

TOSHIBA CMOS DIGITAL INTEGRATED CIRCUIT SILICON MONOLITHIC

# TC9412AP, TC9412AF, TC9413AP

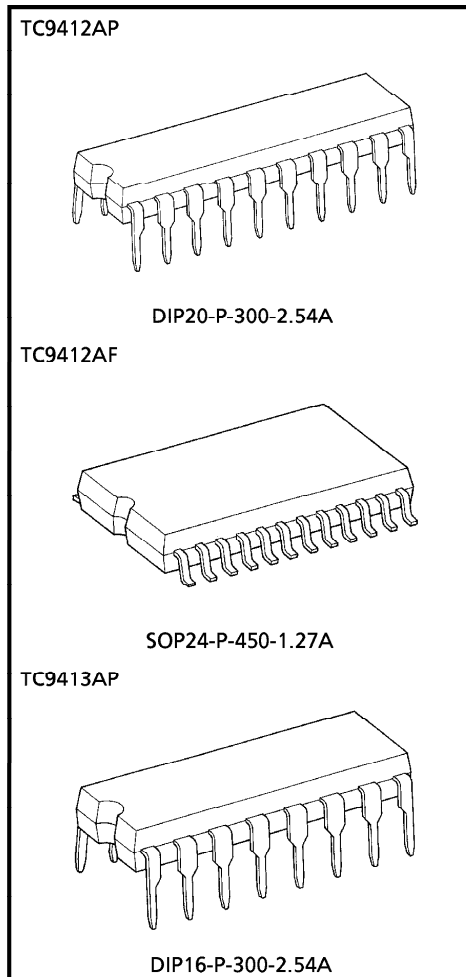
## ELECTRONIC VOLUME CONTROL

The TC9412AP, TC9412AF, TC9413AP are electronic volume control ICs developed for use in home stereos and other audio equipment.

Using serial data input from external sources, it controls the sound volume, balance and loudness circuits.

### FEATURES

- Sound volume can be controlled in 62 steps from 0 to 78dB or up to an infinite level in 1 or 2dB increments.
- Incorporating two channels of volume control circuits, the device allows independent volume control : therefore, it also provides the balancing function.
- A loudness circuit (20dB tap) is built in TC9412AP and TC9412AF.
- Can operate with a single or dual power supplies.
- Can control up to 4 chips on the same bus by using chip select input.
- Thanks to its polysilicon resistor, the device allows you to configure a low-distortion, high-performance volume control system.



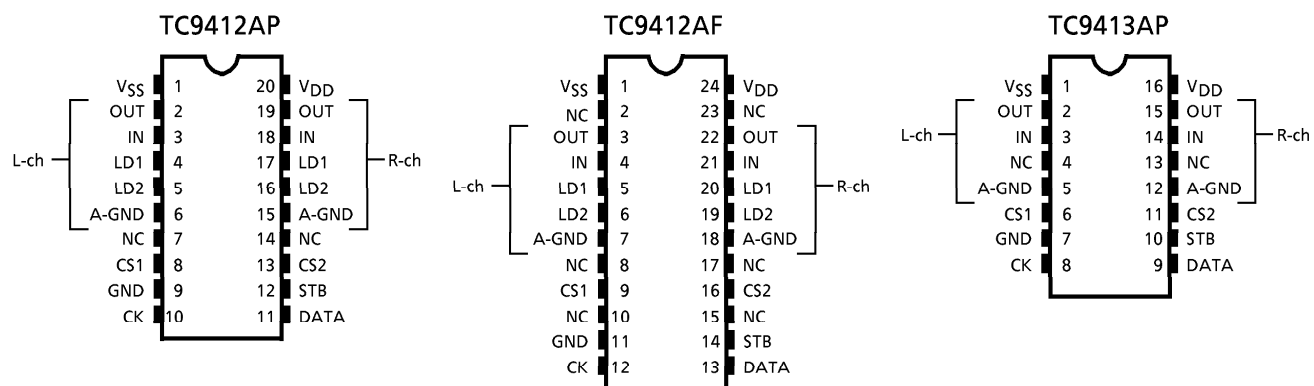
### Weight

|                   |                |
|-------------------|----------------|
| DIP20-P-300-2.54A | : 1.4g (Typ.)  |
| SOP24-P-450-1.27A | : 0.44g (Typ.) |
| DIP16-P-300-2.54A | : 1.0g (Typ.)  |

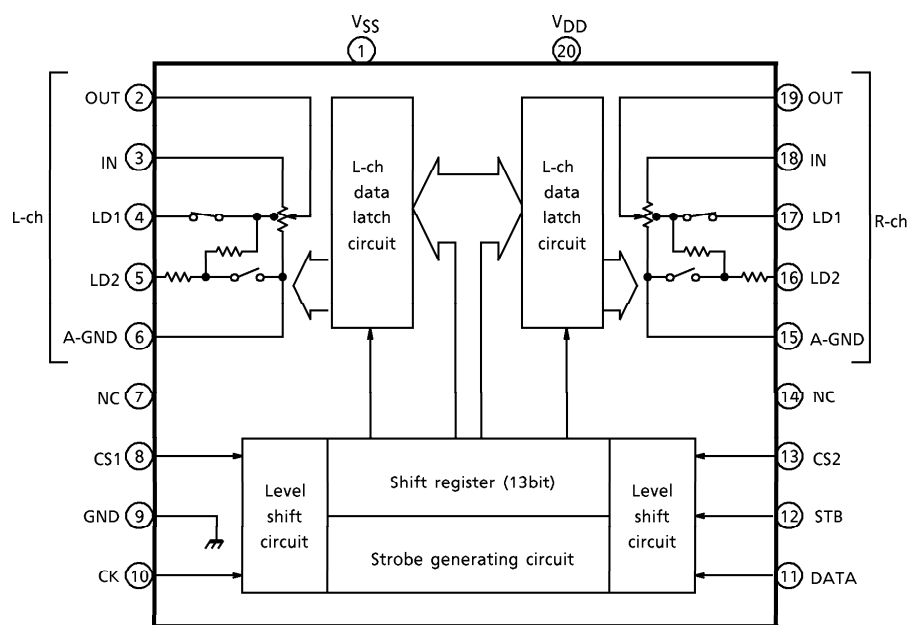
961001EBA2

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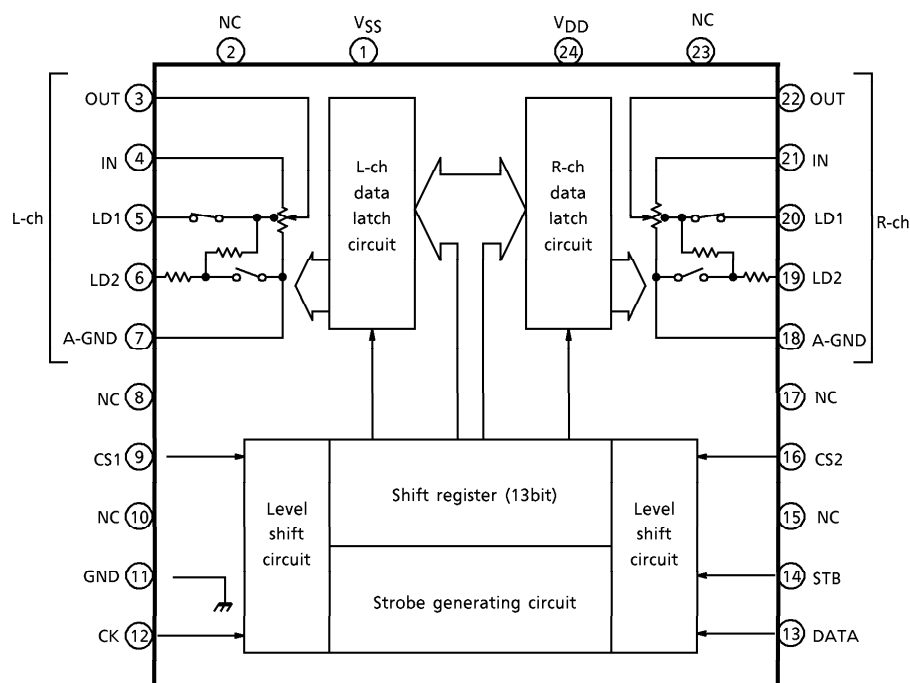
## PIN CONNECTIONS



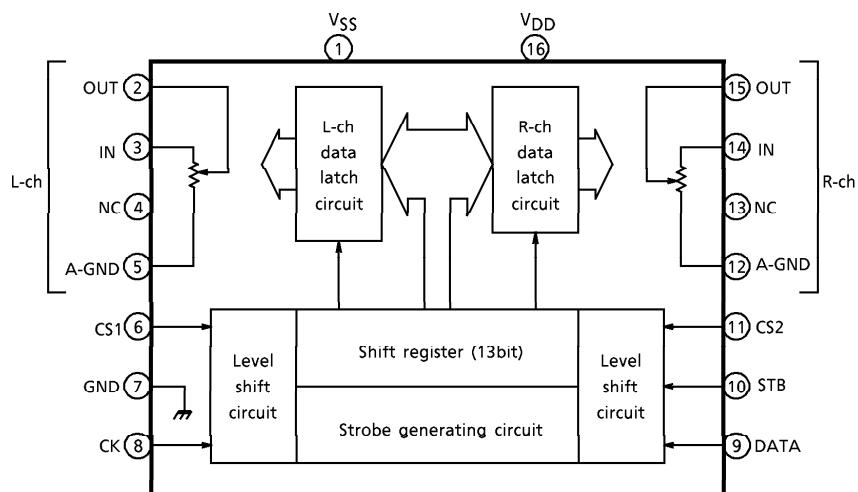
## BLOCK DIAGRAM (TC9412AP)



## BLOCK DIAGRAM (TC9412AF)

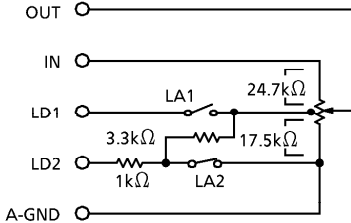


## BLOCK DIAGRAM (TC9413AP)



## PIN DESCRIPTION

Numerals in [ ] means the pin No. of TC9412AF and ( ) means the pin No. of TC9413AP.

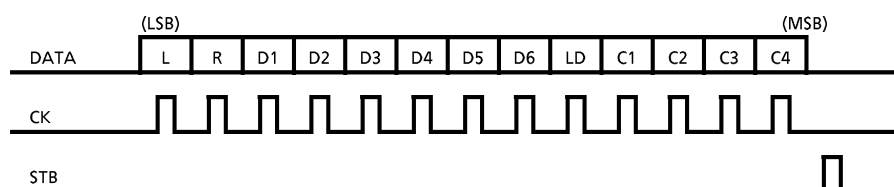
| PIN No.                                     | SYMBOL  | PIN NAME                  | FUNCTION                                                                                                                                                                                                                                                                                                                    | REMARK                        |     |     |               |    |     |                |     |    |   |
|---------------------------------------------|---------|---------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|-----|-----|---------------|----|-----|----------------|-----|----|---|
| 1 [ 1 ] ( 1 )                               | VSS     | Negative power supply pin | When using two power supplies<br><div><div><div>VDD = 6.0~17V</div><div>GND = 0V</div><div>VSS = - 6.0~ - 17V</div></div></div>                                                                                                                                                                                             | —                             |     |     |               |    |     |                |     |    |   |
| 9 [ 11 ] ( 7 )                              | GND     | Digital GND pin           |                                                                                                                                                                                                                                                                                                                             |                               |     |     |               |    |     |                |     |    |   |
| 20 [ 24 ] ( 16 )                            | VDD     | Positive power supply pin |                                                                                                                                                                                                                                                                                                                             |                               |     |     |               |    |     |                |     |    |   |
|                                             |         |                           | When using a single power supply<br><div><div><div>VDD = 6.0~18V</div><div>GND = VSS = 0V</div></div></div>                                                                                                                                                                                                                 |                               |     |     |               |    |     |                |     |    |   |
| 2 [ 3 ] ( 2 )                               | L-OUT   | Volume output pin         | <div>• Volume circuit (TC9412AP / AF)</div> <div></div> <div><table><tr><td></td><td>LA1</td><td>LA2</td></tr><tr><td>Loudness "ON"</td><td>ON</td><td>OFF</td></tr><tr><td>Loudness "OFF"</td><td>OFF</td><td>ON</td></tr></table></div> |                               | LA1 | LA2 | Loudness "ON" | ON | OFF | Loudness "OFF" | OFF | ON | — |
|                                             | LA1     |                           |                                                                                                                                                                                                                                                                                                                             | LA2                           |     |     |               |    |     |                |     |    |   |
| Loudness "ON"                               | ON      | OFF                       |                                                                                                                                                                                                                                                                                                                             |                               |     |     |               |    |     |                |     |    |   |
| Loudness "OFF"                              | OFF     | ON                        |                                                                                                                                                                                                                                                                                                                             |                               |     |     |               |    |     |                |     |    |   |
| 19 [ 22 ] ( 15 )                            | R-OUT   |                           |                                                                                                                                                                                                                                                                                                                             |                               |     |     |               |    |     |                |     |    |   |
| 3 [ 4 ] ( 3 )                               | L-IN    | Volume input pin          |                                                                                                                                                                                                                                                                                                                             |                               |     |     |               |    |     |                |     |    |   |
| 18 [ 21 ] ( 14 )                            | R-IN    |                           |                                                                                                                                                                                                                                                                                                                             |                               |     |     |               |    |     |                |     |    |   |
| 4 [ 5 ] ( — )                               | L-LD1   | Loudness tap output pin   |                                                                                                                                                                                                                                                                                                                             |                               |     |     |               |    |     |                |     |    |   |
| 17 [ 20 ] ( — )                             | R-LD1   |                           |                                                                                                                                                                                                                                                                                                                             |                               |     |     |               |    |     |                |     |    |   |
| 5 [ 6 ] ( — )                               | L-LD2   |                           |                                                                                                                                                                                                                                                                                                                             |                               |     |     |               |    |     |                |     |    |   |
| 16 [ 19 ] ( — )                             | R-LD2   |                           |                                                                                                                                                                                                                                                                                                                             |                               |     |     |               |    |     |                |     |    |   |
| 6 [ 7 ] ( 5 )                               | L-A-GND | Analog GND pin            |                                                                                                                                                                                                                                                                                                                             |                               |     |     |               |    |     |                |     |    |   |
| 15 [ 18 ] ( 12 )                            | R-A-GND |                           |                                                                                                                                                                                                                                                                                                                             |                               |     |     |               |    |     |                |     |    |   |
| 8 [ 9 ] ( 6 )                               | CS1     | Chip select input pin     | Up to 4 chips on the same bus can be used by switching over chip select code.                                                                                                                                                                                                                                               | —                             |     |     |               |    |     |                |     |    |   |
| 13 [ 16 ] ( 11 )                            | CS2     |                           |                                                                                                                                                                                                                                                                                                                             |                               |     |     |               |    |     |                |     |    |   |
| 10 [ 12 ] ( 8 )                             | CK      | Clock input pin           | Data transfer clock input                                                                                                                                                                                                                                                                                                   | Low threshold value input pin |     |     |               |    |     |                |     |    |   |
| 11 [ 13 ] ( 9 )                             | DATA    | Data input pin            | Volume setup serial data input                                                                                                                                                                                                                                                                                              |                               |     |     |               |    |     |                |     |    |   |
| 12 [ 14 ] ( 10 )                            | STB     | Strobe input pin          | Data write strobe input                                                                                                                                                                                                                                                                                                     |                               |     |     |               |    |     |                |     |    |   |
| 7, 14 [ 2, 8, 10, 15, 17, 23 ]<br>( 4, 13 ) | NC      | No connection             |                                                                                                                                                                                                                                                                                                                             | —                             |     |     |               |    |     |                |     |    |   |

**DEVICE OPERATION**

## 1. Setting up volume value (amount of attenuation)

Serial data consisting of 13 bits is used to set a volume value.

## • Data format



- 1) The bits "L" and "R" respectively are the left- and right-channel select data.  
The left-channel volume is set when L = 1 : the right-channel volume is set when R = 1.  
(L = R = 1 are set simultaneously.)
- 2) The bit "LD" is the loudness setup data. Loudness is turned on when LD = 1.  
(This only applies to the TC9412AP and TC9412AF. Set this bit to "0" for the TC9413AP.)

3) The bits "D1" through "D6" are the volume setup data. For details, see the tables below.

| VOLUME<br>VALUE | D1 | D2 | D3 | D4 | D5 | D6 |
|-----------------|----|----|----|----|----|----|
| 0dB             | 0  | 0  | 0  | 0  | 0  | 0  |
| -1              | 1  | 0  | 0  | 0  | 0  | 0  |
| -2              | 0  | 1  | 0  | 0  | 0  | 0  |
| -3              | 1  | 1  | 0  | 0  | 0  | 0  |
| -4              | 0  | 0  | 1  | 0  | 0  | 0  |
| -5              | 1  | 0  | 1  | 0  | 0  | 0  |
| -6              | 0  | 1  | 1  | 0  | 0  | 0  |
| -7              | 1  | 1  | 1  | 0  | 0  | 0  |
| -8              | 0  | 0  | 0  | 1  | 0  | 0  |
| -9              | 1  | 0  | 0  | 1  | 0  | 0  |
| -10             | 0  | 1  | 0  | 1  | 0  | 0  |
| -11             | 1  | 1  | 0  | 1  | 0  | 0  |
| -12             | 0  | 0  | 1  | 1  | 0  | 0  |
| -13             | 1  | 0  | 1  | 1  | 0  | 0  |
| -14             | 0  | 1  | 1  | 1  | 0  | 0  |
| -15             | 1  | 1  | 1  | 1  | 0  | 0  |
| -16             | 0  | 0  | 0  | 0  | 1  | 0  |
| -17             | 1  | 0  | 0  | 0  | 1  | 0  |
| -18             | 0  | 1  | 0  | 0  | 1  | 0  |
| -19             | 1  | 1  | 0  | 0  | 1  | 0  |
| -20             | 0  | 0  | 1  | 0  | 1  | 0  |
| -21             | 1  | 0  | 1  | 0  | 1  | 0  |
| -22             | 0  | 1  | 1  | 0  | 1  | 0  |
| -23             | 1  | 1  | 1  | 0  | 1  | 0  |
| -24             | 0  | 0  | 0  | 1  | 1  | 0  |
| -25             | 1  | 0  | 0  | 1  | 1  | 0  |
| -26             | 0  | 1  | 0  | 1  | 1  | 0  |
| -27             | 1  | 1  | 0  | 1  | 1  | 0  |
| -28             | 0  | 0  | 1  | 1  | 1  | 0  |
| -29             | 1  | 0  | 1  | 1  | 1  | 0  |
| -30             | 0  | 1  | 1  | 1  | 1  | 0  |
| -31             | 1  | 1  | 1  | 1  | 1  | 0  |

| VOLUME<br>VALUE | D1 | D2 | D3 | D4 | D5 | D6 |
|-----------------|----|----|----|----|----|----|
| -32dB           | 0  | 0  | 0  | 0  | 0  | 1  |
| -33             | 1  | 0  | 0  | 0  | 0  | 1  |
| -34             | 0  | 1  | 0  | 0  | 0  | 1  |
| -35             | 1  | 1  | 0  | 0  | 0  | 1  |
| -36             | 0  | 0  | 1  | 0  | 0  | 1  |
| -37             | 1  | 0  | 1  | 0  | 0  | 1  |
| -38             | 0  | 1  | 1  | 0  | 0  | 1  |
| -39             | 1  | 1  | 1  | 0  | 0  | 1  |
| -40             | 0  | 0  | 0  | 1  | 0  | 1  |
| -41             | 1  | 0  | 0  | 1  | 0  | 1  |
| -42             | 0  | 1  | 0  | 1  | 0  | 1  |
| -43             | 1  | 1  | 0  | 1  | 0  | 1  |
| -44             | 0  | 0  | 1  | 1  | 0  | 1  |
| -46             | 1  | 0  | 1  | 1  | 0  | 1  |
| -48             | 0  | 1  | 1  | 1  | 0  | 1  |
| -50             | 1  | 1  | 1  | 1  | 0  | 1  |
| -52             | 0  | 0  | 0  | 0  | 1  | 1  |
| -54             | 1  | 0  | 0  | 0  | 1  | 1  |
| -56             | 0  | 1  | 0  | 0  | 1  | 1  |
| -58             | 1  | 1  | 0  | 0  | 1  | 1  |
| -60             | 0  | 0  | 1  | 0  | 1  | 1  |
| -62             | 1  | 0  | 1  | 0  | 1  | 1  |
| -64             | 0  | 1  | 1  | 0  | 1  | 1  |
| -66             | 1  | 1  | 1  | 0  | 1  | 1  |
| -68             | 0  | 0  | 0  | 1  | 1  | 1  |
| -70             | 1  | 0  | 0  | 1  | 1  | 1  |
| -72             | 0  | 1  | 0  | 1  | 1  | 1  |
| -74             | 1  | 1  | 0  | 1  | 1  | 1  |
| -76             | 0  | 0  | 1  | 1  | 1  | 1  |
| -78             | 1  | 0  | 1  | 1  | 1  | 1  |
| -∞              | 0  | 1  | 1  | 1  | 1  | 1  |
| Use Inhibited   | 1  | 1  | 1  | 1  | 1  | 1  |

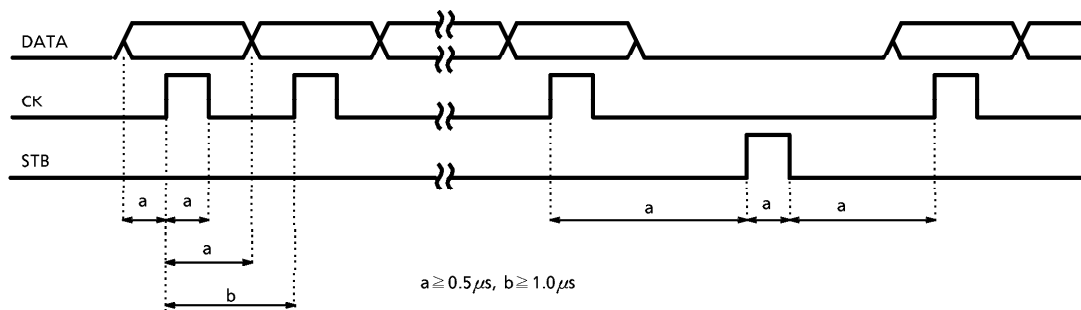
4) The bits "C1" through "C4" are the chip select code data.

These bits set the code data that corresponds to the CS1 and CS2 inputs.

| CS1 | CS2 | C1 | C2 | C3 | C4 |
|-----|-----|----|----|----|----|
| L   | L   | 0  | 0  | 1  | 1  |
| H   | L   | 1  | 0  | 1  | 1  |
| L   | H   | 0  | 1  | 1  | 1  |
| H   | H   | 1  | 1  | 1  | 1  |

## 2. Serial data timing

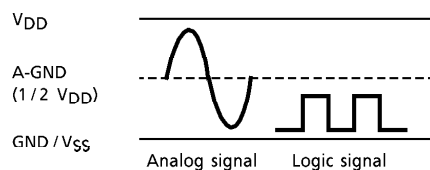
Make sure that CK, DATA and STB are input to the device at the timings shown below.



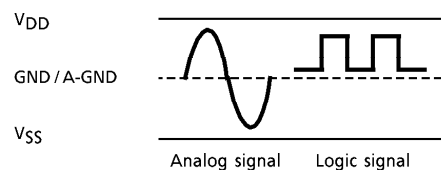
## 3. Operating with a single or dual power supplies

The TC9412AP, TC9412AF, TC9413AP can operate with either a single power supply or dual power supplies.

### • Operation with single power supply



### • Operation with dual power supplies

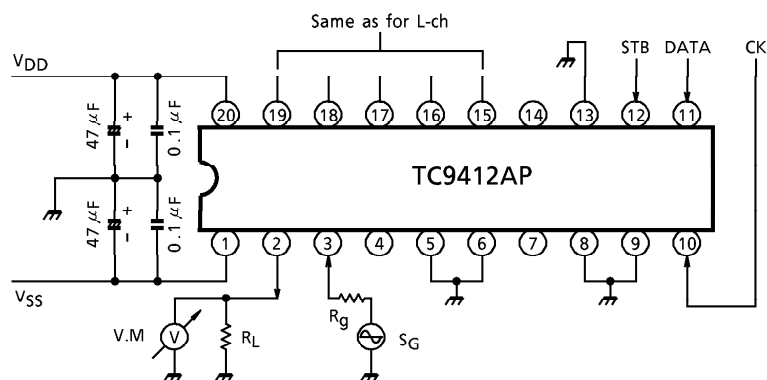
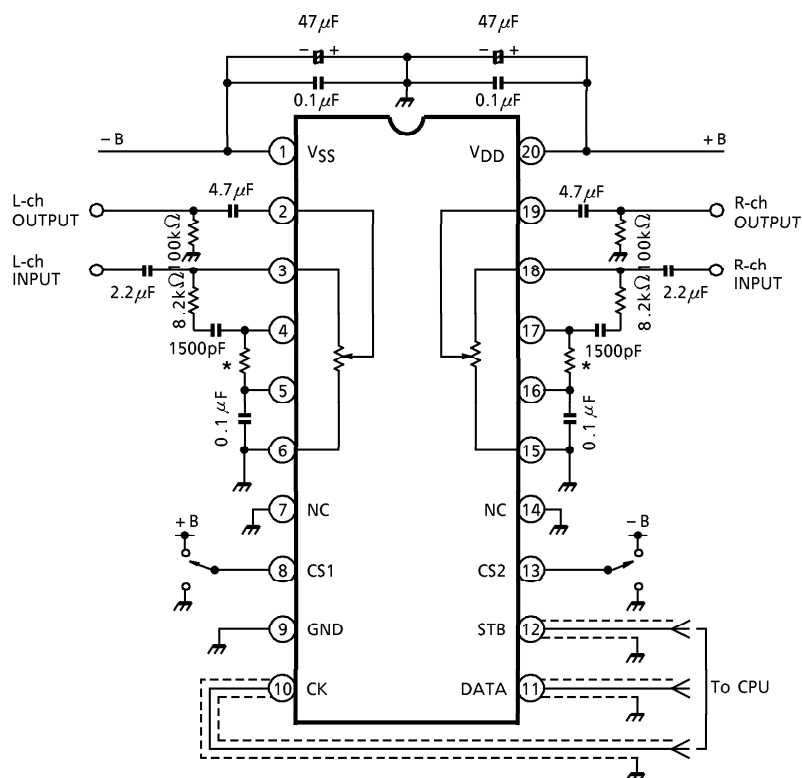


**MAXIMUM RATINGS** (Ta = 25°C)

| CHARACTERISTIC                      | SYMBOL                           | RATING                                      | UNIT |
|-------------------------------------|----------------------------------|---------------------------------------------|------|
| Supply Voltage (1)                  | V <sub>DD</sub> -V <sub>SS</sub> | - 0.3~36                                    | V    |
| Supply Voltage (2)                  | V <sub>DD</sub> -GND             | - 0.3~20                                    | V    |
| GND Block Input Voltage             | V <sub>IN</sub> (1)              | - 0.3~V <sub>DD</sub> + 0.3                 | V    |
| V <sub>SS</sub> Block Input Voltage | V <sub>IN</sub> (2)              | V <sub>SS</sub> - 0.3~V <sub>DD</sub> + 0.3 | V    |
| Power Dissipation                   | P <sub>D</sub>                   | 300                                         | mW   |
| Operating Temperature               | T <sub>opr</sub>                 | - 40~85                                     | °C   |
| Storage Temperature                 | T <sub>stg</sub>                 | - 65~150                                    | °C   |

**ELECTRICAL CHARACTERISTICS**(Referenced to V<sub>DD</sub> = 15V, V<sub>SS</sub> = - 15V, GND = 0V at Ta = 25°C unless otherwise noted)

| CHARACTERISTIC                |           | SYMBOL                           | TEST CIR-<br>CUIT | TEST CONDITION                                                                                                                    | MIN.                  | TYP.  | MAX.                  | UNIT              |
|-------------------------------|-----------|----------------------------------|-------------------|-----------------------------------------------------------------------------------------------------------------------------------|-----------------------|-------|-----------------------|-------------------|
| Operating Supply Voltage (1)  |           | V <sub>DD</sub> -V <sub>SS</sub> | —                 | Operating with dual power supplies                                                                                                | 12                    | ~     | 34                    | V                 |
| Operating Supply Voltage (2)  |           | V <sub>DD</sub> -GND             | —                 | Operating with single power supply                                                                                                | 6.0                   | ~     | 18                    | V                 |
| Operating Supply Current      |           | I <sub>DD</sub>                  | 1                 | Non-loaded, no input                                                                                                              | —                     | 0.5   | 2.0                   | mA                |
| Input Voltage                 | "H" Level | V <sub>IH</sub> (1)              | —                 | CK, DATA, STB pins<br>V <sub>DD</sub> = 6.0~18V                                                                                   | 4.0                   | ~     | V <sub>DD</sub>       | V                 |
|                               | "L" Level | V <sub>IL</sub> (1)              |                   |                                                                                                                                   | GND                   | ~     | 1.0                   |                   |
| Input Voltage                 | "H" Level | V <sub>IH</sub> (2)              | —                 | CS1 and CS2 pins                                                                                                                  | V <sub>DD</sub> × 0.7 | ~     | V <sub>DD</sub>       | V                 |
|                               | "L" Level | V <sub>IL</sub> (2)              |                   |                                                                                                                                   | GND                   | ~     | V <sub>DD</sub> × 0.3 |                   |
| Input Current                 | "H" Level | I <sub>IH</sub>                  | —                 | CK, DATA, STB, CS1, CS2 pins<br>V <sub>IH</sub> = 15V<br>V <sub>IL</sub> = 0V                                                     | - 1.0                 | ~     | 1.0                   | μA                |
|                               | "L" Level | I <sub>IL</sub>                  |                   |                                                                                                                                   | - 1.0                 | ~     | 1.0                   |                   |
| Operating Frequency           |           | f <sub>op</sub>                  | —                 | CK, DATA, STB pins                                                                                                                | 0                     | ~     | 1.0                   | MHz               |
| Min. Operating Clock Width    |           | T <sub>ck</sub>                  |                   |                                                                                                                                   | 0.5                   | —     | —                     | μs                |
| Volume Resistance             |           | R <sub>VR</sub>                  | —                 | When loudness OFF                                                                                                                 | 18.5                  | 27.5  | 36.5                  | kΩ                |
| Step Deviation                |           | ΔVR                              | —                 | Deviation between volume steps                                                                                                    | - 1.2                 | ~     | 1.2                   | dB                |
| Analog Switch ON-Resistance   |           | R <sub>ON</sub>                  | —                 | Internal analog switch                                                                                                            | —                     | 750   | 1500                  | Ω                 |
| Analog Switch Leakage Current |           | I <sub>OFF</sub>                 |                   |                                                                                                                                   | - 0.1                 | ~     | 0.1                   | μA                |
| Total Harmonic Distortion     |           | THD                              | 1                 | f <sub>IN</sub> = 1kHz<br>V <sub>IN</sub> = 1V <sub>rms</sub><br>R <sub>g</sub> = 600Ω, R <sub>L</sub> = 100kΩ<br>BW = 20Hz~20kHz | —                     | 0.005 | —                     | %                 |
| Maximum Attenuation           |           | ATT <sub>MAX</sub>               |                   |                                                                                                                                   | —                     | 100   | —                     | dB                |
| Output Noise Voltage          |           | V <sub>N</sub>                   |                   |                                                                                                                                   | —                     | 1.0   | —                     | μV <sub>rms</sub> |
| Crosstalk                     |           | C·T                              |                   |                                                                                                                                   | —                     | 100   | —                     | dB                |

**TEST CIRCUIT ( $I_{DD}/THD/ATT_{MAX}/V_N/C\cdot T$ )**

**EXAMPLE OF APPLICATION CIRCUIT (TC9412AP)**


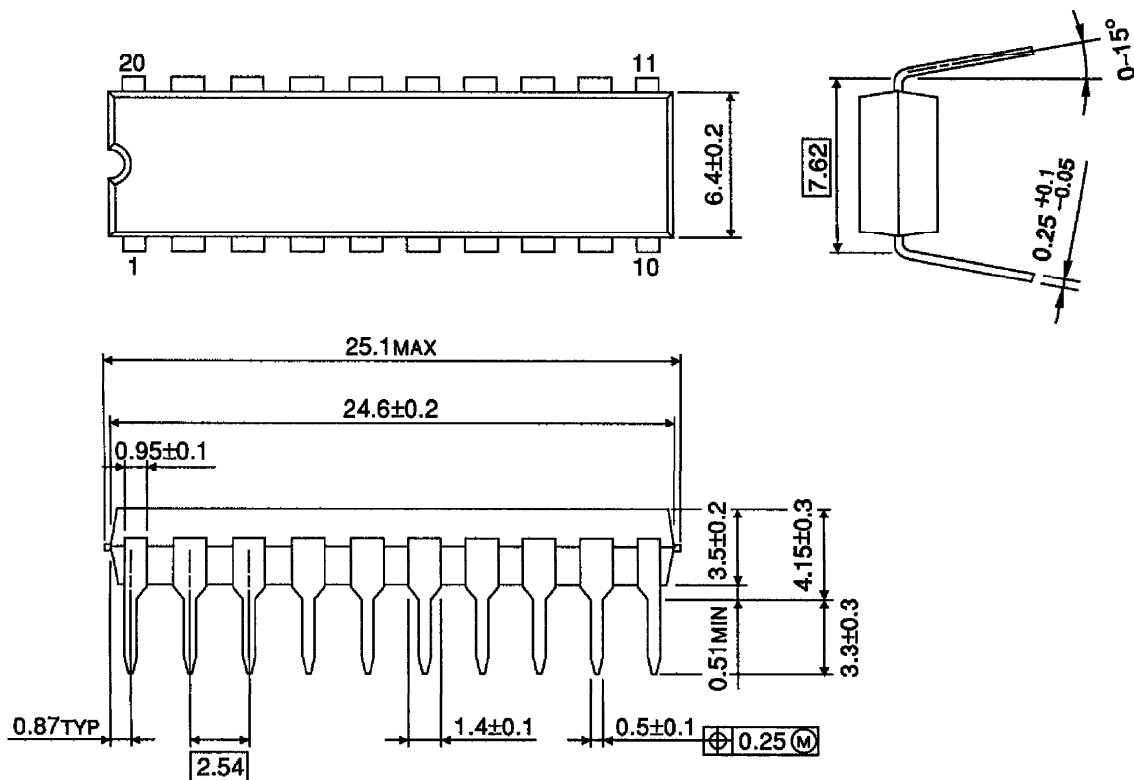
\* Used to prevent noise when loudness control is turned on or off.  $R = 220 \sim 470k\Omega$

(Note) Since a high-frequency digital signal is input to the CK, DATA and STB pins, corrective measures must be taken to prevent it from getting mixed in the analog circuit to generate noise by, for example, guarding the above signal lines with ground patterns or using shielding wire for these lines.

## OUTLINE DRAWING

DIP20-P-300-2.54A

Unit : mm

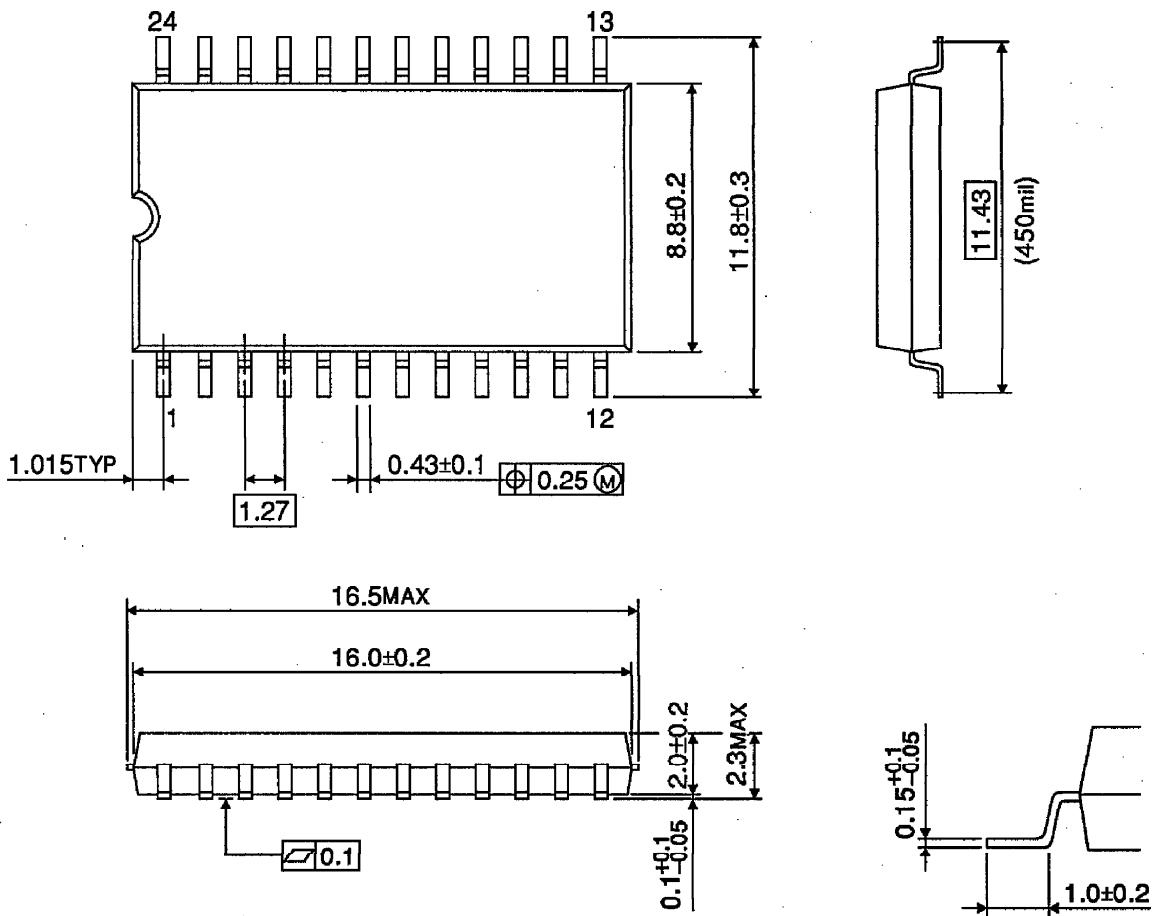


Weight : 1.4g (Typ.)

OUTLINE DRAWING

SOP24-P-450-1.27A

Unit : mm

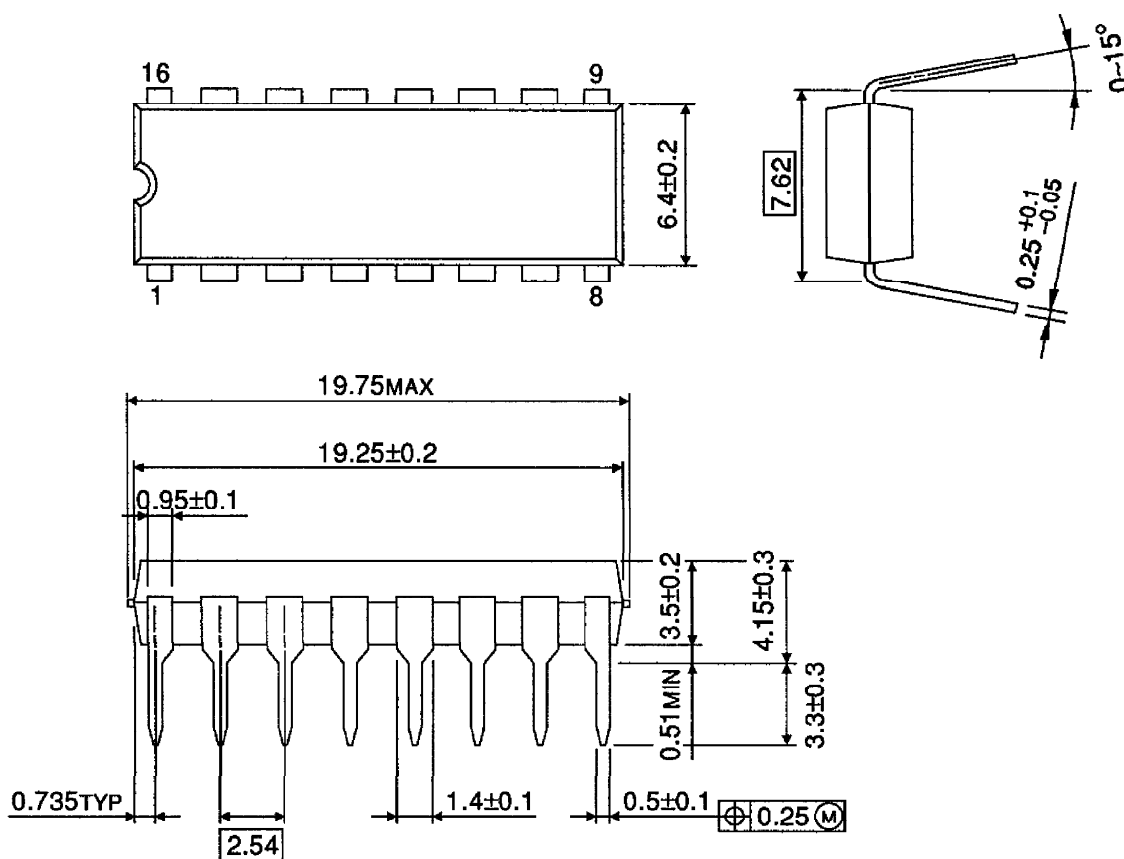


Weight : 0.44g (Typ.)

## OUTLINE DRAWING

DIP16-P-300-2.54A

Unit : mm



Weight : 1.0g (Typ.)