

## OVERVIEW

The QS7785PF/CF is an audio processor IC that generates 2, 4, 5-channel stereo surround signals from 2-channel stereo or mono sources using QSurround™ technology developed and licensed by QSound Labs, Inc.

It can create 2-channel left and right surround effect signal for front speakers, and a rich enhanced surround signal using front speakers and surround speakers for 4-channel output. It also features a center signal output for clear listening of vocal and speech signals.

## FEATURES

- Surround signal output for 2-channel front speakers
- Surround signal output for 4-channel front + surround speakers
- Center speaker output for voice signals
- Parallel and 2 serial interfaces for mode control supported

- QS7785CF: I<sup>2</sup>C bus 2-wire serial interface (Data and Clock)
- QS7785PF: 3-wire serial interface (Data, Clock and Strobe)
- 5 to 13V analog supply
- 4.5 to 5.5V digital supply
- 48-pin QFP package

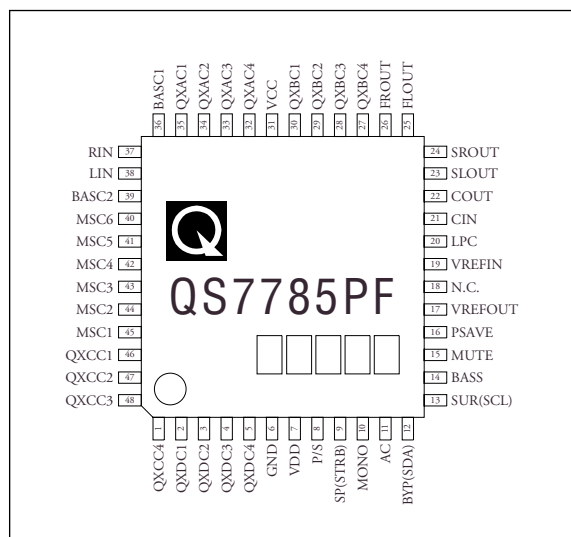
## APPLICATIONS

- TV, radio and VCRs
- Car audio

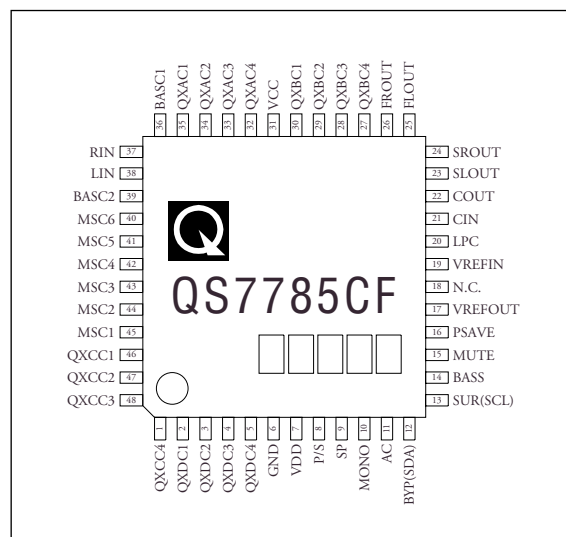
- Multimedia products

## PINOUT (Top view)

### QS7785PF



### QS7785CF



## ORDERING INFORMATION

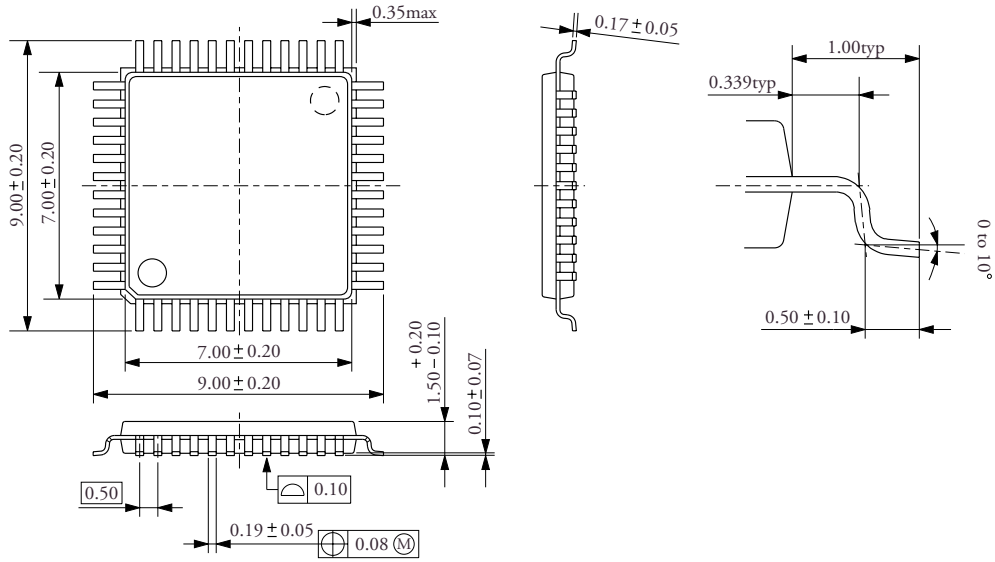
Device	Package
QS7785PF	48-pin QFP
QS7785CF	48-pin QFP

I<sup>2</sup>C bus is a registered trademark of Philips Electronics N.V.

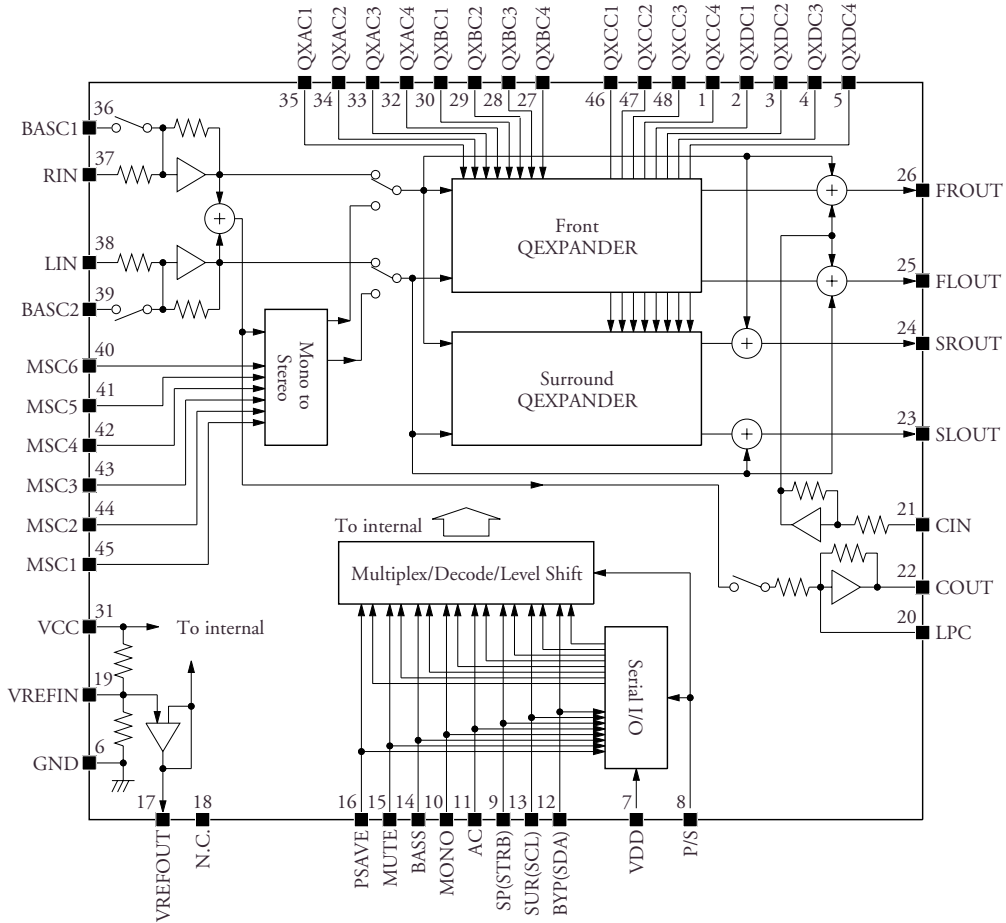
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**PACKAGE DIMENSIONS**

(Unit: mm)



**BLOCK DIAGRAM**



**PIN DESCRIPTION**

Number	Name		I/O	Description
	Parallel	Serial		
1	QXCC4		O	QEXPANDER C capacitor 4
2	QXDC1		I	QEXPANDER D capacitor 1
3	QXDC2		O	QEXPANDER D capacitor 2
4	QXDC3		I	QEXPANDER D capacitor 3
5	QXDC4		O	QEXPANDER D capacitor 4
6	GND		–	Ground
7	VDD		–	4.5 to 5.5V digital supply
8	P/S		I	Input mode control (HIGH: parallel, LOW: serial)
9	SP	–	I	Enhancement control (HIGH: high spread, LOW: low spread)
	–	STRB	I	Serial data strobe (not applicable to QS7785CF)
10	MONO		I	Mono-to-stereo convert select (HIGH: mono to stereo mode, LOW: normal mode)
11	AC		I	Center output control (HIGH: center on, LOW: center off)
12	BYP	–	I	Bypass control (HIGH: bypass, LOW: Qsurround)
	–	SDA	I/O	Serial data input (also serves as ACK signal output for I <sup>2</sup> C bus)
13	SUR	–	I	Surround speaker control (HIGH: surround speaker on, LOW: off)
	–	SCL	I	Serial clock signal input
14	BASS		I	Bass boost mode control (HIGH: bass boost on, LOW: bass boost off)
15	MUTE		I	Mute signal control (HIGH: mute on, LOW: mute off)
16	PSAVE		I	Power save control (HIGH: power save on, LOW: power save off)
17	VREFOUT		O	V <sub>CC</sub> /2 reference voltage output
18	NC		–	No connection
19	VREFIN		I	V <sub>CC</sub> /2 reference voltage output (biased internally to V <sub>CC</sub> /2)
20	LPC		I	Center output lowpass filter
21	CIN		I	COUT output signal feedback input for front-channel output
22	COUT		O	Center signal output
23	SLOUT		O	Surround left-channel signal output
24	SROUT		O	Surround right-channel signal output
25	FLOUT		O	Front left-channel signal output
26	FROUT		O	Front right-channel signal output
27	QXBC4		O	QEXPANDER B capacitor 4
28	QXBC3		I	QEXPANDER B capacitor 3
29	QXBC2		O	QEXPANDER B capacitor 2
30	QXBC1		I	QEXPANDER B capacitor 1
31	VCC		–	5 to 13V DC analog supply
32	QXAC4		O	QEXPANDER A capacitor 4
33	QXAC3		I	QEXPANDER A capacitor 3
34	QXAC2		O	QEXPANDER A capacitor 2
35	QXAC1		I	QEXPANDER A capacitor 1
36	BASC1		I	Bass boost right-channel signal input

## QS7785PF/CF

Number	Name		I/O	Description
	Parallel	Serial		
37	RIN		I	Right-channel signal input
38	LIN		I	Left-channel signal input
39	BASC2		I	Bass boost left-channel signal input
40	MSC6		I	Mono/stereo conversion filter capacitor 6
41	MSC5		I	Mono/stereo conversion filter capacitor 5
42	MSC4		I	Mono/stereo conversion filter capacitor 4
43	MSC3		I	Mono/stereo conversion filter capacitor 3
44	MSC2		I	Mono/stereo conversion filter capacitor 2
45	MSC1		I	Mono/stereo conversion filter capacitor 1
46	QXCC1		I	QEXPANDER C capacitor 1
47	QXCC2		O	QEXPANDER C capacitor 2
48	QXCC3		I	QEXPANDER C capacitor 3

## SPECIFICATIONS

### Absolute Maximum Ratings

GND = 0V

Parameter	Symbol	Rating	Unit
Supply voltage range (analog)	$V_{CC}$	-0.3 to 15	V
Supply voltage range (digital)	$V_{DD}$	-0.3 to 7	V
Input voltage range (analog)	$V_{IANA}$	-0.3 to $V_{CC} + 0.3$	V
Input voltage range (digital)	$V_{IDIG}$	-0.3 to $V_{DD} + 0.3$	V
I <sup>2</sup> C signal input voltage (SDA, SCL)	$V_{IOPEN}$	10	V
Power dissipation	$P_D$	250	mW
Storage temperature range	$T_{stg}$	-40 to 125	°C

### Recommended Operating Conditions

GND = 0V

Parameter	Symbol	Rating	Unit
Supply voltage range (analog)	$V_{CC}$	5 to 13	V
Supply voltage range (digital)	$V_{DD}$	4.5 to 5.5	V
Operating temperature range	$T_{opr}$	-20 to 85	°C

## DC Characteristics

$V_{CC} = 9V$ ,  $V_{DD} = 5V$ ,  $GND = 0V$ ,  $T_a = 25^\circ C$

Parameter	Symbol	Condition	Rating			Unit
			min	typ	max	
Analog input impedance	$Z_{AIN1}$	LIN, RIN	16	20	24	$k\Omega$
	$Z_{AIN2}$	CIN	8	10	12	
Reference voltage output	$V_{REFOUT}$		–	$V_{CC}/2$	–	V
HIGH-level input voltage	$V_{IH}$		$0.7V_{DD}$	–	–	V
LOW-level input voltage	$V_{IL}$		–	–	$0.3V_{DD}$	V
Input leakage current	$I_{LEAK}$	Digital inputs, $V_{DD}$ input voltage	–3	–	3	$\mu A$
	$I_{LOPD}$	SDA, SCL, 10V input voltage	–3	–	3	
LOW-level output voltage	$V_{OL}$	ACK signal output from SDA, 3mA sink current	0	–	0.4	V
Supply voltage (analog)	$V_{CC}$		5	–	13	V
Supply voltage (digital)	$V_{DD}$		4.5	–	5.5	V
Current consumption (analog)	$I_{CC}$		–	6	8	mA
Current consumption (digital)	$I_{DD}$		–	0.3	0.5	mA
Standby current (analog)	$I_{CCSAVE}$		–	0.1	0.2	mA

## Noise and THD Characteristics

$V_{CC} = 9V$ ,  $V_{DD} = 5V$ ,  $GND = 0V$ ,  $T_a = 25^\circ C$

Parameter	Symbol	Condition	Rating			Unit
			min	typ	max	
Bypass noise voltage	$N_{BYP}$	BYP = HIGH, SUR = MONO = SP = LOW, "A"-wgt, FLOUT, FROUT	–	10	20	$\mu V_{RMS}$
Qsurround noise voltage (front)	$N_{QSF}$	SUR = SP = HIGH, BYP = MONO = LOW, "A"-wgt, FLOUT, FROUT	–	20	40	$\mu V_{RMS}$
Qsurround noise voltage (surround)	$N_{QSR}$	SUR = SP = HIGH, BYP = MONO = LOW, "A"-wgt, SLOUT, SROUT	–	15	30	$\mu V_{RMS}$
Bypass total harmonic distortion	$THD_B$	BYP = SUR = HIGH, MONO = SP = LOW, LIN = RIN = $1V_{RMS}$ , $f = 1kHz$ , FLOUT, FROUT, SLOUT, SROUT	–	–	0.1	%
Qsurround mono total harmonic distortion	$THD_{QM}$	BYP = LOW, SUR = MONO = SP = HIGH, LIN = RIN = $1V_{RMS}$ , $f = 1kHz$ , FLOUT, FROUT, SLOUT, SROUT	–	–	0.1	%

**AC Characteristics**

$V_{CC} = 9V$ ,  $V_{DD} = 5V$ ,  $GND = 0V$ ,  $T_a = 25^\circ C$

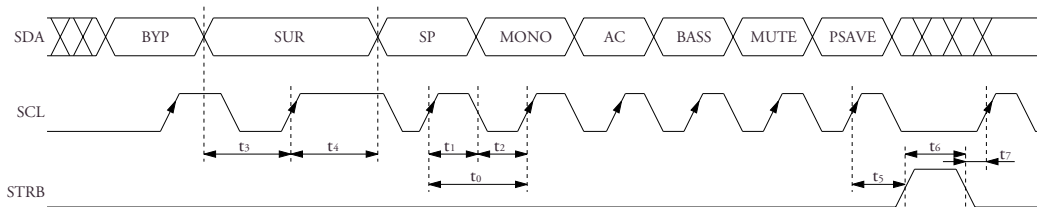
Parameter	Symbol	Condition	Rating			Unit
			min	typ	max	
Bypass-mode maximum input voltage	$V_B$	BYP = SUR = HIGH, MONO = SP = LOW, LIN = RIN, $f = 1kHz$	1.7	2.3	–	$V_{RMS}$
Qsurround enhanced-mode maximum input voltage	$V_{Q+}$	BYP = MONO = SUR = LOW, SP = HIGH, LIN = RIN, $f = 1kHz$	1.8	2.4	–	$V_{RMS}$
Qsurround-mode maximum input voltage (surround speakers on)	$V_{QS}$	BYP = MONO = SP = LOW, SUR = HIGH, LIN = RIN, $f = 1kHz$	1.3	1.7	–	$V_{RMS}$
Mono/stereo conversion enhanced mode maximum input voltage	$V_{M+}$	BYP = SUR = LOW, MONO = SP = HIGH, LIN = RIN, $f = 1kHz$	0.8	1.0	–	$V_{RMS}$
Mono/stereo conversion mode maximum input voltage (surround speakers on)	$V_{MS}$	BYP = SP = LOW, MONO = SUR = HIGH, LIN = RIN, $f = 1kHz$	0.8	1.0	–	$V_{RMS}$
Bypass gain	$G_{BYP1}$	BYP = HIGH, MONO = SUR = SP = LOW, LIN to FLOUT, RIN to FROUT, $f = 1kHz$	–2	0	2	dB
Bypass gain (surround speakers on)	$G_{BYP2}$	BYP = SUR = HIGH, MONO = SP = LOW, LIN to SLOUT, RIN to SROUT, $f = 1kHz$	–2	0	2	dB
Qsurround mode gain	$G_Q$	BYP = MONO = SUR = SP = LOW, LIN to FLOUT, RIN to FROUT, $f = 1kHz$	3.9	5.9	7.9	dB
Qsurround mode crosstalk gain	$G_{QX}$	BYP = MONO = SUR = SP = LOW, LIN to FROUT, RIN to FLOUT, $f = 1kHz$	–1.5	0.5	2.5	dB
Qsurround mode gain (surround)	$G_{QS}$	BYP = MONO = SP = LOW, SUR = HIGH, LIN to SLOUT, RIN to SROUT, $f = 1kHz$	–2.3	–0.3	1.7	dB
Qsurround mode crosstalk gain (surround)	$G_{QXS}$	BYP = MONO = SP = LOW, SUR = HIGH, LIN to SROUT, RIN to SLOUT, $f = 1kHz$	–1.9	0.1	2.1	dB
Qsurround enhanced mode gain	$G_{Q+}$	BYP = MONO = SUR = LOW, SP = HIGH, LIN to FLOUT, RIN to FROUT, $f = 1kHz$	4.7	6.7	8.7	dB
Qsurround enhanced mode crosstalk gain	$G_{QX+}$	BYP = MONO = SUR = LOW, SP = HIGH, LIN to FROUT, RIN to FLOUT, $f = 1kHz$	1.3	3.3	5.3	dB
Mono/stereo conversion mode left-channel gain	$G_{ML}$	BYP = SUR = SP = LOW, MONO = HIGH, LIN = RIN, FLOUT, $f = 1kHz$	2.6	4.6	6.6	dB
Mono/stereo conversion mode right-channel gain	$G_{MR}$	BYP = SUR = SP = LOW, MONO = HIGH, LIN = RIN, FROUT, $f = 1kHz$	3.6	5.6	7.6	dB
Mono/stereo conversion enhanced mode left-channel gain	$G_{ML+}$	BYP = SUR = LOW, MONO = SP = HIGH, LIN = RIN, FLOUT, $f = 1kHz$	2.4	4.4	6.4	dB
Mono/stereo conversion enhanced mode right-channel gain	$G_{MR+}$	BYP = SUR = LOW, MONO = SP = HIGH, LIN = RIN, FROUT, $f = 1kHz$	3.3	5.3	7.3	dB
Mono/stereo conversion mode surround left-channel gain	$G_{MSL}$	BYP = SP = LOW, MONO = SUR = HIGH, LIN = RIN, SLOUT, $f = 1kHz$	–3.8	–1.8	0.2	dB
Mono/stereo conversion mode surround right-channel gain	$G_{MSR}$	BYP = SP = LOW, MONO = SUR = HIGH, LIN = RIN, SROUT, $f = 1kHz$	–1.6	0.4	2.4	dB
SCL clock pulse period	$t_0$	QS7785PF	100	–	–	ns
SCL clock HIGH-level pulsewidth	$t_1$	QS7785PF	40	–	–	ns
SCL clock LOW-level pulsewidth	$t_2$	QS7785PF	40	–	–	ns
SDA setup time	$t_3$	QS7785PF	15	–	–	ns
SDA hold time	$t_4$	QS7785PF	30	–	–	ns
STRB setup time	$t_5$	QS7785PF	50	–	–	ns
STRB pulsewidth	$t_6$	QS7785PF	100	–	–	ns
STRB hold time	$t_7$	QS7785PF	50	–	–	ns

## QS7785PF/CF

Parameter	Symbol	Condition	Rating			Unit
			min	typ	max	
SCL hold time (I <sup>2</sup> C)	$t_{HD:STA}$	QS7785CF	4.0	–	–	$\mu$ s
SCL setup time (I <sup>2</sup> C)	$t_{SU:STO}$	QS7785CF	4.0	–	–	$\mu$ s
SDA hold time (I <sup>2</sup> C)	$t_{HD:DAT}$	QS7785CF	5.0	–	–	$\mu$ s
SDA setup time (I <sup>2</sup> C)	$t_{SU:DAT}$	QS7785CF	250	–	–	ns
SCL clock HIGH-level pulsewidth (I <sup>2</sup> C)	$t_{HIGH}$	QS7785CF	4.0	–	–	$\mu$ s
SCL clock LOW-level pulsewidth (I <sup>2</sup> C)	$t_{LOW}$	QS7785CF	4.7	–	–	$\mu$ s
SCL rise time (I <sup>2</sup> C)	$t_r$	QS7785CF	–	–	1000	ns
SCL fall time (I <sup>2</sup> C)	$t_f$	QS7785CF	–	–	300	ns

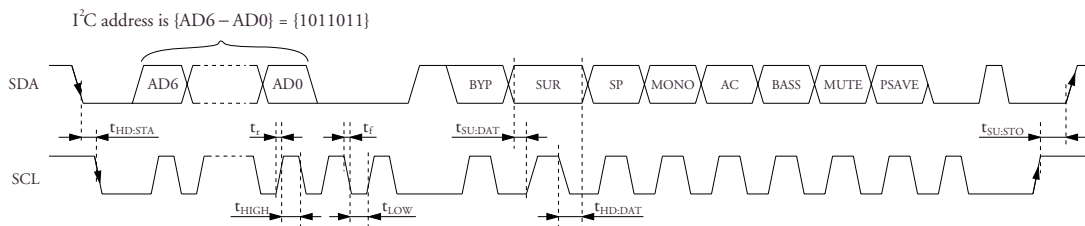
### Serial Interface Timing

#### 3-wire (QS7785PF) timing



Pin	Description
SDA	Data signal. Sets mode settings. See “Operating Modes.”
SCL	Clock signal. Data is read on the rising edge.
STRB	Strobe signal. Mode switches occur on the rising edge of this signal.

#### I<sup>2</sup>C 2-wire (QS7785CF) timing



Pin	Description
SDA	Data signal. Sets slave address and mode settings. Address value, {1011011}, is shown in the figure above. See “Operating Modes.”
SCL	Clock signal. Data is read on the rising edge.

## FUNCTIONAL DESCRIPTION

### Operating Modes

The QS7785PF/CF operating mode can be controlled over either a parallel interface (P/S = HIGH) or one of two serial interfaces (P/S = LOW). The

operating mode, control pins and SDA signal relationship is shown in the table below. Refer to “Serial Interface Timing” for the SDA signal format.

### Output mode

No.	Input signals	Control pins/SDA signal				Output signals <sup>1</sup>	
		BYP	MONO	SUR	SP	FROUT/FLOUT	SROUT/SLOUT
1	Stereo only	0	0	0	0	Stereo Q	–
2		0	0	0	1	Stereo Q+	–
3		0	0	1	0	Stereo Q	Stereo Q1
4		0	0	1	1	Stereo Q+	Stereo Q1
5	Mono only	0	1	0	0	Mono → Stereo Q	–
6		0	1	0	1	Mono → Stereo Q+	–
7		0	1	1	0	Mono → Stereo Q	Mono → Stereo Q1
8		0	1	1	1	Mono → Stereo Q+	Mono → Stereo Q1
9	Stereo/Mono	1	0	0	×	Stereo bypass	–
10		1	0	1	×	Stereo bypass	Stereo bypass
11		1	1	0	×	–	Stereo bypass
12	Stereo only	1	1	1	×	Stereo bypass	Stereo Q1

1. – (dash) = no output signal.  
 × = indicates don't care.  
 1 = HIGH, 0 = LOW

### Output signal description

Output signal	Description
Stereo Q	Mixed front-channel Qsurround processed signal and input stereo signal output
Stereo Q+	Same as Stereo Q with increased Qsurround signal component and reduced input stereo signal component.
Stereo Q1	Mixed surround-channel Qsurround processed signal and input stereo signal output.
Mono → Stereo Q	Mono signal converted to virtual stereo signal, and then processed in the same way as Stereo Q signals.
Mono → Stereo Q+	Mono signal converted to virtual stereo signal, and then processed in the same way as Stereo Q+ signals.
Stereo bypass	Input stereo signal is output as-is without processing.

Mono signals should be input on both LIN and RIN.

In output mode 1, the output signal is a mixed signal comprising the front-channel Qsurround processed signal and the input stereo signal, that is output on the 2-channel front speakers only.

In output mode 2, the signal path is the same as in output mode 1, but the surround effect is enhanced by increasing the component of the Qsurround processed signal and reducing the component of the input stereo signal.

In output modes 3 and 4, both the front speakers and surround speakers are used to form a 4-channel sys-

tem for a rich surround space. The front-channel signal is the same as in output modes 1 and 2. The surround-channel signal is a mixed signal comprising an enhanced surround effect Qsurround processed signal and the input stereo signal.

In output modes 5 to 8, the input signal is a mono signal. The mono signal is first converted to a virtual stereo signal and then processed in the same way as in output modes 1 to 4, respectively. In modes 5 and 6, the surround signal is output on 2-channel front speakers only. In modes 7 and 8, the surround signals are output on 4-channel front and surround speakers.



In output modes 9 to 11, the input stereo signal is output to the speakers without processing. The bypass function works for both stereo and mono input signals, and is used to listen to the original signals. In mode 9, the stereo signal is output on front speakers only. In mode 10, the stereo signal is output

on both front and surround speakers. In mode 11, the stereo signal is output on surround speakers only.

In output mode 12, the input stereo signal is output on front speakers, and a surround effect enhanced signal is output on the surround speakers.

**Center signal output**

Control pins/SDA signal <sup>1</sup>					Output signal
BYP	MONO	SUR	SP	AC	COUT
×	×	×	×	0	–
×	×	×	×	1	(RIN + LIN) / 2

- 1. – (dash) = no output signal.
- × = indicates don't care.
- 1 = HIGH, 0 = LOW

The center signal is output on COUT. See “Center Control.”

**Bass boost mode**

Control pins/SDA signal <sup>1</sup>						Output signal		
BYP	MONO	SUR	SP	AC	BASS	FROUT/FLOUT	SROUT/SLOUT	COUT
×	×	×	×	×	0	Bass boost OFF	Bass boost OFF	Bass boost OFF
×	×	×	×	×	1	Bass boost ON	Bass boost ON	Bass boost ON

- 1. × = indicates don't care.
- 1 = HIGH, 0 = LOW

The bass boost function is used to enhance the bass frequency component. See “Bass Boost.”

**Mute and power save**

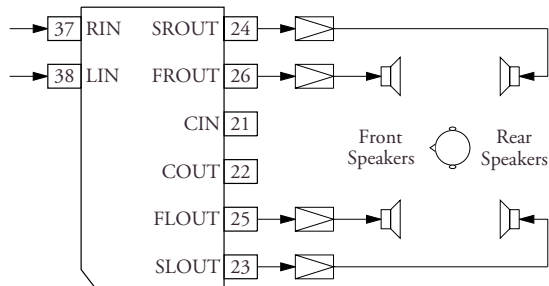
Control pins/SDA signal <sup>1</sup>								Output signal		
BYP	MONO	SUR	SP	AC	BASS	MUTE	PSAVE	FROUT/FLOUT	SROUT/SLOUT	COUT
×	×	×	×	×	×	0	0	Available	Available	Available
×	×	×	×	×	×	1	0	–	–	–
×	×	×	×	×	×	1	1	–	–	–

- 1. – (dash) = no output signal.
- × = indicates don't care.
- 1 = HIGH, 0 = LOW

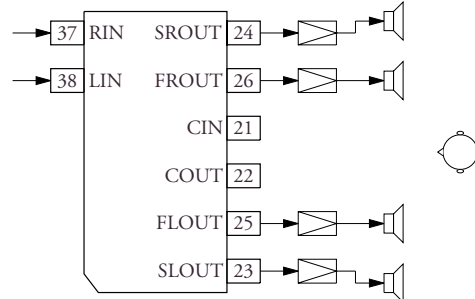
When PSAVE is HIGH, the analog stages of the device are turned OFF to save power. When MUTE is HIGH, all outputs are muted.

## Speaker Arrangement

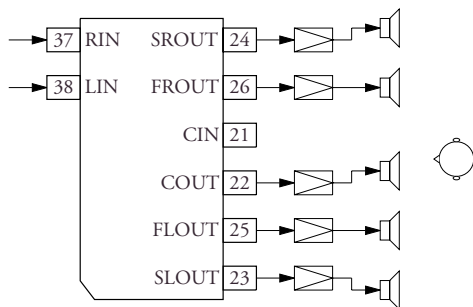
The QS7785PF/CF supports the following speaker arrangements.



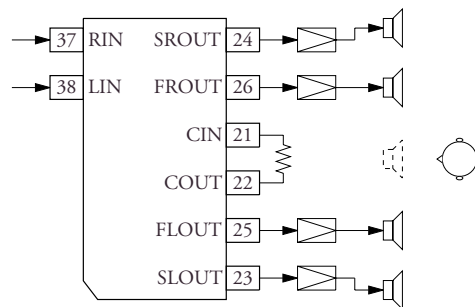
Type A. Two front speakers in front and two surround speakers in rear



Type B. Front speakers and surround speakers in front



Type C. Front speakers and surround speakers in front with actual center speaker



Type D. Front speakers and surround speakers in front with center

### Type A

The front speakers are placed in front and the surround speakers are placed behind the audience to create a full rich enhanced space. Since the output signal for each channel has undergone Qsurround processing, the audio enhancement can be reduced to an adequate level even for television and similar signals where the left and right channels are located close to each other.

### Type B

The front speakers and surround speakers are both placed in front of the audience, perhaps because it is not possible to place speakers behind the audience. If the surround speakers are turned to face outwards, to spread the surround signal, the surround effect can be obtained.

### Type C

A center speaker can be added in the center to reproduce vocal and speech signals for easy listening. The center signal is output on COUT. The signal is comprised of LIN and RIN signals, producing a sound image in the center.

### Type D

If a center speaker is not available or not required, COUT can be connected to CIN using a resistor and the center signal is then added to the front-channel signal. The presence of the center signal added to the front channels reproduces the center signal sound image with virtually the same effect as that obtained using a center speaker. The connection using a resistor can be utilized for voice and similar fixed-band signals. See "Center Control" for a description of the method.

### Center Control

The center signal output on COUT is enabled when AC is HIGH.

This section describes the output function whereby fixed frequency sound sources, such as vocal and speech signals, can be output on the center signal. As mentioned for “Type C” and “Type D” speaker arrangements, the center signal can be output by direct connection to a speaker or by adding the signal to the front-channel output using a resistor connection between CIN and COUT.

### Using a center speaker

When using a speaker, a capacitor Ca can be connected between LPC and COUT, forming a lowpass filter. The -3dB cutoff frequency of the filter is given by the following equation.

$$f = \frac{1}{2\pi C_a \times R_1}$$

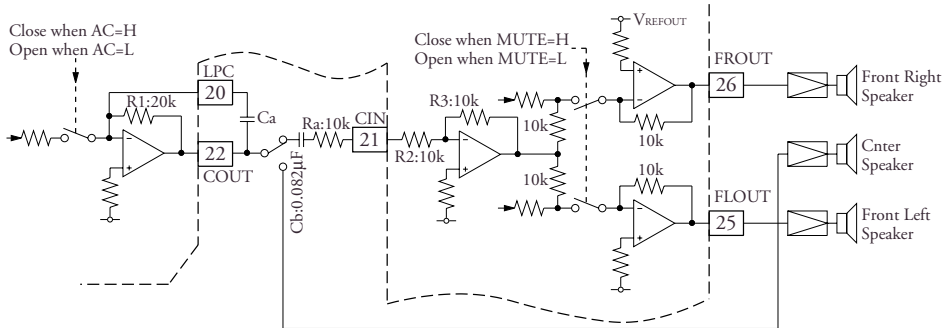
Frequencies higher than voice tones are cut from the signal sent to the center speaker for clear reproduction of voice-band signals.

### Adding to the front-channel output

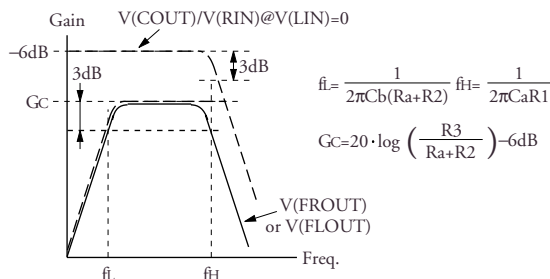
With this connection, the bass frequency components can be removed from a signal. Capacitors Ca and Cb and resistor Ra can be connected between CIN and COUT to form a highpass filter. The -3dB cutoff frequency of the filter is given by the following equation.

$$f = \frac{1}{2\pi C_b (R_a + R_2)}$$

The input signal on CIN is added equally to both front-channel outputs FLOUT and FROUT. Frequencies lower than voice tones are cut from the signal added to the front-channel outputs for clear reproduction of voice-band signals.



Center output connection



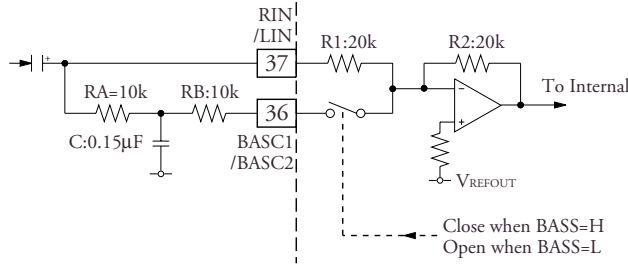
Center output frequency response

Note: Internal resistance value, R1 and R2, may vary ± 15%.

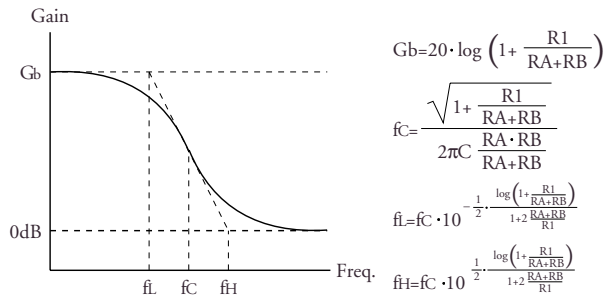
**Bass Boost**

With a signal input connected to BASC1 and BASC2, a bass boost function can be implemented. When BASS is HIGH, resistors RA and RB and

capacitor C are connected to form a lowpass filter. The lowpass filter signal and the original signal (RIN, LIN) are combined to boost bass frequencies.



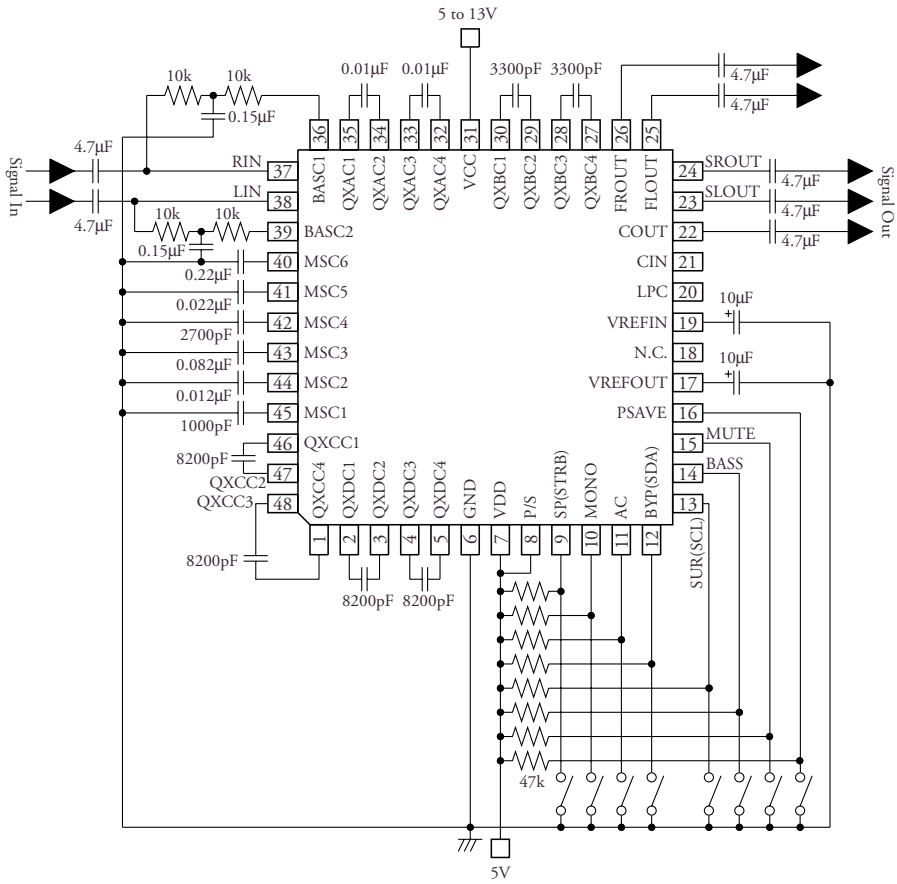
Bass boost connection (Gb = 6dB, fC = 300Hz)



Bass boost frequency response

TYPICAL APPLICATIONS

Parallel Interface

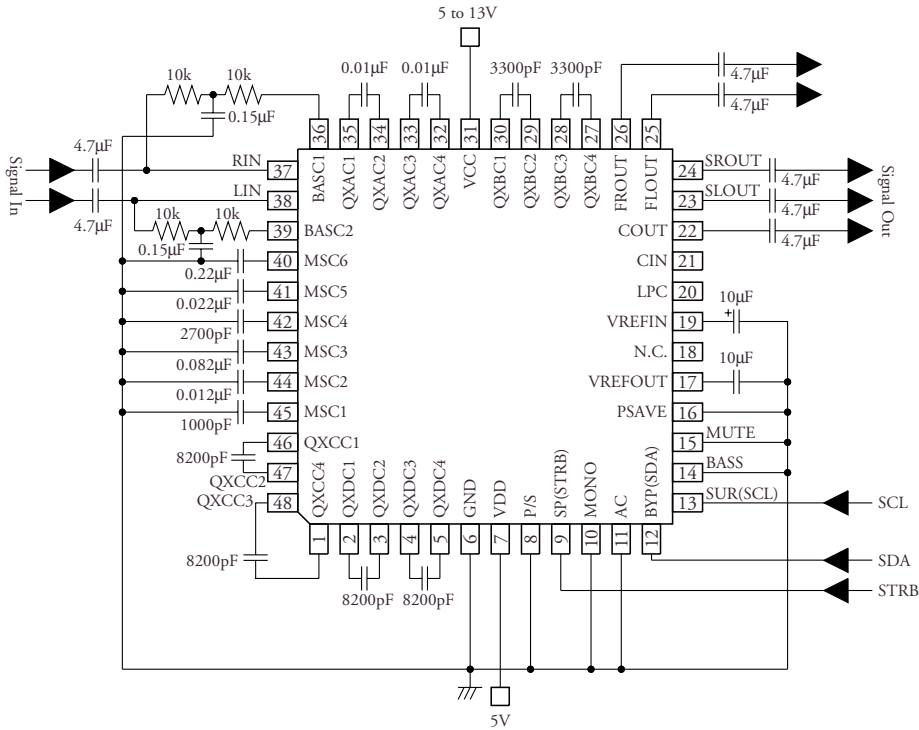


A capacitor for decoupling should be connected between supply and ground.

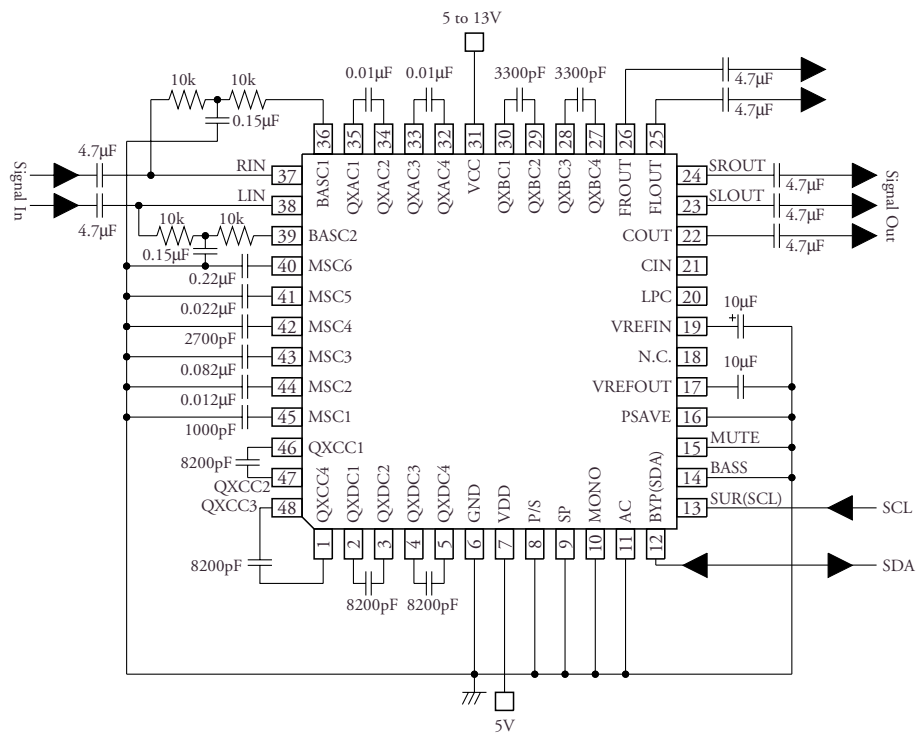
QS7785PF/CF

Serial Interface

QS7785PF



QS7785PF



A capacitor for decoupling should be connected between supply and ground.

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