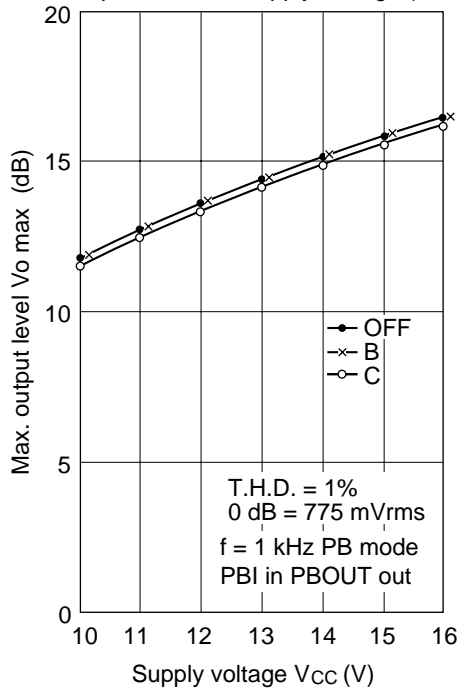


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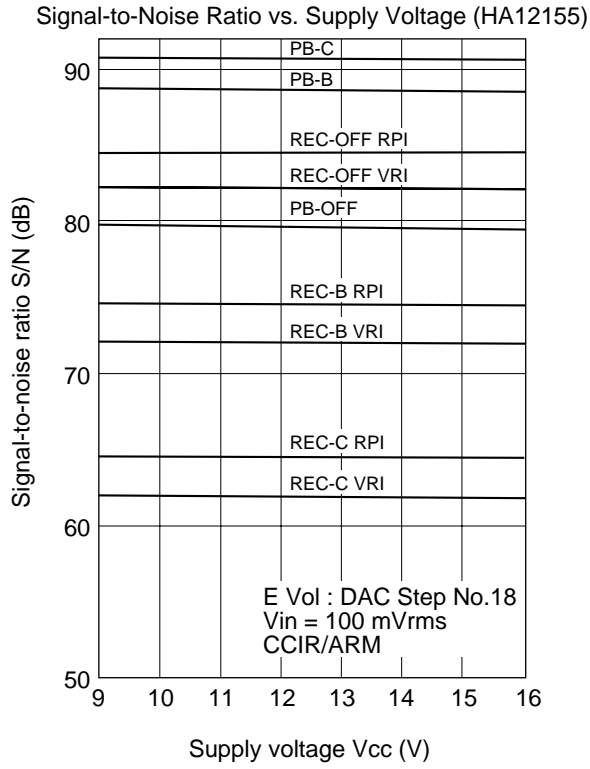
Max. Output Level vs. Supply Voltage (HA12157)



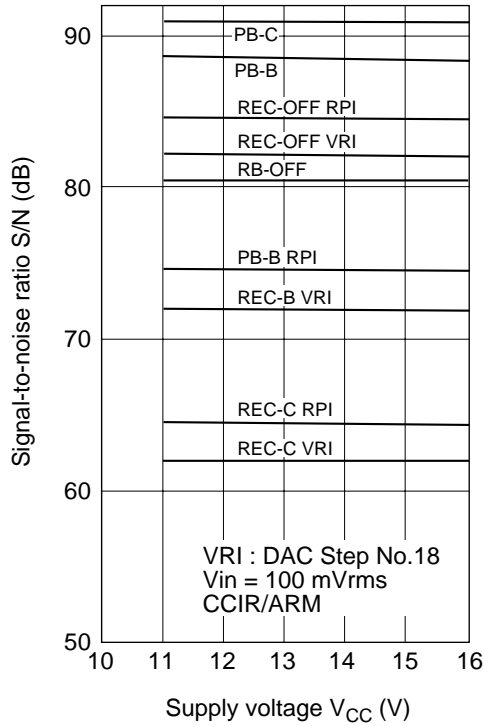
Max. Output Level vs. Supply Voltage (HA12157)



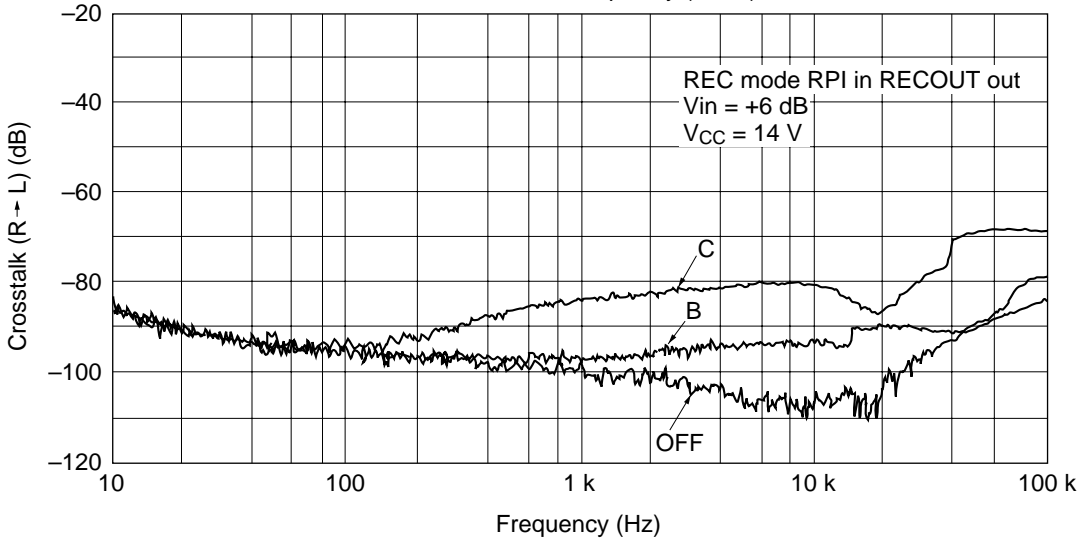




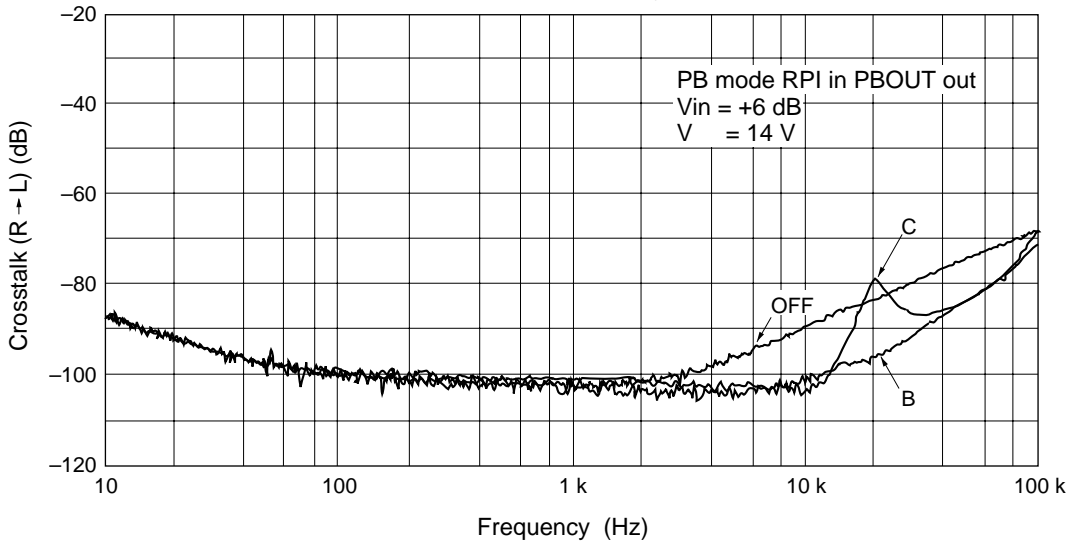
Signal-to-Noise Ratio vs. Supply Voltage (HA12157)



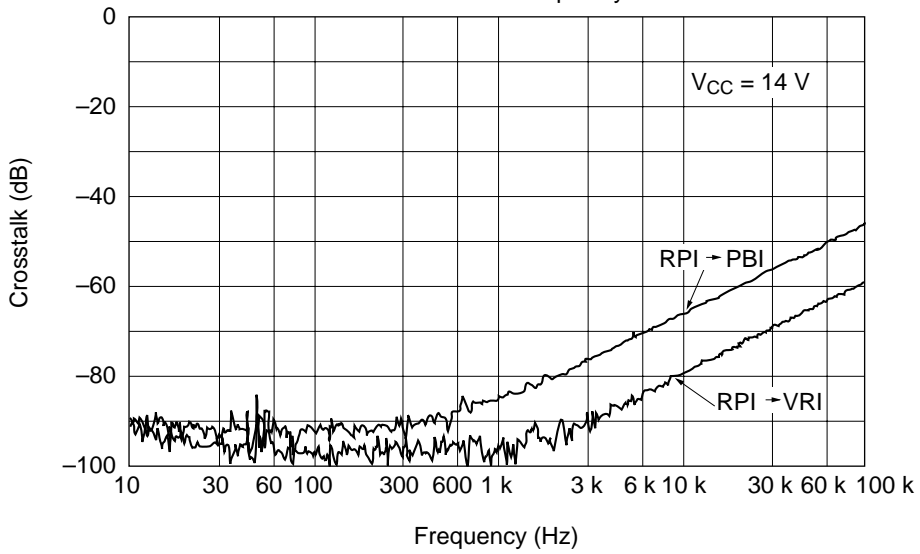
Crosstalk vs. Frequency (R → L)

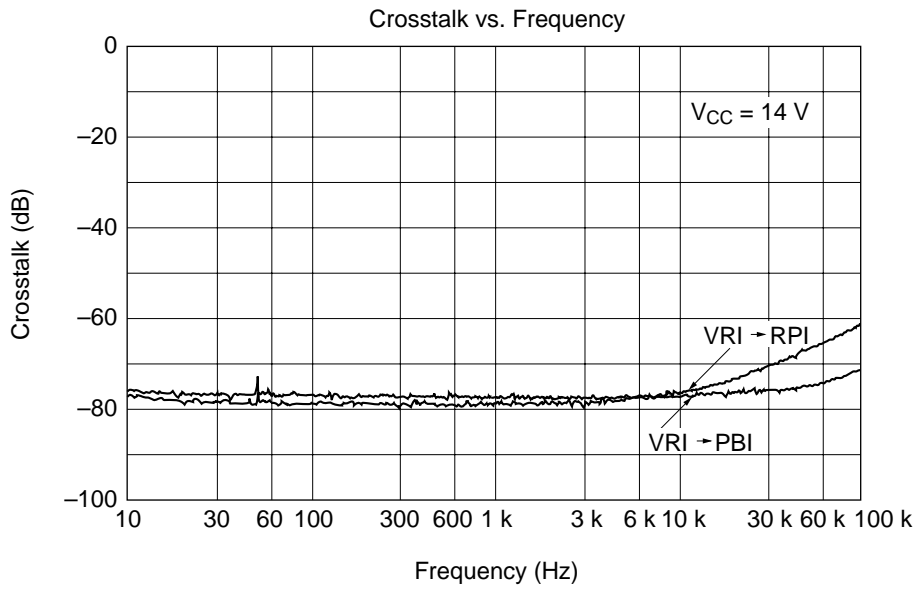
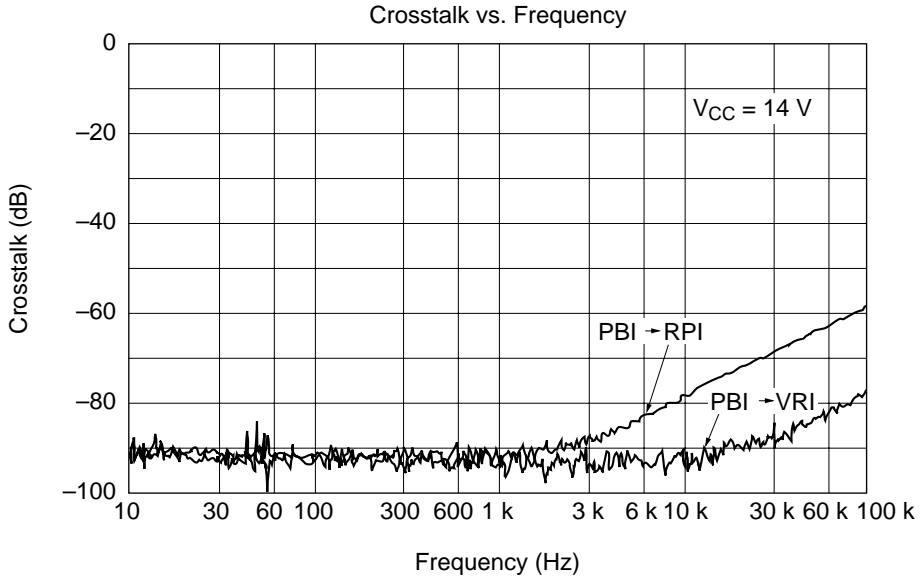


Crosstalk vs. Frequency (R → L)

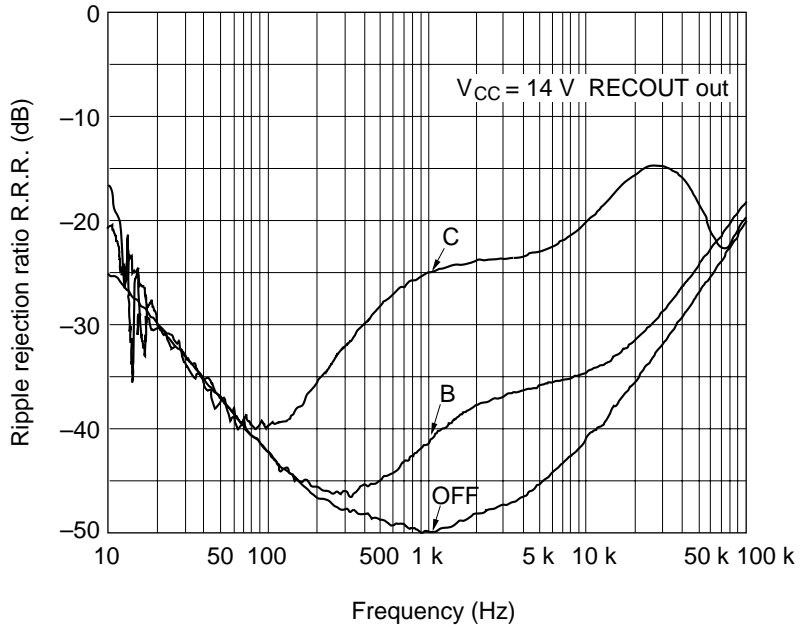


Crosstalk vs. Frequency

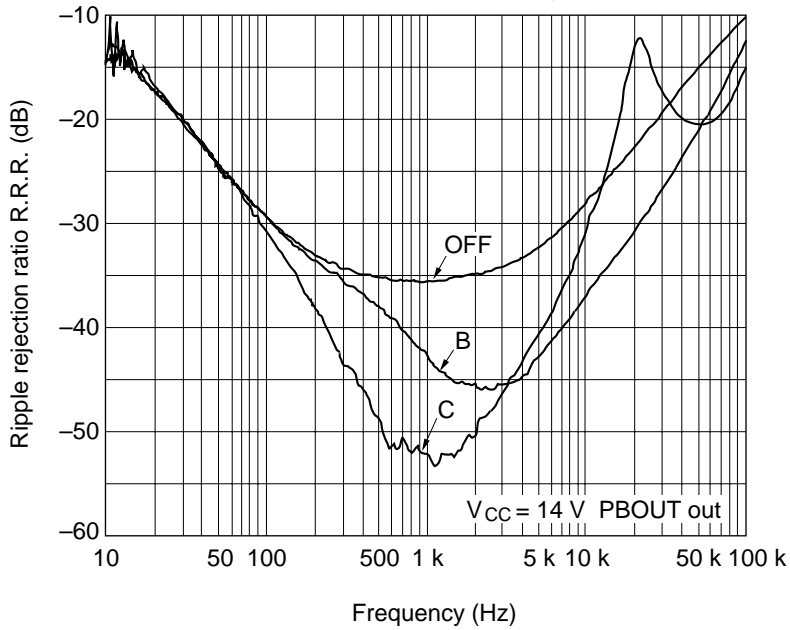


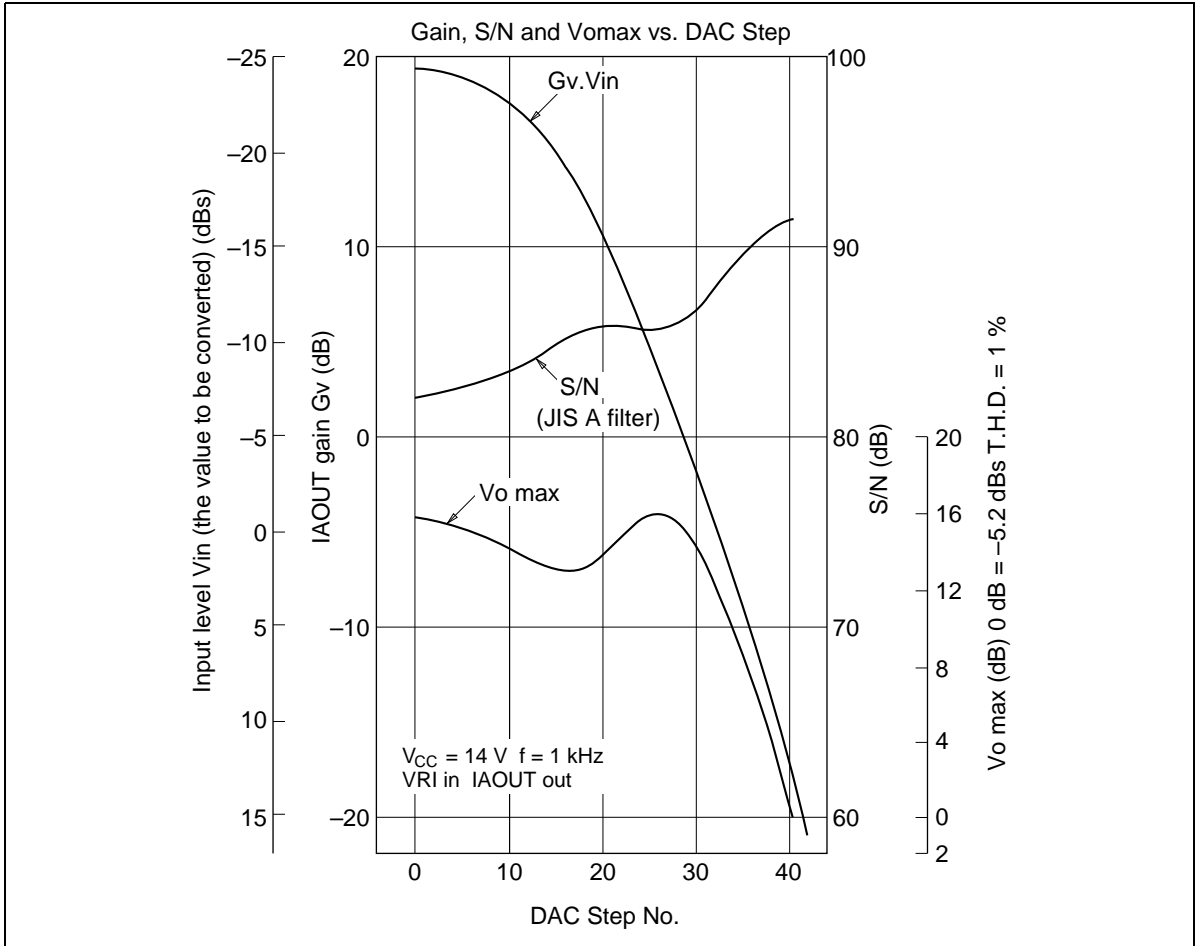


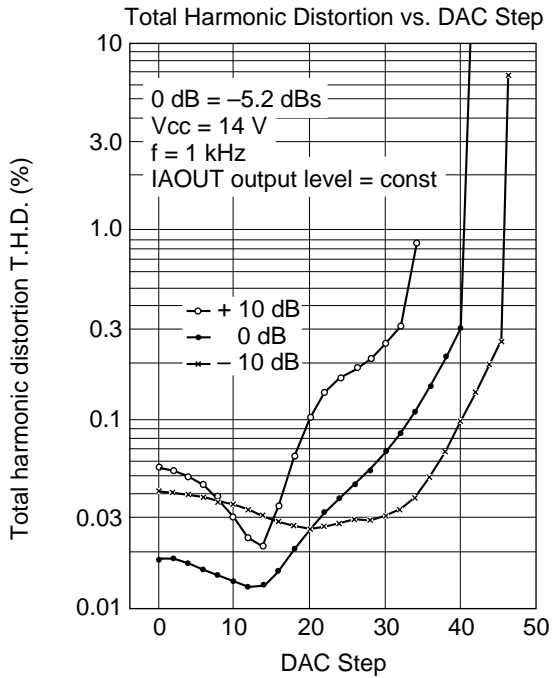
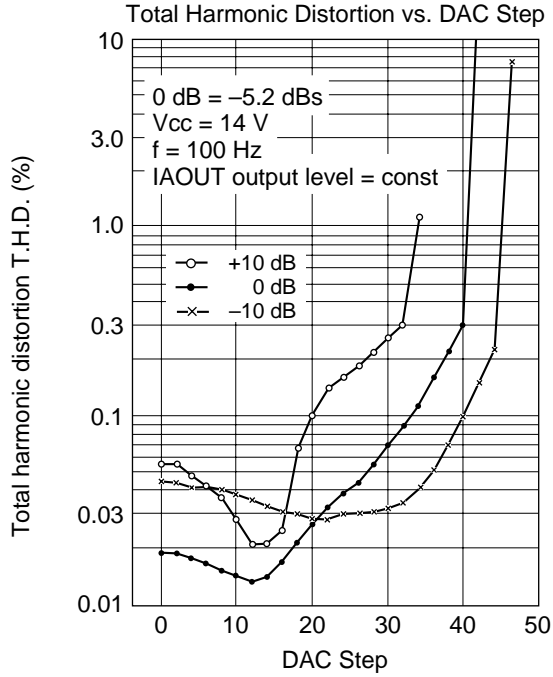
Ripple Rejection Ratio vs. Frequency (REC mode)

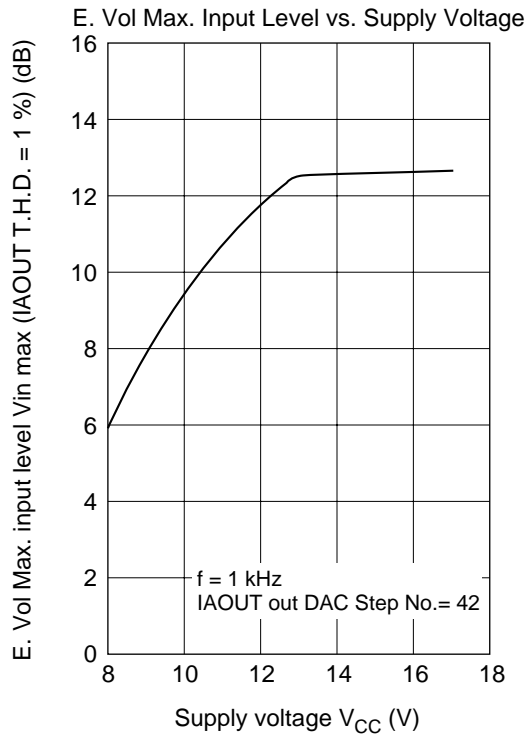
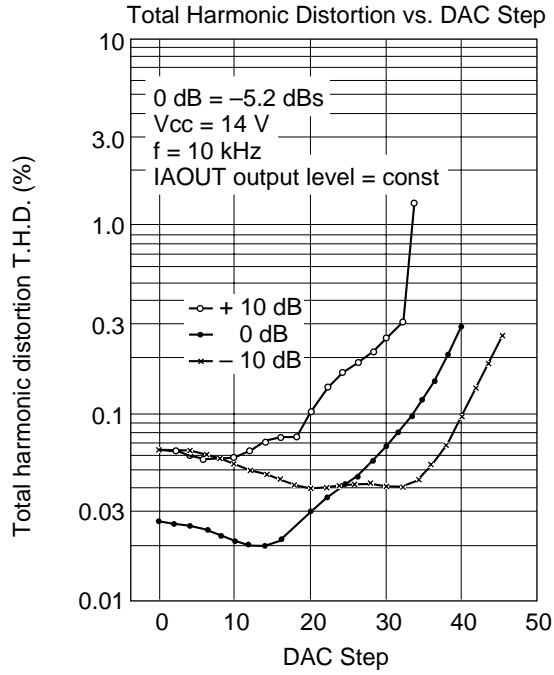


Ripple Rejection Ratio vs. Frequency (PB mode)

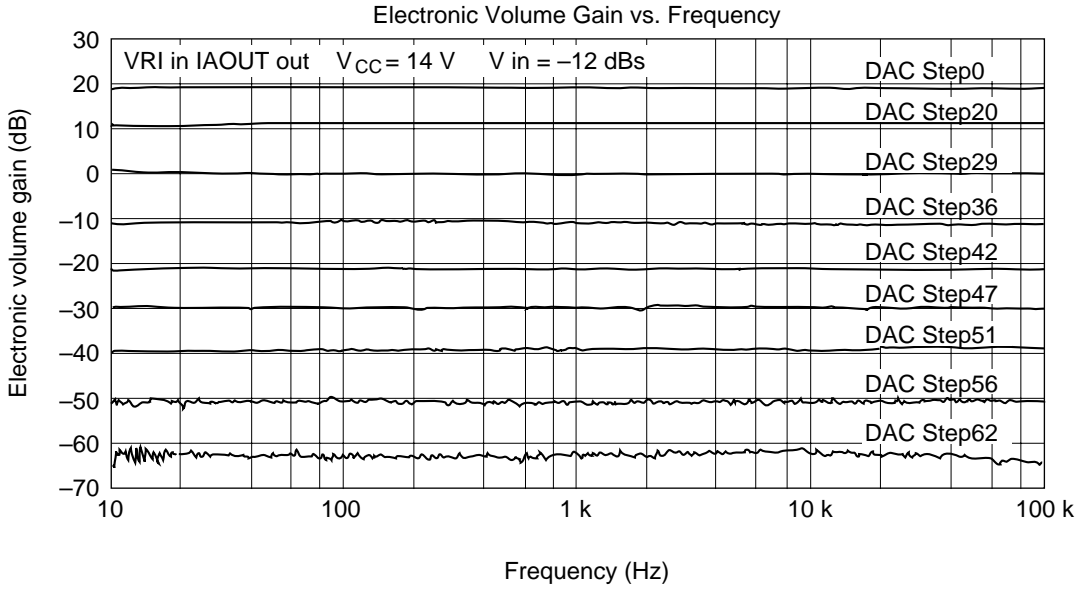




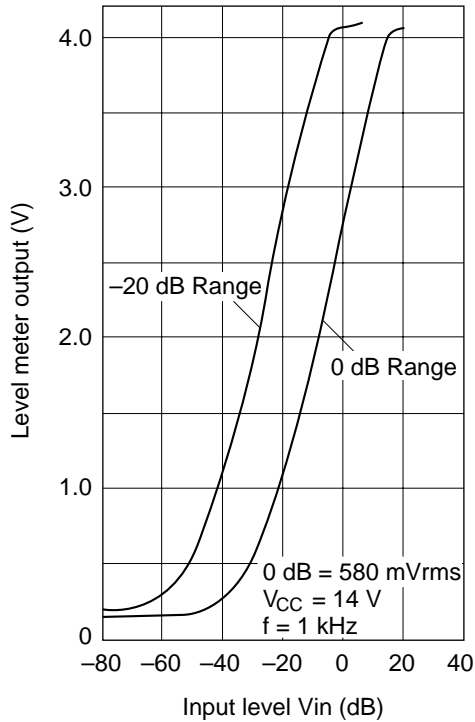




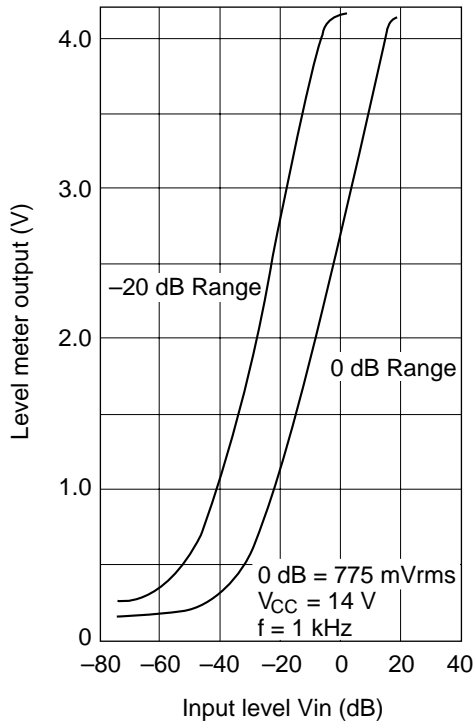




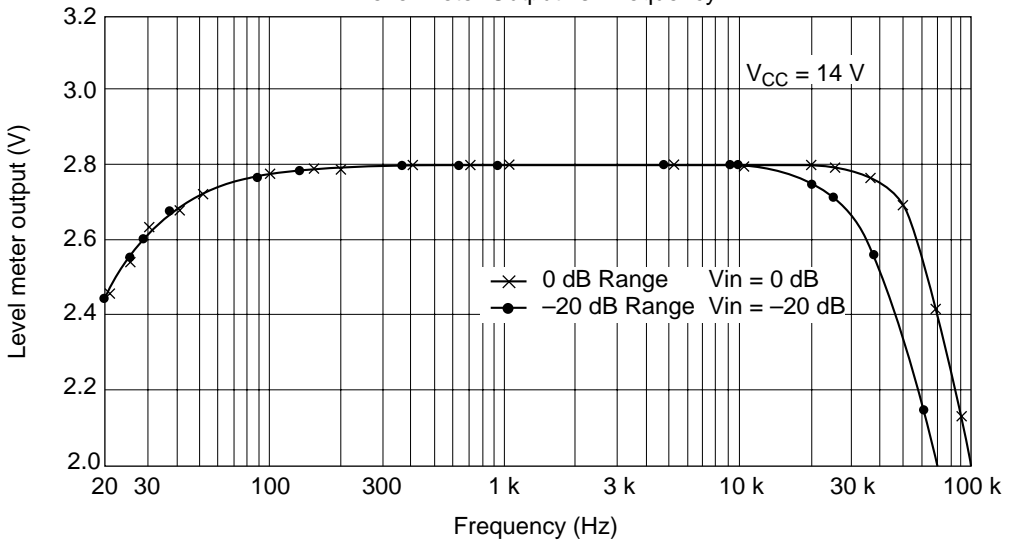
Level Meter Output vs. Input Level (HA12155)



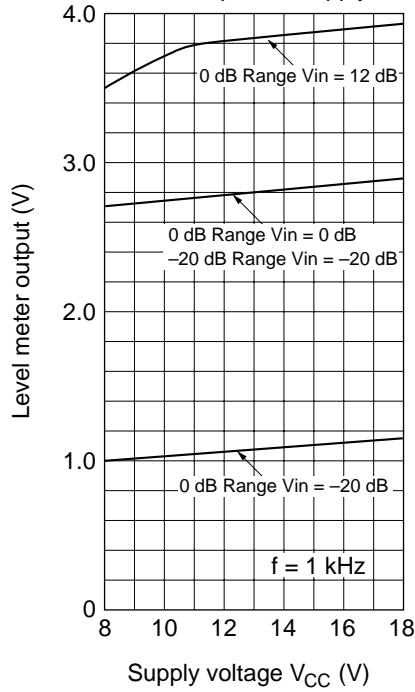
Level Meter Output vs. Input Level (HA12157)



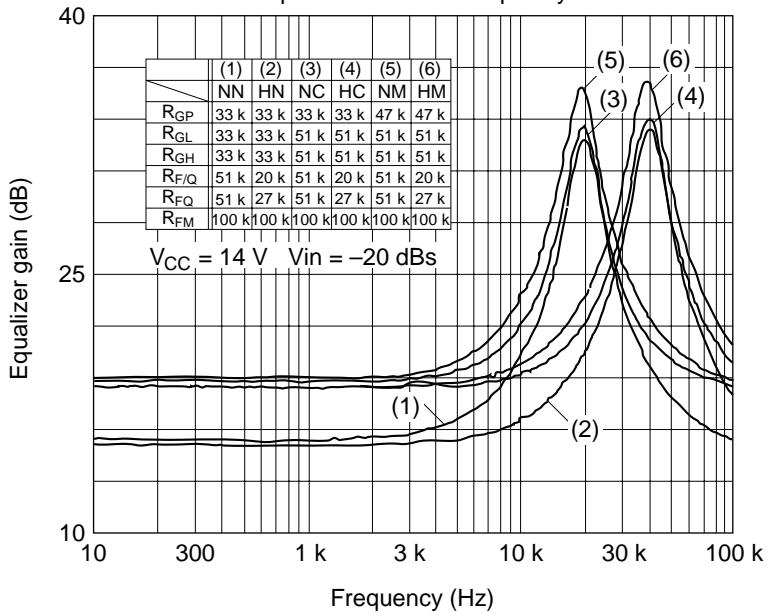
Level Meter Output vs. Frequency

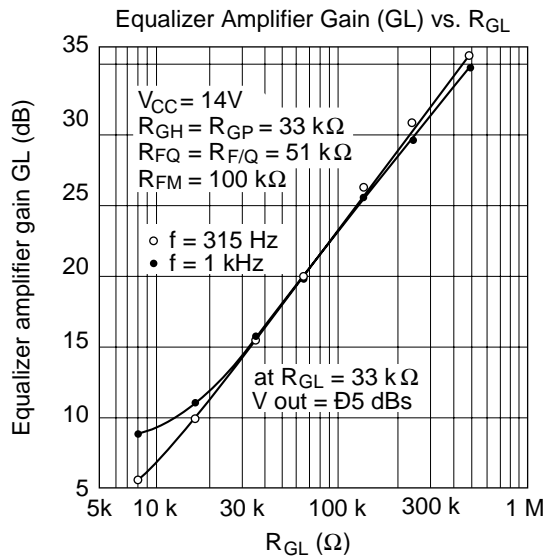
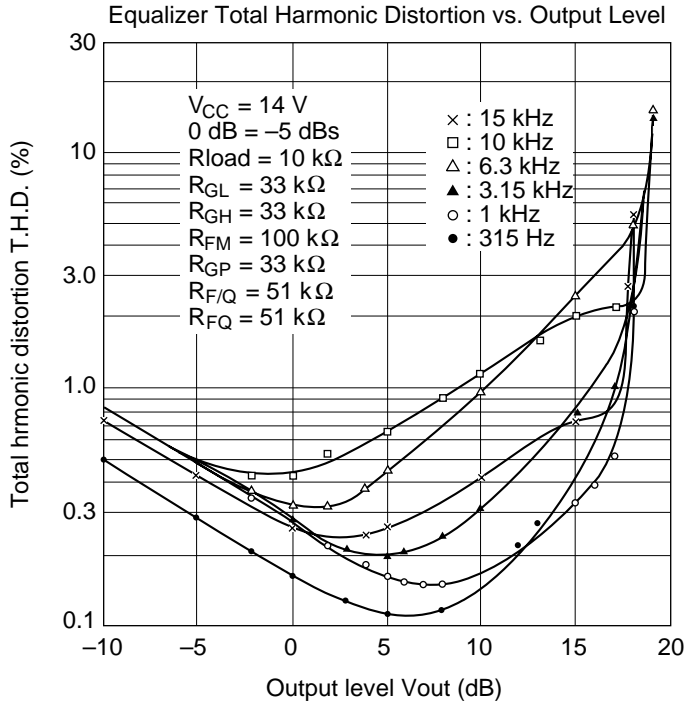


Level Meter Output vs. Supply Voltage

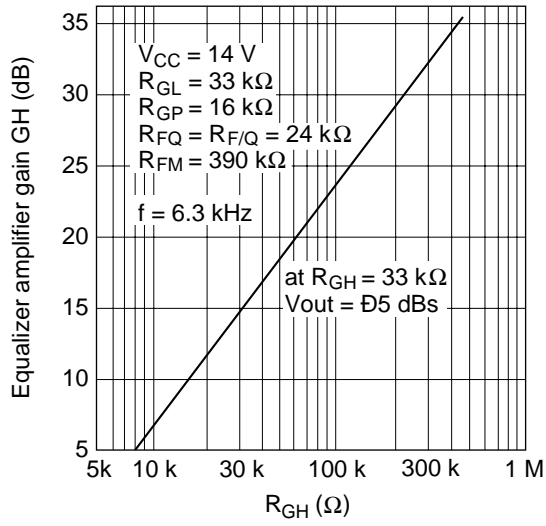


Equalizer Gain vs. Frequency

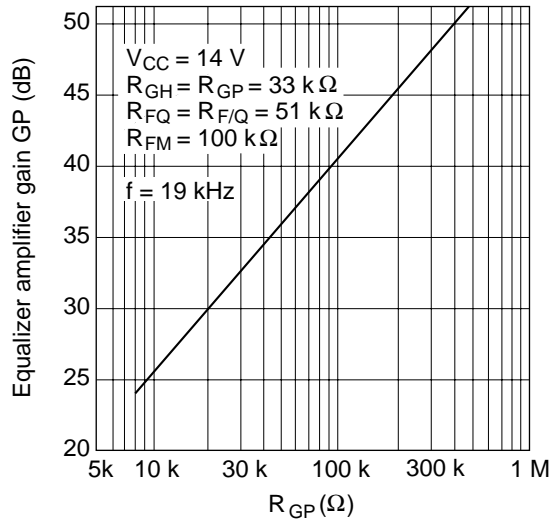


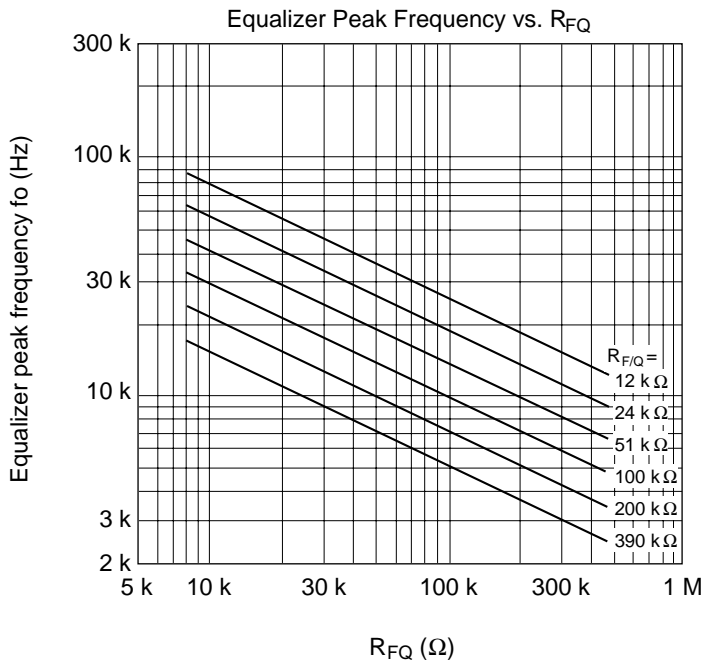
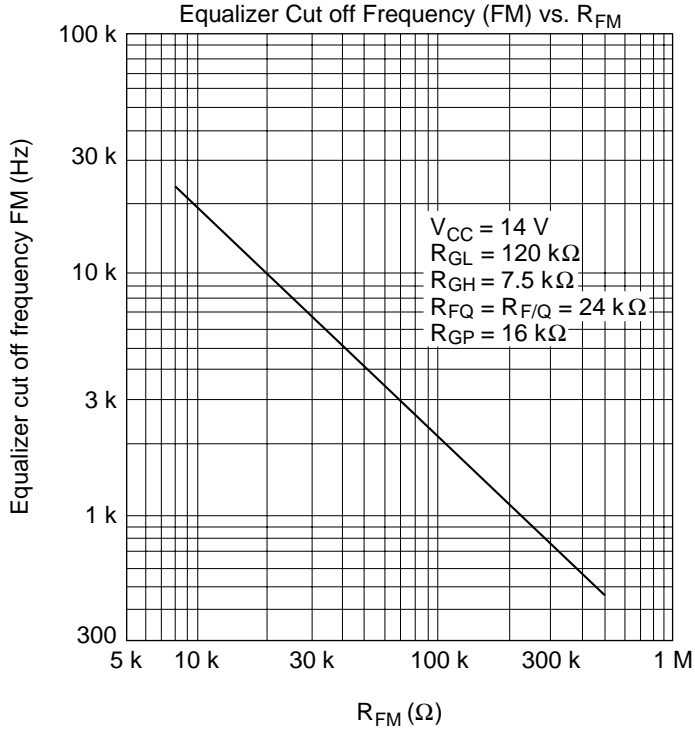


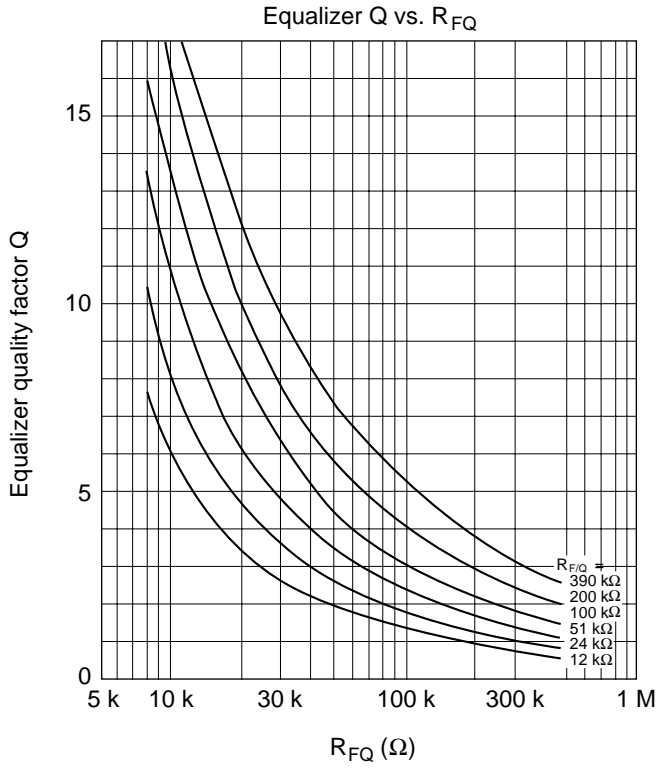
Equalizer Amplifier Gain (GH) vs.  $R_{GH}$



Equalizer Amplifier Gain (GP) vs.  $R_{GP}$











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 Whitebrook Park  
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