



LC75372E

Electronic Volume Control for Car Stereo Systems



Overview

The LC75372E is an electronic volume control that can implement volume, balance, fader, bass/treble, loudness, input switching, and input level control functions with a minimal number of external components.

Features

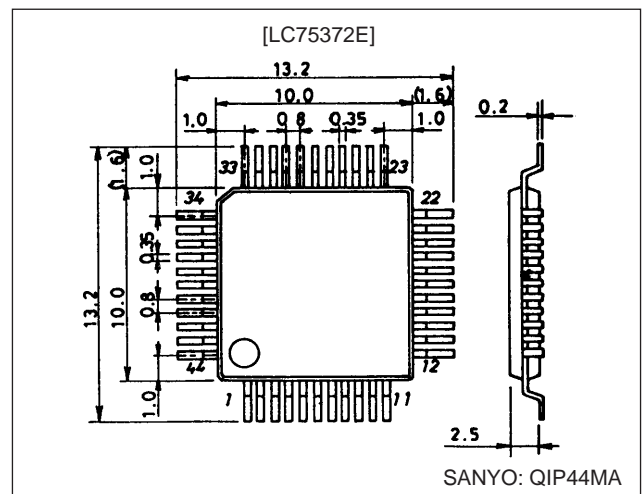
- Volume: Provides 81 positions, from 0 dB to -79 dB (in 1-dB steps) and $-\infty$. A balance function can be implemented by controlling the left and right channels independently.
- Fader: This function can attenuate either the rear or the front outputs over 16 positions. (From 0 to -20 dB in 2-dB steps, from -20 to -25 dB in one 5-dB step, from -25 to -45 dB in 10-dB steps, -60 dB, and $-\infty$.)
- Bass/treble: Forms an NF-type tone control circuit (LUX type) with the addition of external capacitors. The base and treble controls each have 15 positions.
- Loudness: The volume resistor ladders are tapped starting at the -20-dB position. A loudness function can be implemented by adding external RC circuits at these taps.
- The signal can be selected from one of three inputs for each of the left and right channels. The input signals can be amplified from 0 to +18 dB in 6-dB steps.
- On-chip buffer amplifiers for a minimum of external components.
- Minimal switching noise due to fabrication in a silicon-gate CMOS process.

- Built-in reference voltage generation circuit
- Serial data input: Supports CCB format communication with the system controller.

Package Dimensions

unit: mm

3148-QFP44MA



- CCB is a trademark of SANYO ELECTRIC CO., LTD.
- CCB is SANYO's original bus format and all the bus addresses are controlled by SANYO.

Specifications

Absolute Maximum Ratings at $T_a = 25^\circ\text{C}$, $V_{SS} = 0\text{ V}$

Parameter	Symbol	Conditions	Ratings	Unit
Maximum supply voltage	$V_{DD\text{ max}}$	V_{DD}	11	V
Maximum input voltage	$V_{IN\text{ max}}$	CL, DI, CE, LIN, RIN, LFIN, RFIN, L1 to L3, R1 to R3	$V_{SS} - 0.3$ to $V_{DD} + 0.3$	V
Allowable power dissipation	$Pd\text{ max}$	$T_a \leq 85^\circ\text{C}$	260	mW
Operating temperature	$Topr$		-40 to +85	$^\circ\text{C}$
Storage temperature	$Tstg$		-50 to +125	$^\circ\text{C}$

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LC75372E

Allowable Operating Ranges at $T_a = 25^\circ\text{C}$, $V_{SS} = 0\text{ V}$

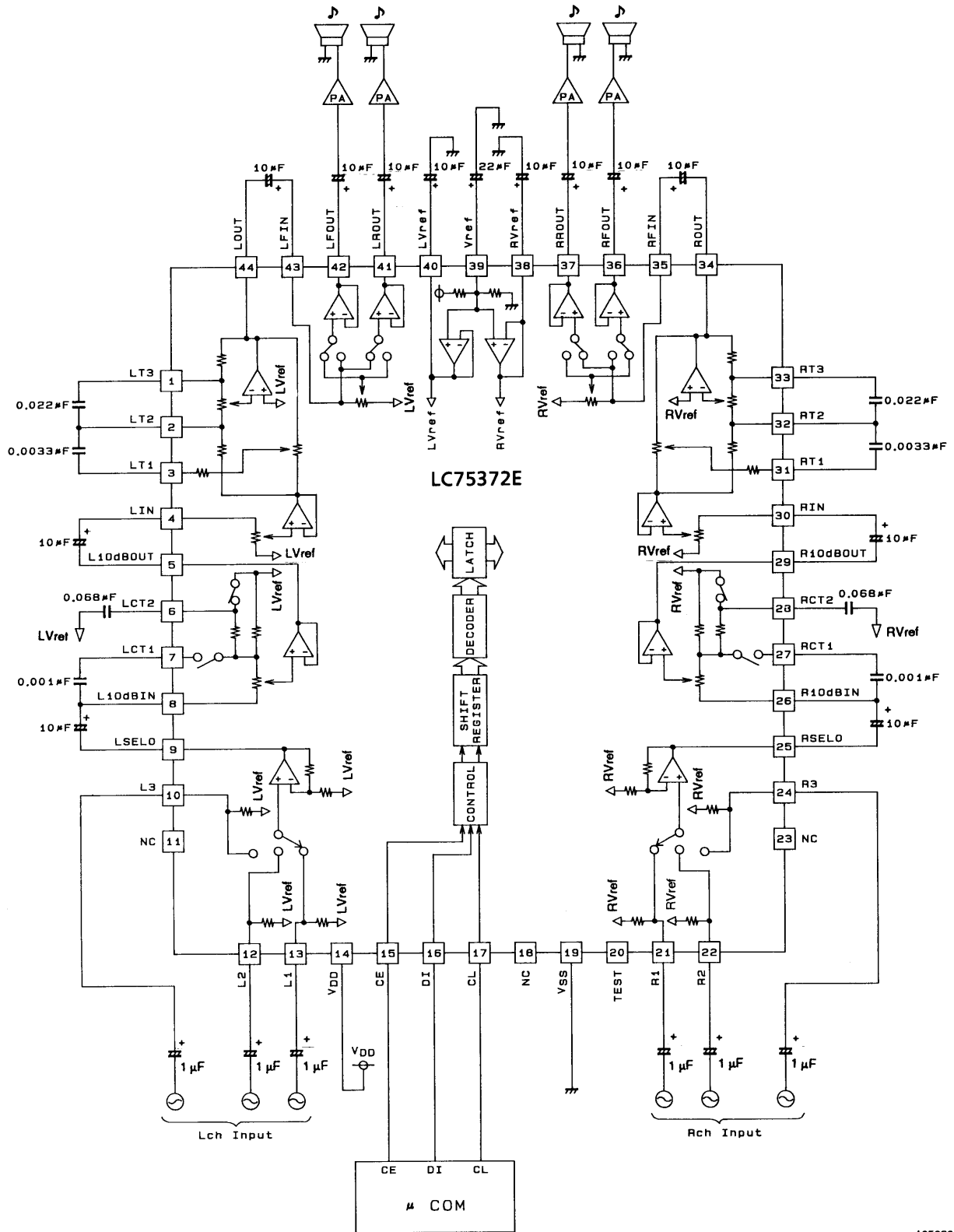
Parameter	Symbol	Conditions	min	typ	max	Unit
Supply voltage	V_{DD}	V_{DD}	6.0		10.0	V
Input high-level voltage	V_{IH}	CL, DI, CE	4.0		V_{DD}	V
Input low-level voltage	V_{IL}	CL, DI, CE	V_{SS}		1.0	V
Input voltage amplitude	V_{IN}	CL, DI, CE, LIN, RIN, LFIN, RFIN, L1 to L3, R1 to R3	V_{SS}		V_{DD}	Vp-p
Input pulse width	t_{pw}	CL	1			μs
Setup time	t_{setup}	CL, DI, CE	1			μs
Hold time	t_{hold}	CL, DI, CE	1			μs
Operating frequency	f_{opg}	CL			500	kHz

Electrical Characteristics at $T_a = 25^\circ\text{C}$, $V_{DD} = 9\text{ V}$, $V_{SS} = 0\text{ V}$

Parameter	Symbol	Conditions	min	typ	max	Unit
[Input Block]						
Input resistance	R_{in}	L1 to L3, R1 to R3	30	50	70	k Ω
Minimum input gain	$G_{in\ min}$		-2	0	+2	dB
Maximum input gain	$G_{in\ max}$		+16.0	+18.0	+20.0	dB
Step resolution	G_{step}			+6.0		dB
[Volume Control Block]						
Input resistance	R_{v10}	L10dBIN, R10dBIN: 10-dB steps, loudness off	30	50	70	k Ω
	R_{v1}	LIN, RIN: 1-dB steps	12	20	28	k Ω
Step resolution	AT_{step}			1		dB
Step error	AT_{err}	step = 0 to -20 dB	-1	0	+1	dB
		step = -20 to -50 dB	-3	0	+3	dB
[Fader Volume Block]						
Input resistance	R_{fed}	LFIN, RFIN	12	20	28	k Ω
Step resolution	AT_{step}	step = 0 to -20 dB		2		dB
		step = -20 to -25 dB		5		dB
		step = -25 to -45 dB		10		dB
Step error	AT_{err}	step = 0 to -45 dB	-2	0	+2	dB
		step = -45 to -60 dB	-3	0	+3	dB
Output load resistance	R_L	LFOUT, LROUT, RFOUT, RROUT	10			k Ω
[Bass/Treble Control Block]						
Bass control range	G_{bass}	Max. boost/cut	± 9	± 10.5	± 12	dB
Treble control range	G_{tre}	Max. boost/cut	± 8	± 10.5	± 13	dB
[Overall Characteristics]						
Total harmonic distortion	THD (1)	$V_{IN} = 1\text{ V}_{rms}$, $f = 1\text{ kHz}$, all settings flat overall		0.045		%
	THD (2)	$V_{IN} = 1\text{ V}_{rms}$, $f = 20\text{ kHz}$, all settings flat overall		0.040		%
Crosstalk	CT	$V_{IN} = 1\text{ V}_{rms}$, $f = 1\text{ kHz}$, all settings flat overall, $R_g = 1\text{ k}\Omega$		80		dB
Output at maximum attenuation	$V_O\ min$	$V_{IN} = 1\text{ V}_{rms}$, $f = 1\text{ kHz}$, main volume at $-\infty$		-78		dB
		$V_{IN} = 1\text{ V}_{rms}$, $f = 1\text{ kHz}$, main volume at $-\infty$, INMUTE		-81		dB
Output noise voltage	$V_N\ (1)$	All settings flat overall (IHF-A), $R_g = 1\text{ k}\Omega$		15	30	μV
	$V_N\ (2)$	All settings flat overall (DIN-AUDIO), $R_g = 1\text{ k}\Omega$		20	40	μV
Current drain	I_{DD}	$V_{DD} - V_{SS} = 10\text{ V}$		25	30	mA
Input high-level current	I_{IH}	CL, DI, CE: $V_{IN} = 9\text{ V}$			10	μA
Input low-level current	I_{IL}	CL, DI, CE: $V_{IN} = 0\text{ V}$	-10			μA
Maximum input level	V_{CL}	All settings flat overall, measurement point; fader output THD = 1%, $R_L = 10\text{ k}\Omega$		2		Vrms

LC75372E

Equivalent Circuit Block Diagram and Sample Application Circuit

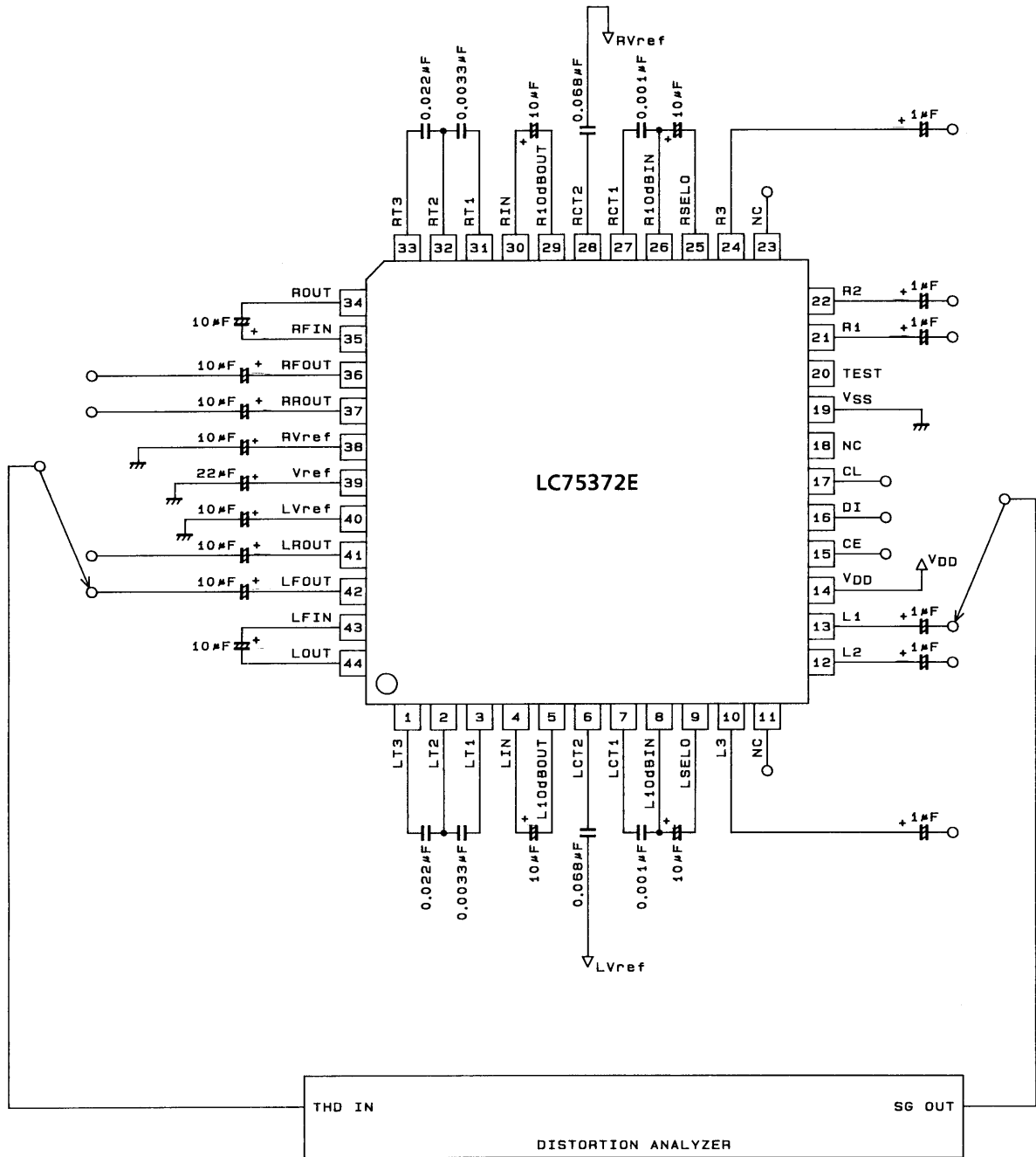


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LC75372E

Electrical Characteristics Test Circuits

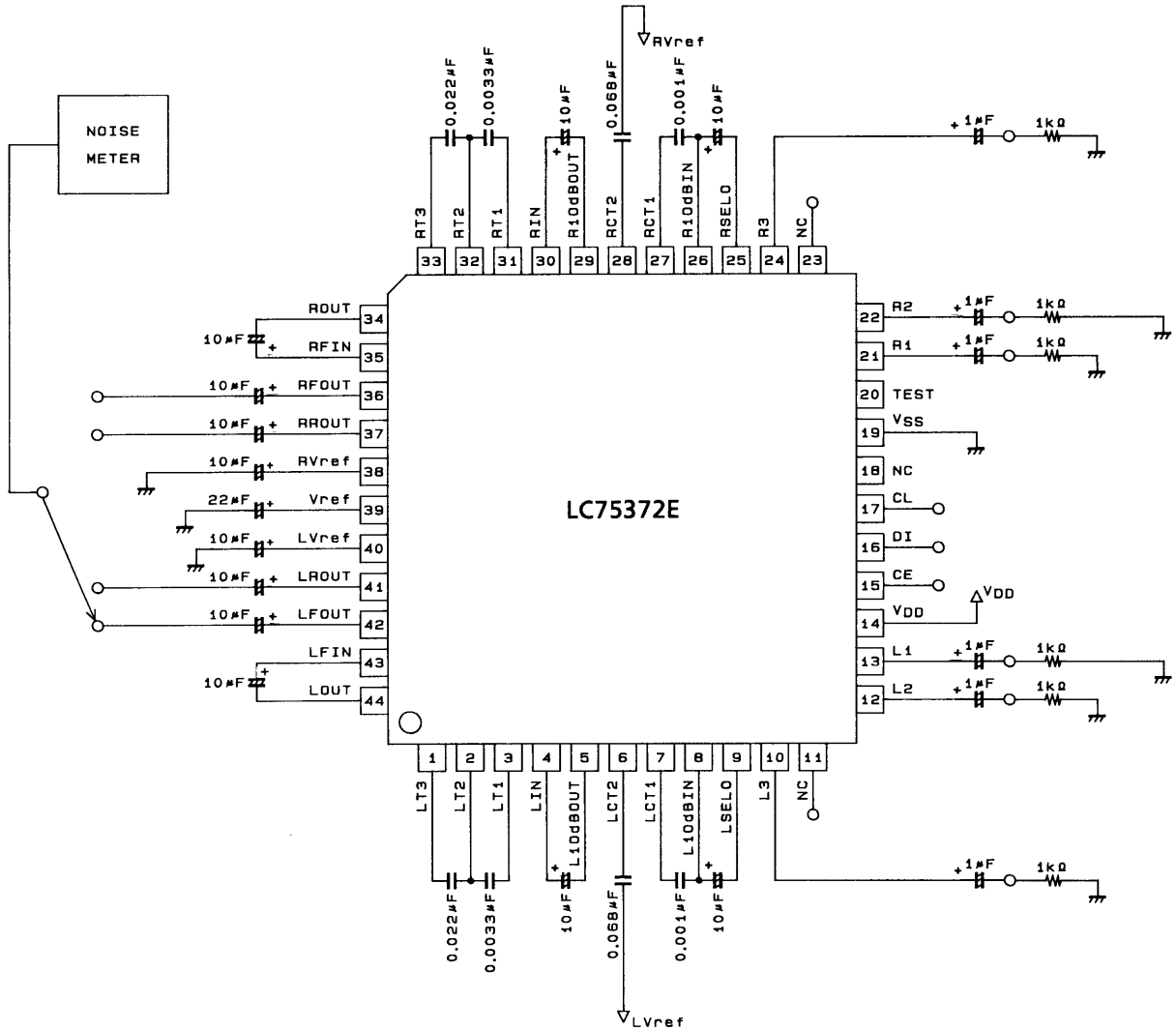
1. Total harmonic distortion



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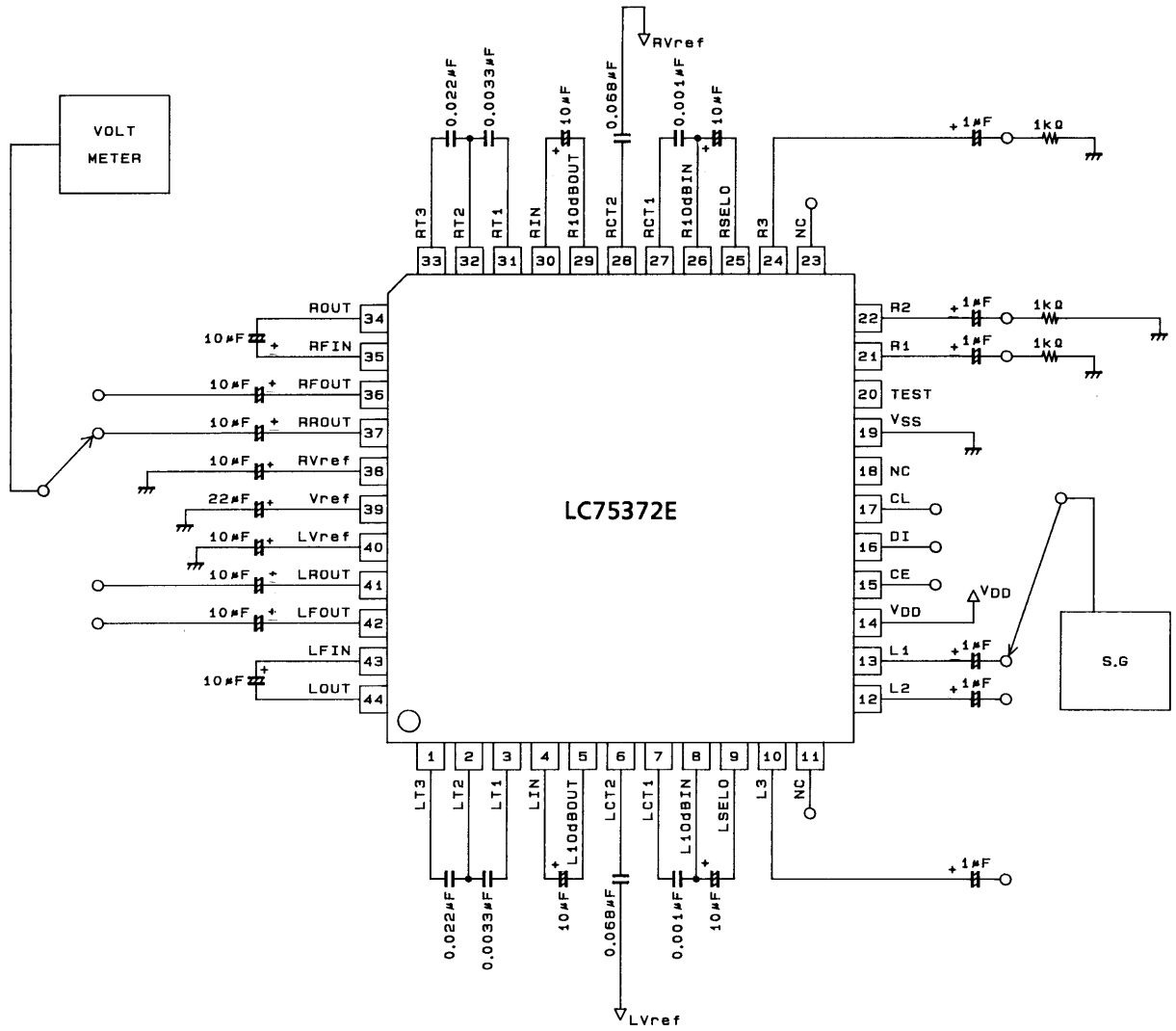
2. Output noise voltage



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LC75372E

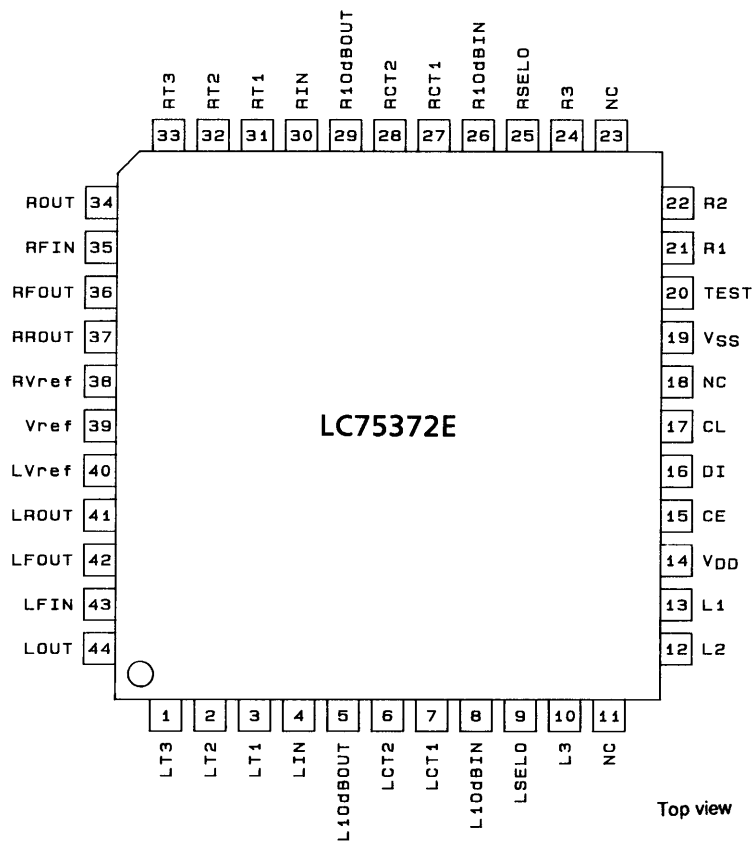
3. Crosstalk



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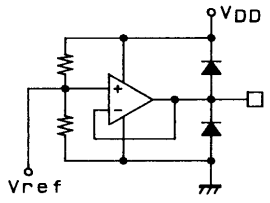
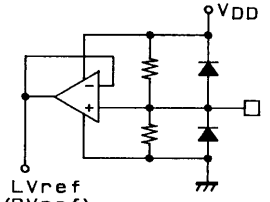
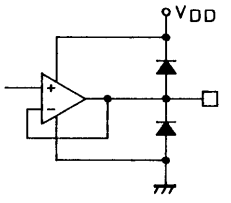
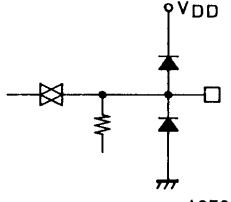
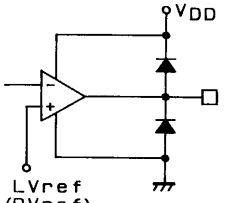
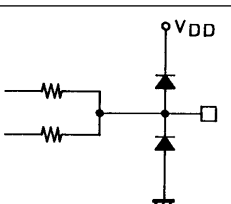
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Pin Assignment



LC75372E

Pin Functions

Pin No.	Symbol	Equivalent I/O circuit	Function
40 38	LVref RVref	<ul style="list-style-type: none"> Common pins for the main volume block, fader volume block, tone block, gain control block, and input switching block. Since the capacitors connected between LVref/RVref and V_{SS} become the residual resistance when the volume control is at maximum attenuation, the values of these capacitors must be chosen carefully. The applied voltage must never exceed V_{DD}. 	 <p style="text-align: right;">A05025</p>
39	Vref	0.488 V_{DD} voltage generation block. A capacitor must be connected between Vref and V_{SS} to suppress power supply ripple.	 <p style="text-align: right;">A05026</p>
41 42 37 36	LROUT LFOUT RROUT RFOUT	<ul style="list-style-type: none"> Fader outputs. The front and rear systems can be attenuated independently. The amount of attenuation is the same in the left and right channels. Low impedance operational amplifier outputs 	 <p style="text-align: right;">A05027</p>
43 35	LFIN RFIN	<ul style="list-style-type: none"> Fader inputs Must be driven from low-impedance circuits. 	 <p style="text-align: right;">A05028</p>
44 34	LOUT ROUT	Tone control outputs	 <p style="text-align: right;">A05029</p>
3 2 1 31 32 33	LT1 LT2 LT3 RT1 RT2 RT3	Connections for the bass and treble compensation capacitors for the tone control circuit Connect high-band compensation capacitors between T1 and T2. Connect low-band compensation capacitors between T2 and T3.	 <p style="text-align: right;">A05030</p>
7 6 27 28	LCT1 LCT2 RCT1 RCT2	Loudness pins. Connect high-band compensation capacitors between LCT1/RCT1 and L10dBIN/R10dBIN, and connect low-band compensation capacitors between LCT2/RCT2 and LVref/RVref.	

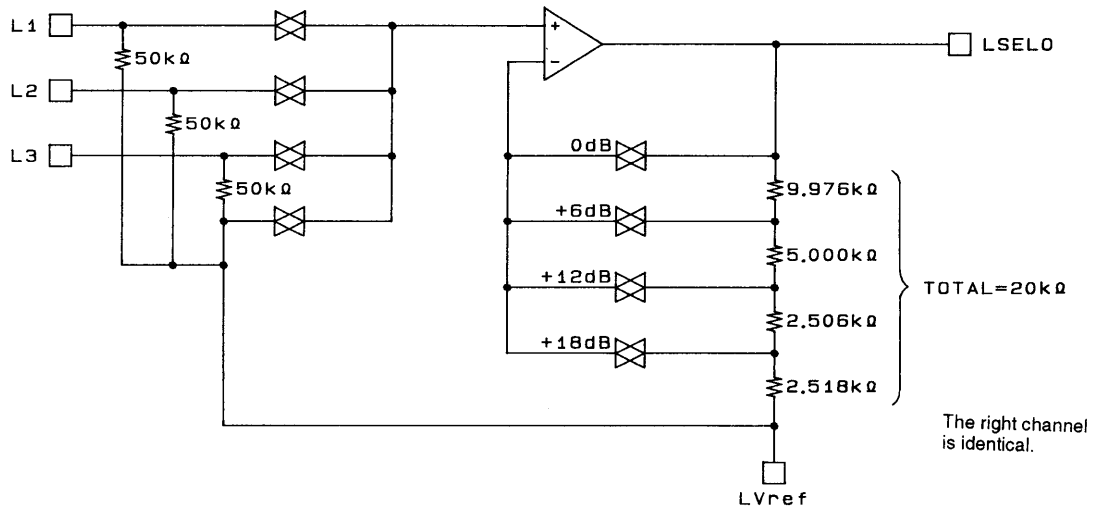
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LC75372E

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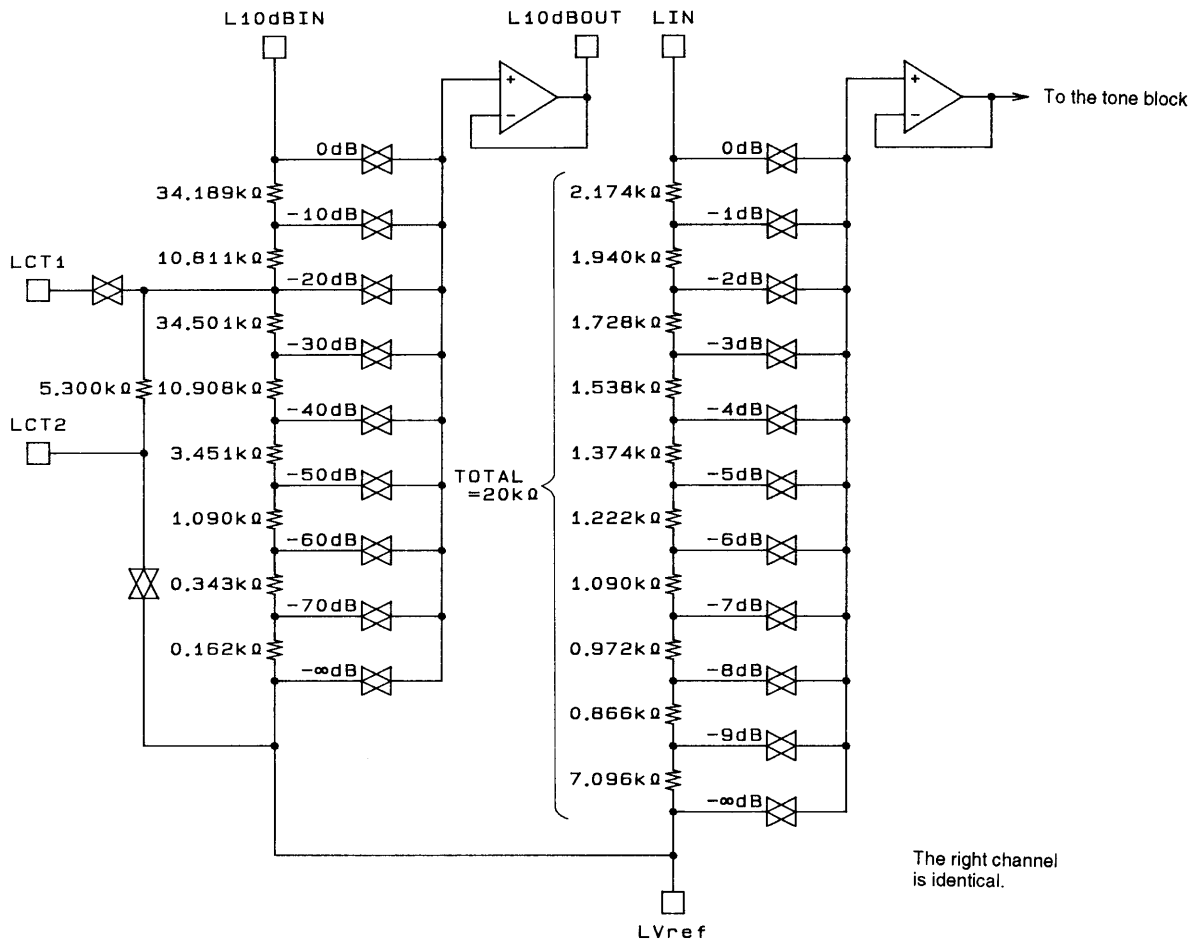
Pin No.	Symbol	Equivalent I/O circuit	Function
8 26	L10dBIN R10dBIN	<ul style="list-style-type: none"> • 10-dB volume control inputs • These inputs must be driven from low-impedance circuits. 	<p style="text-align: right;">A05031</p>
9 25	LSELO RSELO	Outputs from the input selector	<p style="text-align: right;">A05032</p>
13 12 10 21 22 24	L1 L2 L3 R1 R2 R3	Signal inputs	<p style="text-align: right;">A05033</p>
14	V _{DD}	Power supply connection	
19	V _{SS}	Ground	
15	CE	Chip enable. Data is latched internally at the point this pin goes from high to low. The analog switches operate at that point. Data transfer is enabled when this pin is high.	<p style="text-align: right;">A05034</p>
16 17	DI CL	Inputs for the serial data and clock used for LSI control.	
20	TEST	Test input (Must be left open during normal operation.)	
5 29	L10dBOUT R10dBOUT	10-dB block outputs	
4 30	LIN RIN	<ul style="list-style-type: none"> • 1-dB block inputs • These inputs must be driven by low-impedance circuits. 	
11 18 23	NC	No-connection pins.	

Input Block Equivalent Circuit



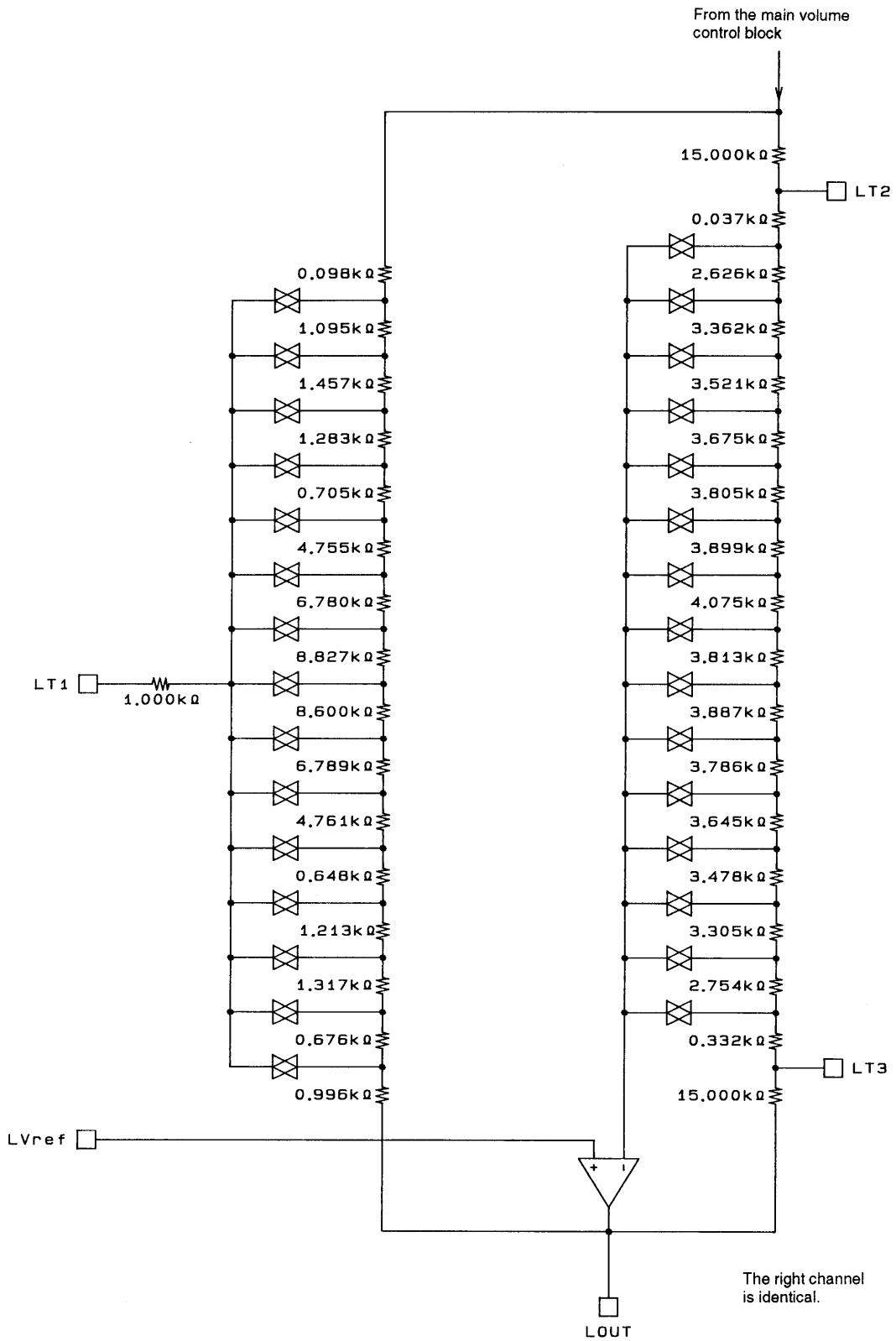
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Main Volume Control Equivalent Circuit



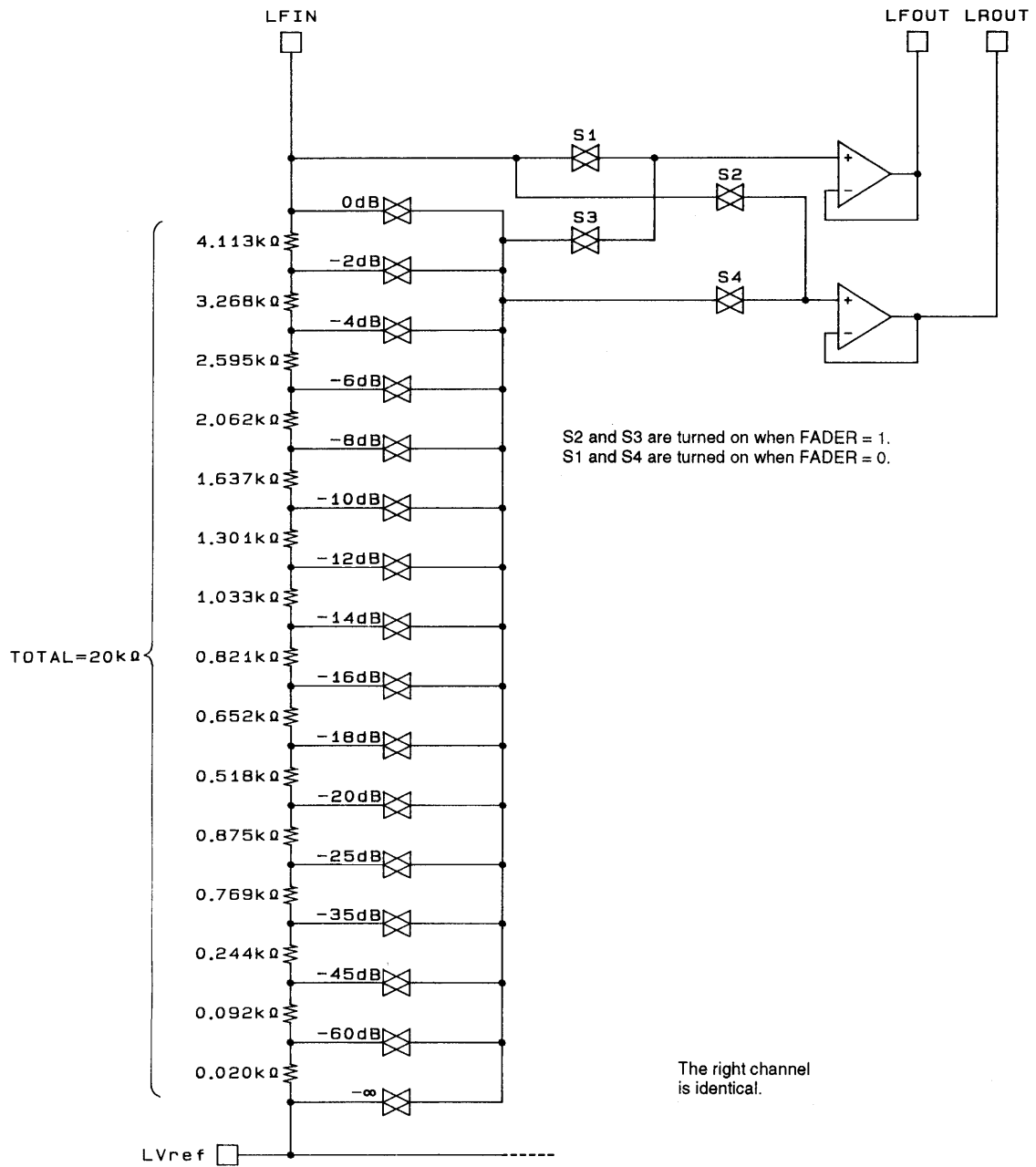
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Tone Control Block Equivalent Circuit



A05037

Fader Volume Control Block Equivalent Circuit



When data indicating an gain of $-\infty$ is sent to the main volume control 1-dB step function, S1 and S2 open, and S3 and S4 go on at the same time.

A0503B

Sample Calculation of the Loudness Circuit External Constants

First, see the LC75372E 10-dB step internal equivalent circuit shown on page 10. Figure 1 shows a circuit to which the loudness circuit external components have been added, and which has been simplified for this calculation. The sample calculation below uses this circuit diagram to acquire a 5-dB boost at $f = 100$ Hz.

($f = 100$ Hz, 5-dB boost)

Assuming that the resistors and capacitors in Figure 1 have the following values:

$R1 = R2 = 50$ k Ω

$R3 = 5$ k Ω

And $C1 = Z1$ and $C2 = Z2$.

Then:

$$V_{OUT} = \frac{\frac{R2 (R3 + Z2)}{R2 + R3 + Z2}}{\frac{R1 \cdot Z1}{R1 + Z1} + \frac{R2 (R3 + Z2)}{R2 + R3 + Z2}} = -20 \text{ dB}$$

(at = 1 kHz)

$$V_{OUT} = \frac{\frac{R2 (R3 + 10 \cdot Z2)}{R2 + R3 + 10 \cdot Z2}}{\frac{R1 \cdot 10 \cdot Z1}{R1 + 10 \cdot Z1} + \frac{R2 (R3 + 10 \cdot Z2)}{R2 + R3 + 10 \cdot Z2}} = -15 \text{ dB}$$

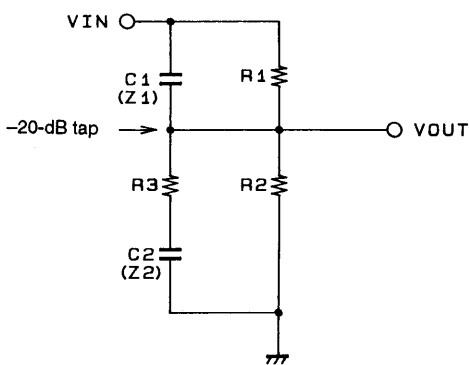
(at = 100 Hz)

From the above equations we find:

$Z1 \neq 891.5$ k Ω and $Z2 = 880$ Ω .

Therefore, the specifications will be met if capacitors that have these impedances at $f = 1$ kHz are connected externally.

The result is that $C1 = 178.5$ pF and $C2 = 0.18$ μ F.



R1, R2, R3: LC75372E internal resistances
 C1: External high-band compensation capacitor
 C2: External low-band compensation capacitor

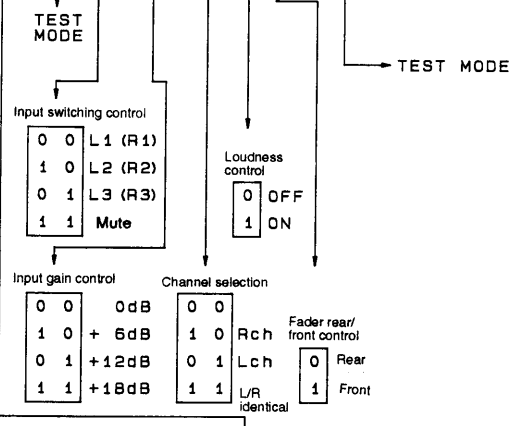
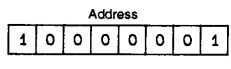
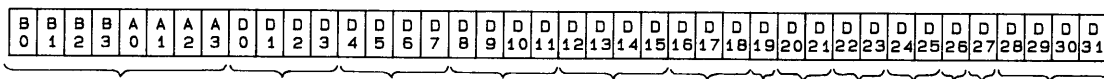
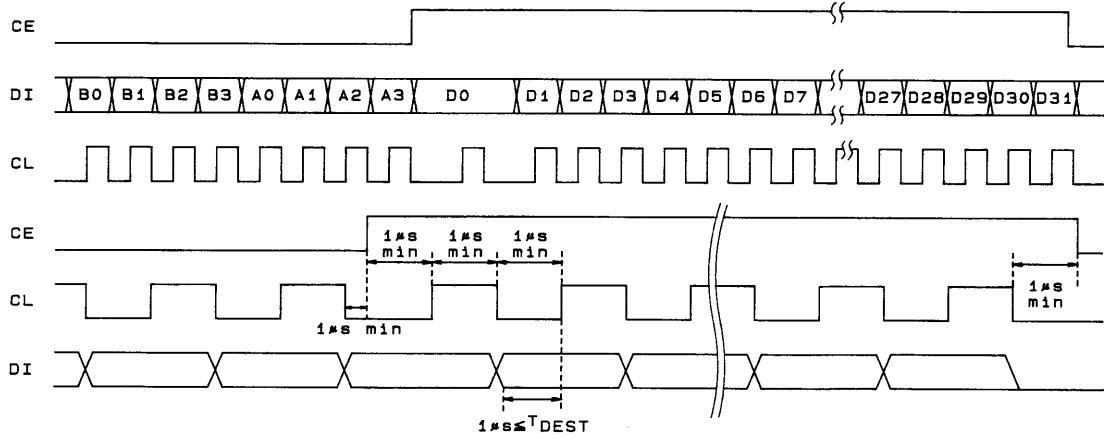
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Figure 1

LC75372E

Control System Timing and Data Format

The LC75372E is controlled by applying data in the stipulated format to the CE, CL, and DI pins. The data consists of 40 bits, of which 8 bits are the chip address and 32 bits are the data.



Fader step control

0	0	0	0	-∞dB
1	0	0	0	-60dB
0	1	0	0	-45dB
1	1	0	0	-35dB
0	0	1	0	-25dB
1	0	1	0	-20dB
0	1	1	0	-18dB
1	1	1	0	-16dB
0	0	0	1	-14dB
1	0	0	1	-12dB
0	1	0	1	-10dB
1	1	0	1	-8dB
0	0	1	1	-6dB
1	0	1	1	-4dB
0	1	1	1	-2dB
1	1	1	1	0dB

Bass control

1	1	1	0	step15
0	1	1	0	step14
1	0	1	0	step13
0	0	1	0	step12
1	1	0	0	step11
0	1	0	0	step10
1	0	0	0	step9
0	0	0	0	step8
1	0	0	1	step7
0	1	0	1	step6
1	1	0	1	step5
0	0	1	1	step4
1	0	1	1	step3
0	1	1	1	step2
1	1	1	1	step1

boost

Treble control

1	1	1	0	step15
0	1	1	0	step14
1	0	1	0	step13
0	0	1	0	step12
1	1	0	0	step11
0	1	0	0	step10
1	0	0	0	step9
0	0	0	0	step8
1	0	0	1	step7
0	1	0	1	step6
1	1	0	1	step5
0	0	1	1	step4
1	0	1	1	step3
0	1	1	1	step2
1	1	1	1	step1

boost

1-dB step control

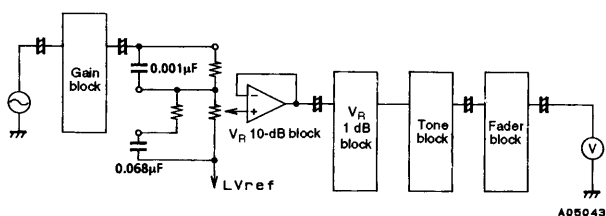
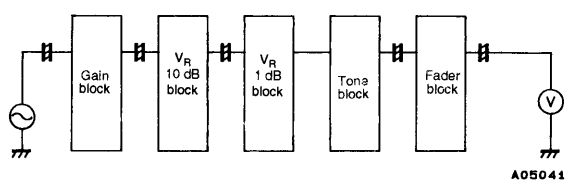
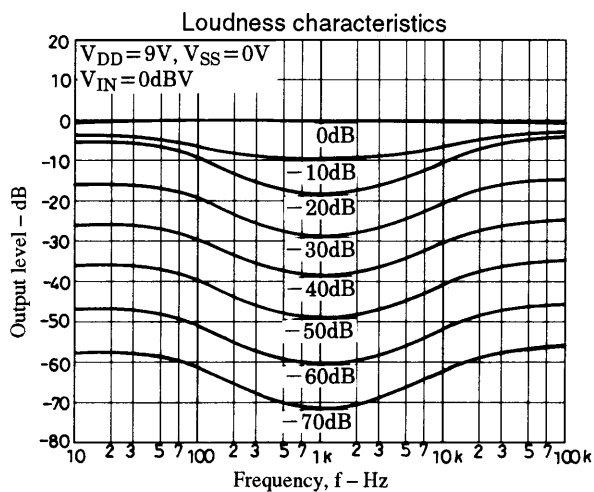
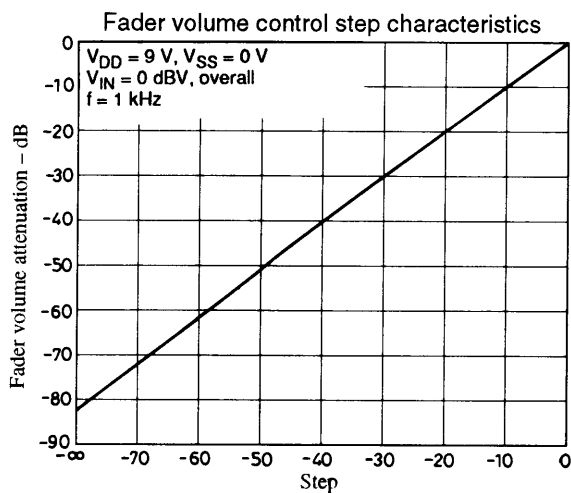
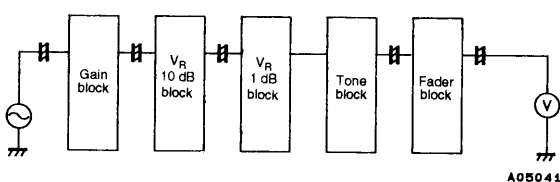
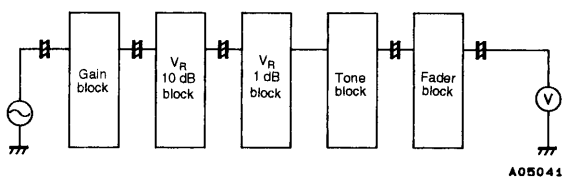
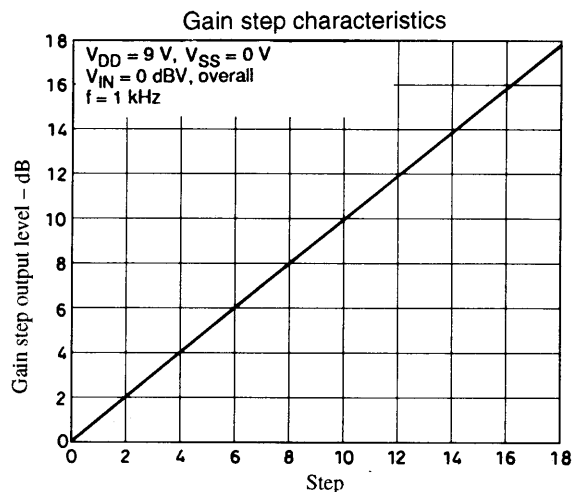
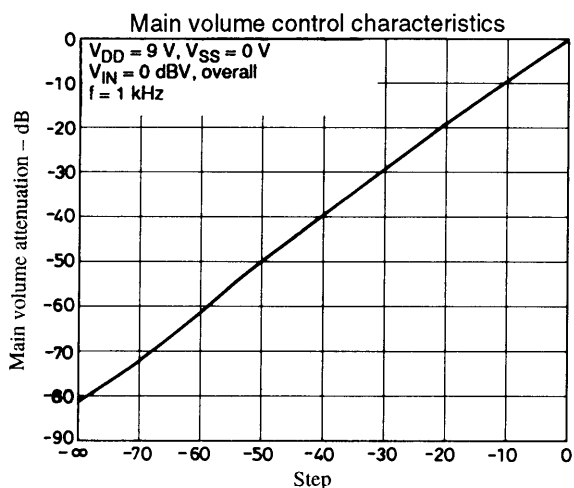
0	0	0	0	-∞dB
1	0	0	0	-9dB
0	1	0	0	-8dB
1	1	0	0	-7dB
0	0	1	0	-6dB
1	0	1	0	-5dB
0	1	1	0	-4dB
1	1	1	0	-3dB
0	0	0	1	-2dB
1	0	0	1	-1dB
0	1	0	1	0dB

10-dB step control

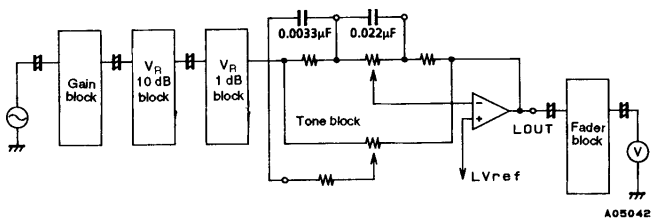
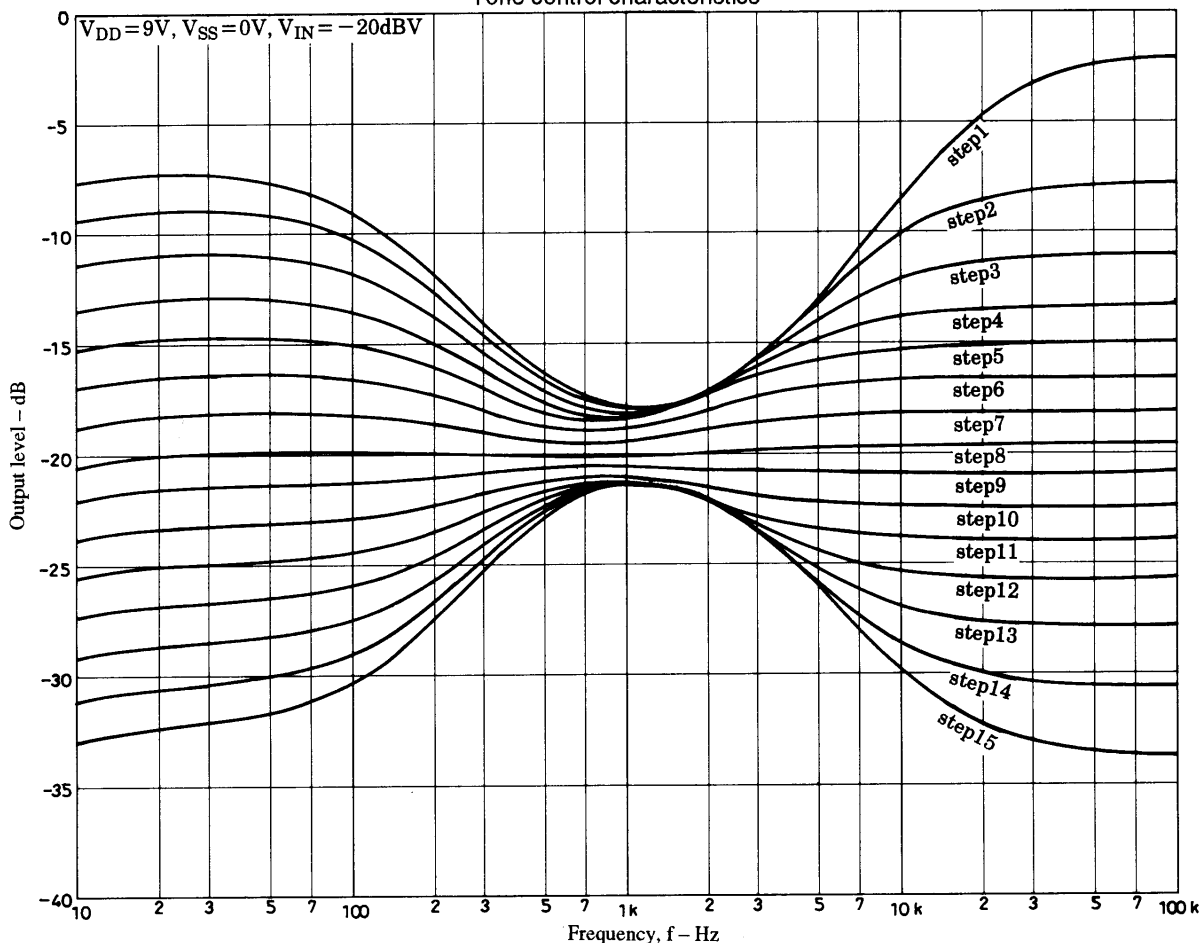
0	0	0	-70dB
1	0	0	-60dB
0	1	0	-50dB
1	1	0	-40dB
0	0	1	-30dB
1	0	1	-20dB
0	1	1	-10dB
1	1	1	0dB

Note: The bits D19 and D28 to D31 are LSI test bits, and must be set to 0.

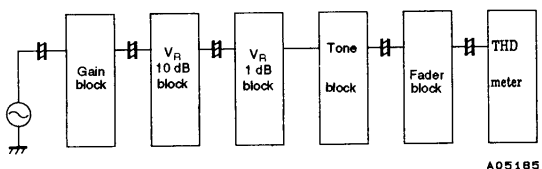
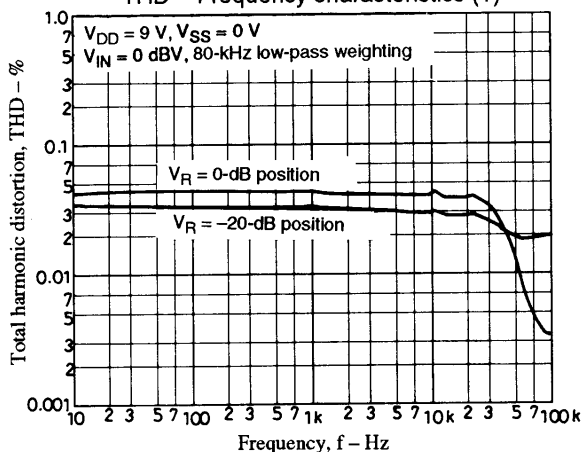
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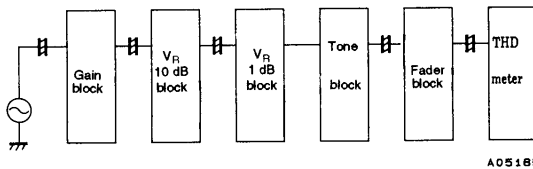
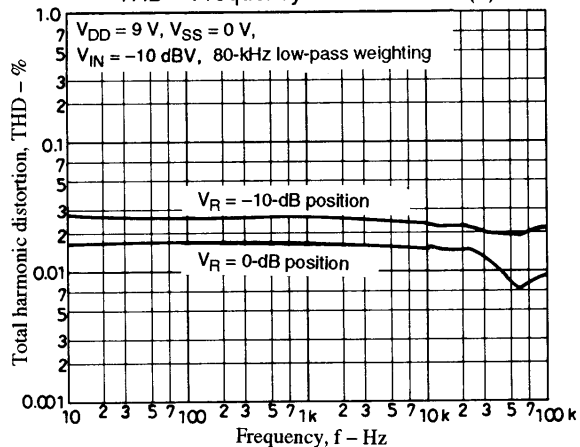
Tone control characteristics



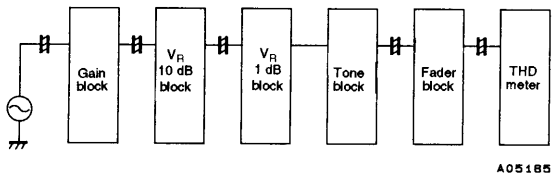
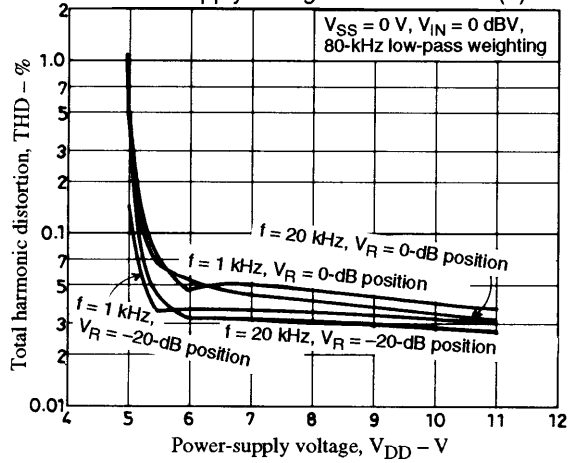
THD - Frequency characteristics (1)



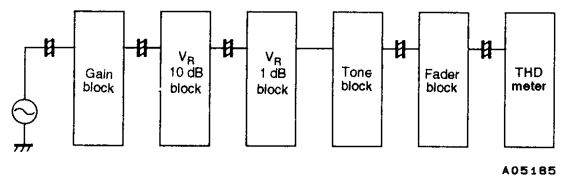
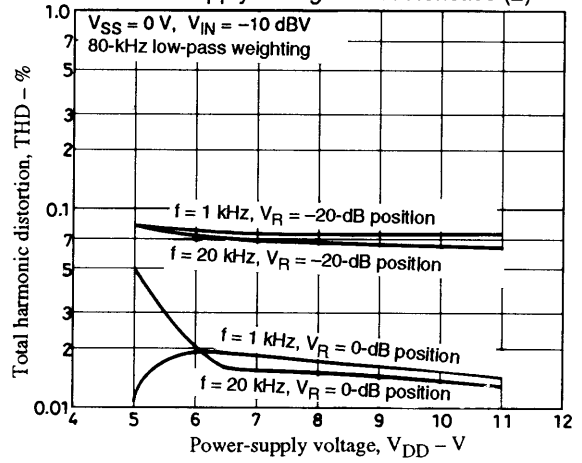
THD - Frequency characteristics (2)



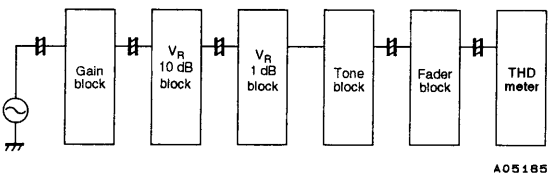
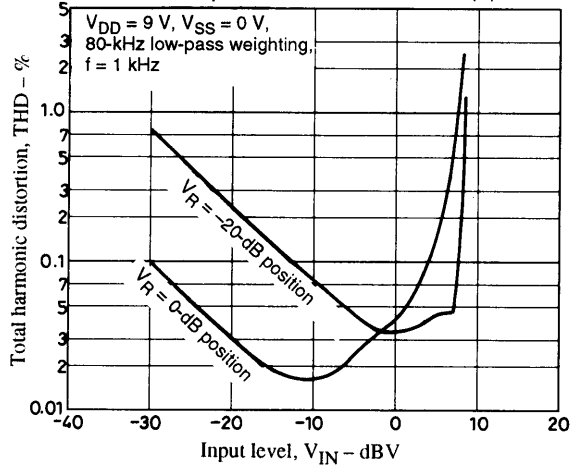
THD – Supply voltage characteristics (1)



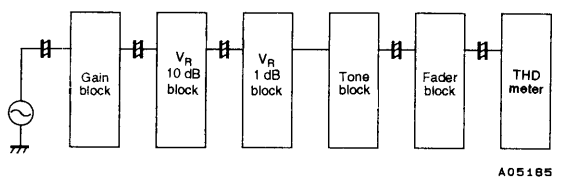
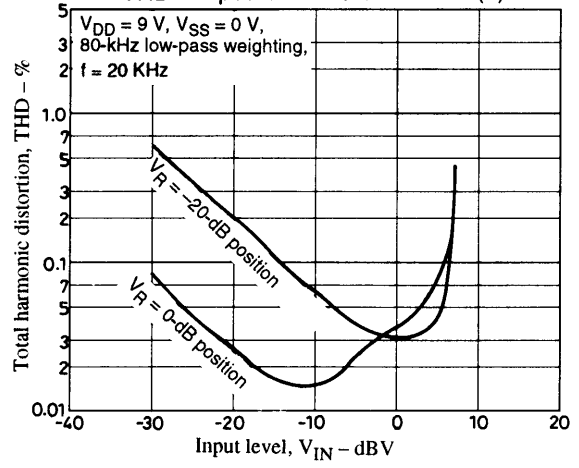
THD – Supply voltage characteristics (2)

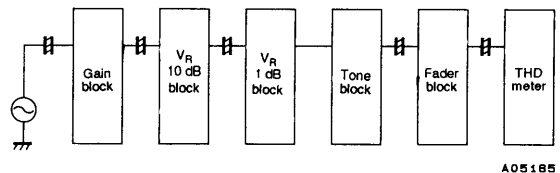
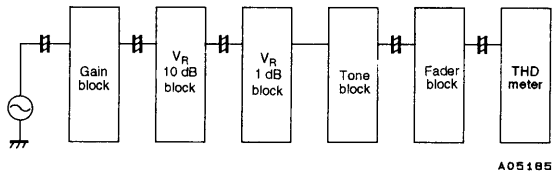
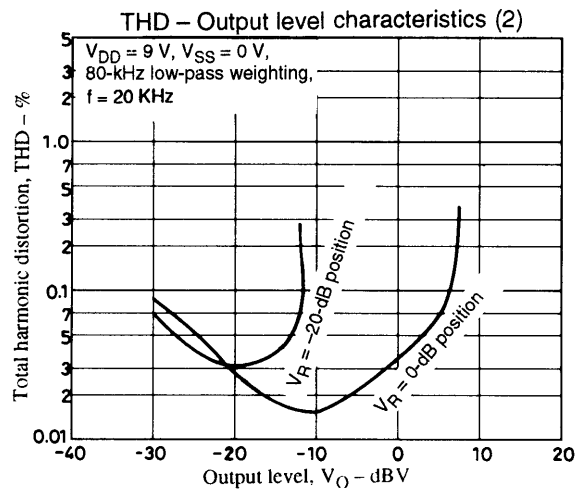
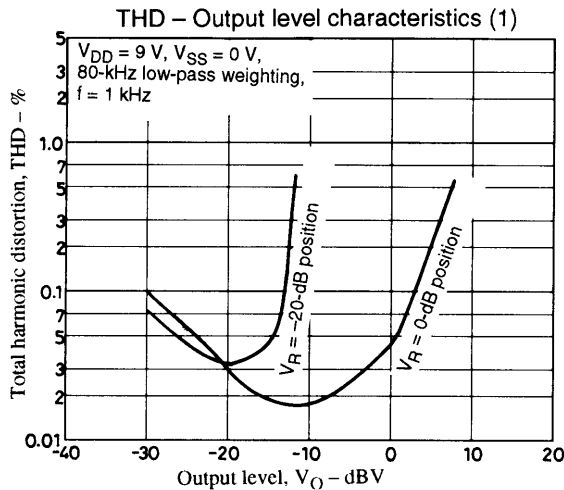


THD – Input level characteristics (1)



THD – Input level characteristics (2)





Usage Notes

1. The states of the internal analog switches are undefined when power is first applied. Use an external muting circuit or other technique to mute the outputs until correct control data has been set up in the LC75372E.
2. Either cover the lines connected to the CL, DI, and CE pins with the ground pattern or use shielded cable for those lines to prevent the high-frequency digital signals on those lines from entering the analog system.
3. Muting by input switching must be used in conjunction with the volume control setting when the maximum volume control attenuation (the VOL = $-\infty$ position) is used.

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