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Contact us

Tel: +86-755-8981 8866 Fax: +86-755-8427 6832

Email & Skype: info@chipsmall.com Web: www.chipsmall.com

Address: A1208, Overseas Decoration Building, #122 Zhenhua RD., Futian, Shenzhen, China



BROADCAST AM/FM RADIO RECEIVER

Features

- NOAA weather band support (162.4–162.55 MHz)
- Worldwide FM band support (64–108 MHz)
- Worldwide AM band support (520–1710 kHz) (Si4736/37)
- 1050 Hz alert tone detection
- Excellent real-world performance
- Freq synthesizer with integrated VCO
- Advanced AM/FM seek tuning
- Automatic frequency control (AFC)
- Automatic gain control (AGC)
- Digital FM stereo decoder
- Programmable AVC max gain
- Programmable de-emphasis
- AM/FM/WB digital tuning
- No manual alignment necessary
- Programmable reference clock
- Volume control
- Adjustable soft mute control
- RDS/RBDS processor (Si4737/39)
- Optional digital audio out (Si4737/39)
- 2-wire and 3-wire control interface
- Integrated LDO regulator
- 2.0 to 5.5 V supply voltage (SSOP)
- 2.7 to 5.5 V supply voltage (QFN)
- Wide range of ferrite loop sticks and air loop antennas supported
- QFN and SSOP packages
 - RoHS compliant

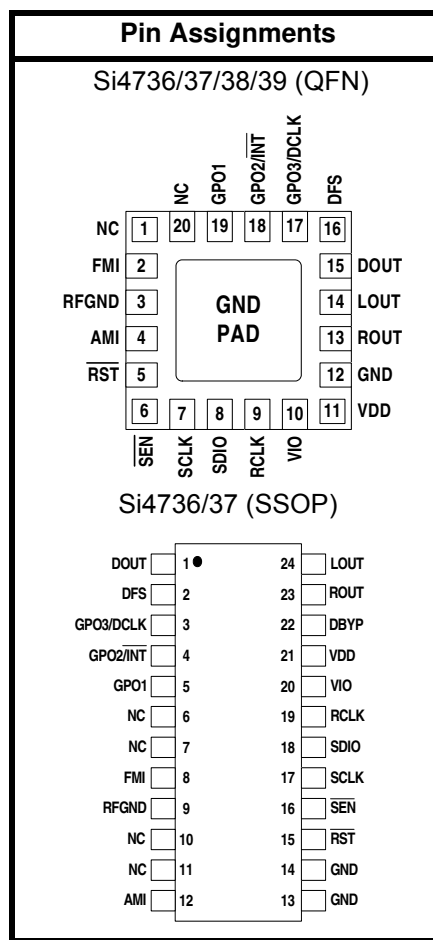
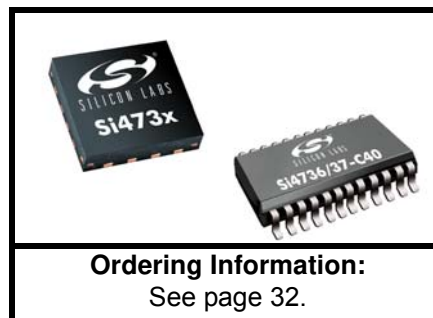
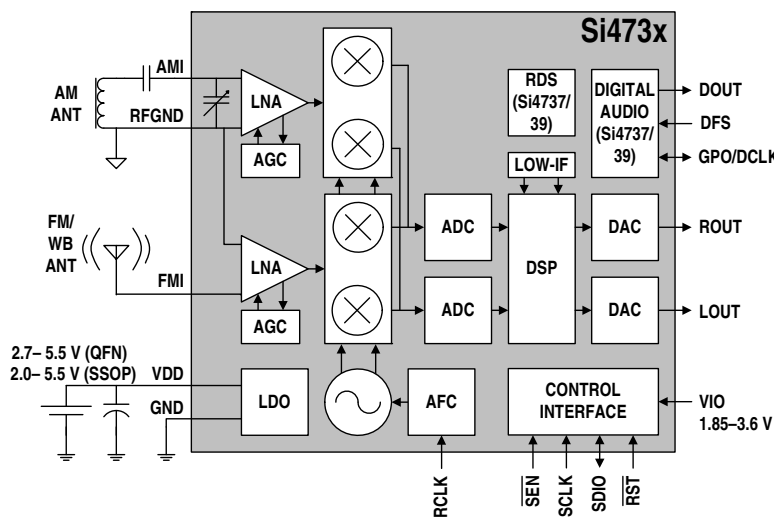
Applications

- Emergency radios
- Table and portable radios
- Stereos
- Mini/micro systems
- Boom boxes
- Modules
- Clock radios
- Mini HiFi

Description

The Si4736/37/38/39 is the first digital CMOS AM/FM radio receiver IC that integrates the complete tuner function from antenna input to audio output.

Functional Block Diagram



This product, its features, and/or its architecture is covered by one or more of the following patents, as well as other patents, pending and issued, both foreign and domestic: 7,127,217; 7,272,373; 7,272,375; 7,321,324; 7,355,476; 7,426,376; 7,471,940; 7,339,503; 7,339,504.

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1. Electrical Specifications

Table 1. Recommended Operating Conditions¹

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Supply Voltage ²	V_{DD}		2.7	—	5.5	V
Interface Supply Voltage	V_{IO}		1.85	—	3.6	V
Power Supply Powerup Rise Time	V_{DDRISE}		10	—	—	μ s
Interface Power Supply Powerup Rise Time	V_{IORISE}		10	—	—	μ s
Ambient Temperature	T_A		-20	25	85	$^{\circ}$ C

Note:

1. All minimum and maximum specifications apply across the recommended operating conditions. Typical values apply at $V_{DD} = 3.3$ V and 25 $^{\circ}$ C unless otherwise stated.
2. SSOP devices operate down to $V_{DD} = 2$ V at 25 $^{\circ}$ C.

Table 2. Absolute Maximum Ratings^{1,2}

Parameter	Symbol	Value	Unit
Supply Voltage	V_{DD}	-0.5 to 5.8	V
Interface Supply Voltage	V_{IO}	-0.5 to 3.9	V
Input Current ³	I_{IN}	10	mA
Input Voltage ³	V_{IN}	-0.3 to ($V_{IO} + 0.3$)	V
Operating Temperature	T_{OP}	-40 to 95	$^{\circ}$ C
Storage Temperature	T_{STG}	-55 to 150	$^{\circ}$ C
RF Input Level ⁴		0.4	V_{PK}

Notes:

1. Permanent device damage may occur if the above Absolute Maximum Ratings are exceeded. Functional operation should be restricted to the conditions as specified in the operational sections of this data sheet. Exposure beyond recommended operating conditions for extended periods may affect device reliability.
2. The Si4736/37/38/39 devices are high-performance RF integrated circuits with certain pins having an ESD rating of < 2 kV HBM. Handling and assembly of these devices should only be done at ESD-protected workstations.
3. For input pins SCLK, SEN, SDIO, RST, RCLK, and DCLK.
4. At RF input pins, FMI and AMI.

Table 3. DC Characteristics $(V_{DD} = 2.7 \text{ to } 5.5 \text{ V}, V_{IO} = 1.85 \text{ to } 3.6 \text{ V}, T_A = -20 \text{ to } 85 \text{ }^\circ\text{C})$

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
FM Mode						
Supply Current ¹	I_{FM}		—	19.2	22	mA
Supply Current ²	I_{FM}	Low SNR level	—	19.9	23	mA
RDS Supply Current ¹	I_{FM}		—	19.2	23	mA
WB Mode						
Supply Current ¹	I_{FM}		—	19.2	22	mA
Supply Current	I_{FM}	Low SNR level	—	19.8	23	mA
AM Mode						
Supply Current ¹	I_{AM}	Analog Output Mode	—	15.4	20.5	mA
Supplies and Interface						
Interface Supply Current	I_{IO}		—	320	600	μA
V_{DD} Powerdown Current	I_{DDPD}		—	10	20	μA
V_{IO} Powerdown Current	I_{IOPD}	SCLK, RCLK inactive	—	1	10	μA
High Level Input Voltage ³	V_{IH}		$0.7 \times V_{IO}$	—	$V_{IO} + 0.3$	V
Low Level Input Voltage ³	V_{IL}		-0.3	—	$0.3 \times V_{IO}$	V
High Level Input Current ³	I_{IH}	$V_{IN} = V_{IO} = 3.6 \text{ V}$	-10	—	10	μA
Low Level Input Current ³	I_{IL}	$V_{IN} = 0 \text{ V},$ $V_{IO} = 3.6 \text{ V}$	-10	—	10	μA
High Level Output Voltage ⁴	V_{OH}	$I_{OUT} = 500 \mu\text{A}$	$0.8 \times V_{IO}$	—	—	V
Low Level Output Voltage ⁴	V_{OL}	$I_{OUT} = -500 \mu\text{A}$	—	—	$0.2 \times V_{IO}$	V
Notes:						
1. Specifications are guaranteed by characterization.						
2. LNA is automatically switched to higher current mode for optimum sensitivity in weak signal conditions.						
3. For input pins SCLK, SEN, SDIO, RST, RCLK, and DCLK.						
4. For output pins SDIO, DOUT, GPO1, GPO2, and GPO3.						

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Table 4. Reset Timing Characteristics^{1,2,3}

($V_{DD} = 2.7$ to 5.5 V, $V_{IO} = 1.85$ to 3.6 V, $T_A = -20$ to 85 °C)

Parameter	Symbol	Min	Typ	Max	Unit
\overline{RST} Pulse Width and GPO1, GPO2/ \overline{INT} Setup to $\overline{RST}\uparrow^4$	t_{SRST}	100	—	—	μs
GPO1, GPO2/ \overline{INT} Hold from $\overline{RST}\uparrow$	t_{HRST}	30	—	—	ns

Important Notes:

1. When selecting 2-wire mode, the user must ensure that a 2-wire start condition (falling edge of SDIO while SCLK is high) does not occur within 300 ns before the rising edge of \overline{RST} .
2. When selecting 2-wire mode, the user must ensure that SCLK is high during the rising edge of \overline{RST} , and stays high until after the first start condition.
3. When selecting 3-wire or SPI modes, the user must ensure that a rising edge of SCLK does not occur within 300 ns before the rising edge of \overline{RST} .
4. If GPO1 and GPO2 are actively driven by the user, then minimum t_{SRST} is only 30 ns. If GPO1 or GPO2 is hi-Z, then minimum t_{SRST} is 100 μs , to provide time for on-chip 1 M Ω devices (active while \overline{RST} is low) to pull GPO1 high and GPO2 low.

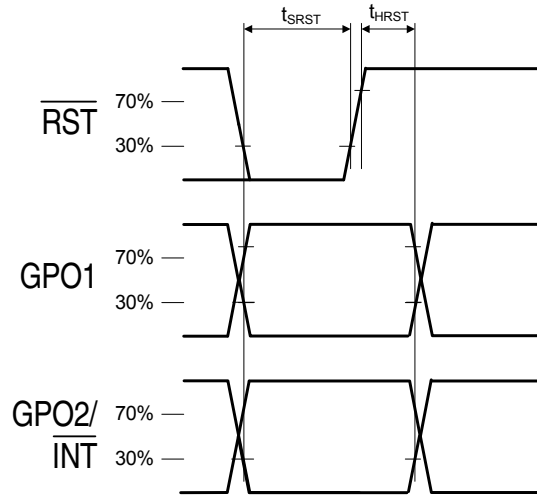


Figure 1. Reset Timing Parameters for Busmode Select

Table 5. 2-Wire Control Interface Characteristics^{1,2,3}(V_{DD} = 2.7 to 5.5 V, V_{IO} = 1.85 to 3.6 V, T_A = -20 to 85 °C)

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
SCLK Frequency	f _{SCL}		0	—	400	kHz
SCLK Low Time	t _{LOW}		1.3	—	—	μs
SCLK High Time	t _{HIGH}		0.6	—	—	μs
SCLK Input to SDIO ↓ Setup (START)	t _{SU:STA}		0.6	—	—	μs
SCLK Input to SDIO ↓ Hold (START)	t _{HD:STA}		0.6	—	—	μs
SDIO Input to SCLK ↑ Setup	t _{SU:DAT}		100	—	—	ns
SDIO Input to SCLK ↓ Hold ^{4,5}	t _{HD:DAT}		0	—	900	ns
SCLK input to SDIO ↑ Setup (STOP)	t _{SU:STO}		0.6	—	—	μs
STOP to START Time	t _{BUF}		1.3	—	—	μs
SDIO Output Fall Time	t _{f:OUT}		$20 + 0.1 \frac{C_b}{1\text{pF}}$	—	250	ns
SDIO Input, SCLK Rise/Fall Time	t _{f:IN} t _{r:IN}		$20 + 0.1 \frac{C_b}{1\text{pF}}$	—	300	ns
SCLK, SDIO Capacitive Loading	C _b		—	—	50	pF
Input Filter Pulse Suppression	t _{SP}		—	—	50	ns

Notes:

1. When V_{IO} = 0 V, SCLK and SDIO are low impedance.
2. When selecting 2-wire mode, the user must ensure that a 2-wire start condition (falling edge of SDIO while SCLK is high) does not occur within 300 ns before the rising edge of $\overline{\text{RST}}$.
3. When selecting 2-wire mode, the user must ensure that SCLK is high during the rising edge of $\overline{\text{RST}}$, and stays high until after the first start condition.
4. The Si4736/37/38/39 delays SDIO by a minimum of 300 ns from the V_{IH} threshold of SCLK to comply with the minimum t_{HD:DAT} specification.
5. The maximum t_{HD:DAT} has only to be met when f_{SCL} = 400 kHz. At frequencies below 400 KHz, t_{HD:DAT} may be violated as long as all other timing parameters are met.

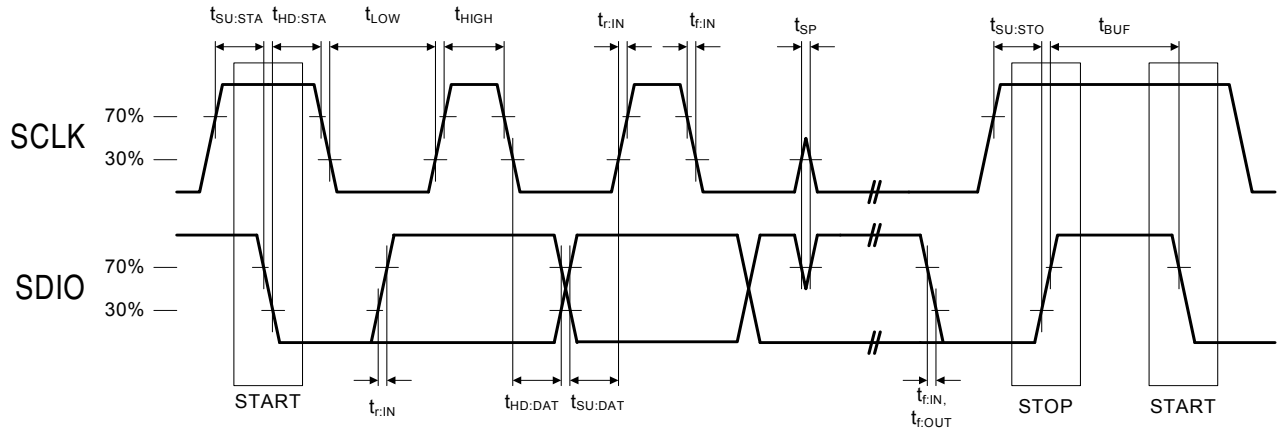


Figure 2. 2-Wire Control Interface Read and Write Timing Parameters

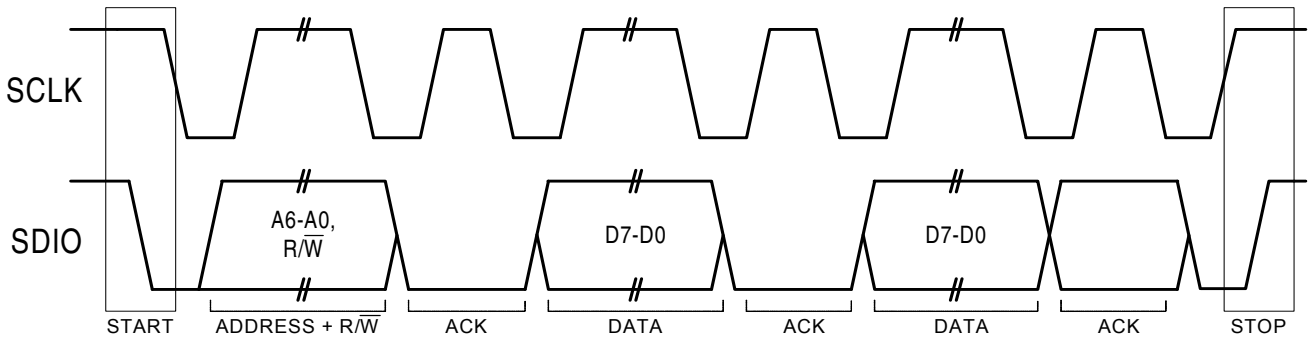


Figure 3. 2-Wire Control Interface Read and Write Timing Diagram

Table 6. 3-Wire Control Interface Characteristics

($V_{DD} = 2.7$ to 5.5 V, $V_{IO} = 1.85$ to 3.6 V, $T_A = -20$ to 85 °C)

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
SCLK Frequency	f_{CLK}		0	—	2.5	MHz
SCLK High Time	t_{HIGH}		25	—	—	ns
SCLK Low Time	t_{LOW}		25	—	—	ns
SDIO Input, \overline{SEN} to SCLK \uparrow Setup	t_S		20	—	—	ns
SDIO Input to SCLK \uparrow Hold	t_{HSDIO}		10	—	—	ns
\overline{SEN} Input to SCLK \downarrow Hold	t_{HSEN}		10	—	—	ns
SCLK \uparrow to SDIO Output Valid	t_{CDV}	Read	2	—	25	ns
SCLK \uparrow to SDIO Output High Z	t_{CDZ}	Read	2	—	25	ns
SCLK, \overline{SEN} , SDIO, Rise/Fall time	t_R, t_F		—	—	10	ns

Note: When selecting 3-wire mode, the user must ensure that a rising edge of SCLK does not occur within 300 ns before the rising edge of RST.

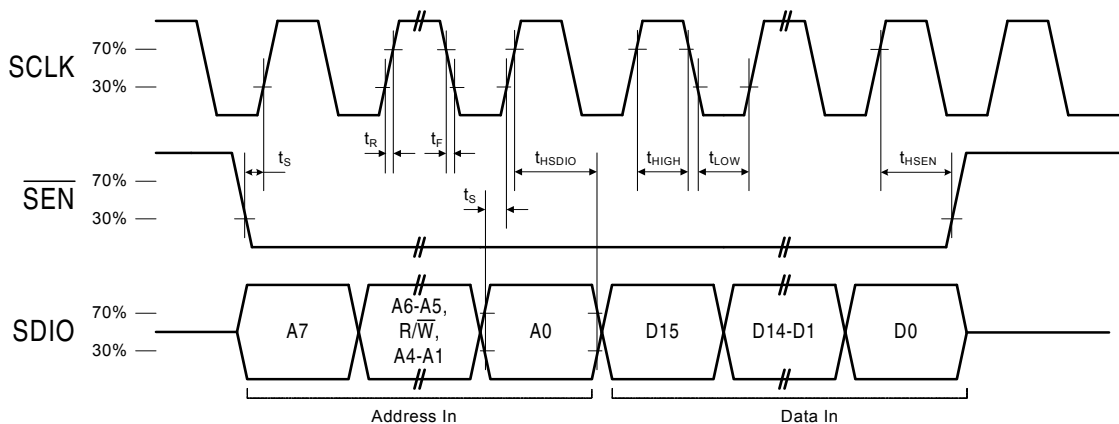


Figure 4. 3-Wire Control Interface Write Timing Parameters

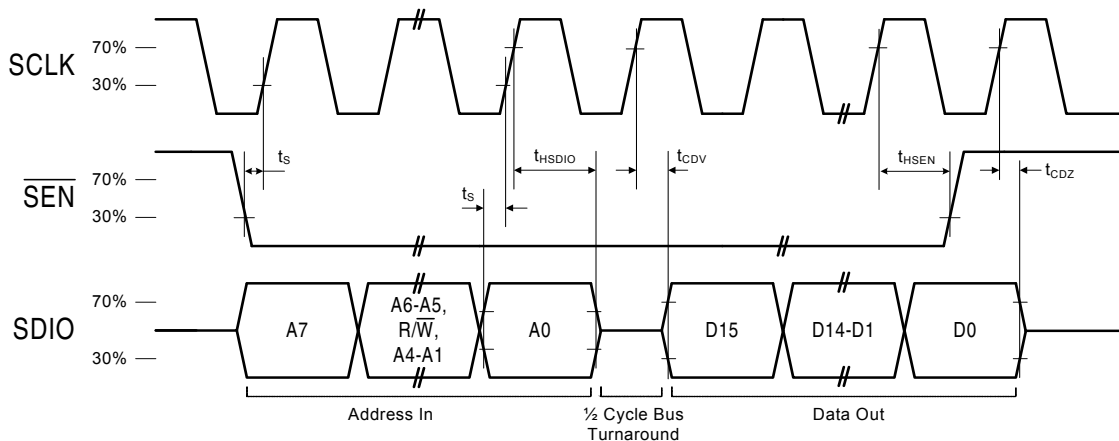


Figure 5. 3-Wire Control Interface Read Timing Parameters

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Table 7. SPI Control Interface Characteristics

($V_{DD} = 2.7$ to 5.5 V, $V_{IO} = 1.85$ to 3.6 V, $T_A = -20$ to 85 °C)

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
SCLK Frequency	f_{CLK}		0	—	2.5	MHz
SCLK High Time	t_{HIGH}		25	—	—	ns
SCLK Low Time	t_{LOW}		25	—	—	ns
SDIO Input, \overline{SEN} to SCLK \uparrow Setup	t_S		15	—	—	ns
SDIO Input to SCLK \uparrow Hold	t_{HSDIO}		10	—	—	ns
\overline{SEN} Input to SCLK \downarrow Hold	t_{HSEN}		5	—	—	ns
SCLK \downarrow to SDIO Output Valid	t_{CDV}	Read	2	—	25	ns
SCLK \downarrow to SDIO Output High Z	t_{CDZ}	Read	2	—	25	ns
SCLK, \overline{SEN} , SDIO, Rise/Fall time	t_R, t_F		—	—	10	ns

Note: When selecting SPI mode, the user must ensure that a rising edge of SCLK does not occur within 300 ns before the rising edge of RST.

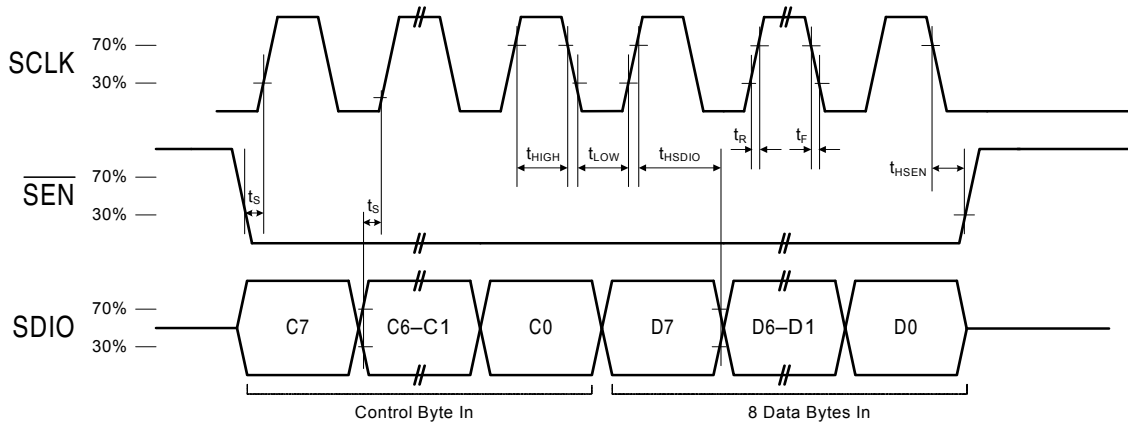


Figure 6. SPI Control Interface Write Timing Parameters

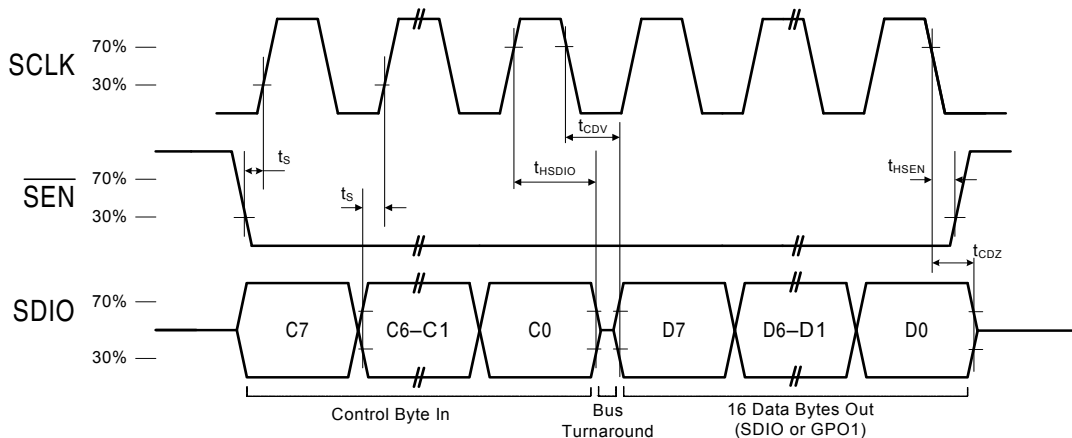
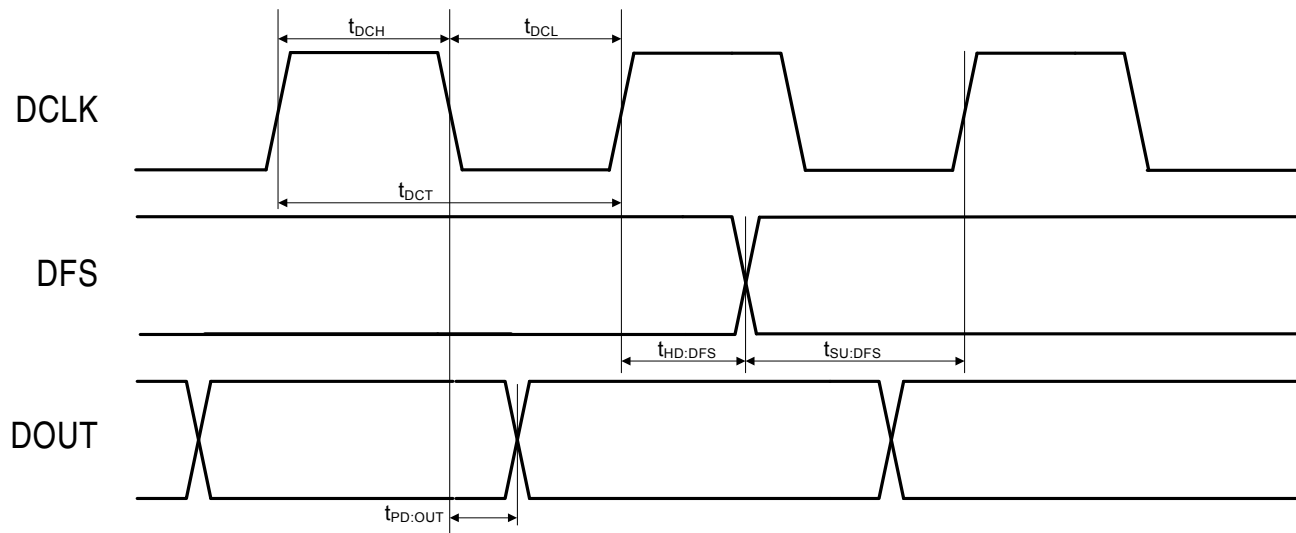


Figure 7. SPI Control Interface Read Timing Parameters

Table 8. Digital Audio Interface Characteristics $(V_{DD} = 2.7 \text{ to } 5.5 \text{ V}, V_{IO} = 1.85 \text{ to } 3.6 \text{ V}, T_A = -20 \text{ to } 85 \text{ }^\circ\text{C})$

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
DCLK Cycle Time	t_{DCT}		26	—	1000	ns
DCLK Pulse Width High	t_{DCH}		10	—	—	ns
DCLK Pulse Width Low	t_{DCL}		10	—	—	ns
DFS Set-up Time to DCLK Rising Edge	$t_{SU:DFS}$		5	—	—	ns
DFS Hold Time from DCLK Rising Edge	$t_{HD:DFS}$		5	—	—	ns
DOOUT Propagation Delay from DCLK Falling Edge	$t_{PD:DOOUT}$		0	—	12	ns

**Figure 8. Digital Audio Interface Timing Parameters, I²S Mode**

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Table 9. FM Receiver Characteristics^{1,2}

($V_{DD} = 2.7$ to 5.5 V, $V_{IO} = 1.85$ to 3.6 V, $T_A = -20$ to 85 °C)

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Input Frequency	f_{RF}		76	—	108	MHz
Sensitivity with Headphone Network ^{3,4,5}		(S+N)/N = 26 dB	—	2.2	3.5	μ V EMF
Sensitivity with 50 Ω Network ^{3,4,5,6}		(S+N)/N = 26 dB	—	1.1	—	μ V EMF
RDS Sensitivity ⁶		$\Delta f = 2$ kHz, RDS BLER < 5%	—	15	—	μ V EMF
LNA Input Resistance ^{6,7}			3	4	5	k Ω
LNA Input Capacitance ^{6,7}			4	5	6	pF
Input IP3 ^{6,8}			100	105	—	dB μ V EMF
AM Suppression ^{3,4,6,7}		m = 0.3	40	50	—	dB
Adjacent Channel Selectivity		± 200 kHz	35	50	—	dB
Alternate Channel Selectivity		± 400 kHz	60	70	—	dB
Spurious Response Rejection ⁶		In-band	35	—	—	dB
Audio Output Voltage ^{3,4,7}			72	80	90	mV _{RMS}
Audio Output L/R Imbalance ^{3,7,9}			—	—	1	dB
Audio Frequency Response Low ⁶		-3 dB	—	—	30	Hz
Audio Frequency Response High ⁶		-3 dB	15	—	—	kHz
Audio Stereo Separation ^{7,9}			32	42	—	dB
Audio Mono S/N ^{3,4,5,7,10}			55	63	—	dB
Audio Stereo S/N ^{4,5,6,7,10,11}			—	58	—	dB
Audio THD ^{3,7,9}			—	0.1	0.5	%
De-emphasis Time Constant ⁶		FM_DEEMPHASIS = 2	70	75	80	μ s
		FM_DEEMPHASIS = 1	45	50	54	μ s

Notes:

1. Additional testing information is available in "AN388: Si470x/1x/2x/3x/4x Evaluation Board Test Procedure." Volume = maximum for all tests. Tested at RF = 98.1 MHz.
2. To ensure proper operation and receiver performance, follow the guidelines in "AN383: Si47xx Antenna, Schematic, Layout, and Design Guidelines." Silicon Laboratories will evaluate schematics and layouts for qualified customers.
3. $F_{MOD} = 1$ kHz, 75 μ s de-emphasis, MONO = enabled, and L = R unless noted otherwise.
4. $\Delta f = 22.5$ kHz.
5. $B_{AF} = 300$ Hz to 15 kHz, A-weighted.
6. Guaranteed by characterization.
7. $V_{EMF} = 1$ mV.
8. $|f_2 - f_1| > 2$ MHz, $f_0 = 2 \times f_1 - f_2$. AGC is disabled.
9. $\Delta f = 75$ kHz.
10. At L_{OUT} and R_{OUT} pins.
11. Analog audio output mode.
12. Blocker Amplitude = 100 dB μ V
13. Sensitivity measured at (S+N)/N = 26 dB.
14. At temperature (25°C).

Table 9. FM Receiver Characteristics^{1,2} (Continued)(V_{DD} = 2.7 to 5.5 V, V_{IO} = 1.85 to 3.6 V, T_A = -20 to 85 °C)

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Blocking Sensitivity ^{3,4,5,6,12,13}		$\Delta f = \pm 400$ kHz	—	32	—	dB μ V
		$\Delta f = \pm 4$ MHz	—	38	—	dB μ V
Intermode Sensitivity ^{3,4,5,6,12,13}		$\Delta f = \pm 400$ kHz, ± 800 kHz	—	40	—	dB μ V
		$\Delta f = \pm 4$ MHz, ± 8 MHz	—	35	—	dB μ V
Audio Output Load Resistance ^{6,10}	R _L	Single-ended	10	—	—	k Ω
Audio Output Load Capacitance ^{6,10}	C _L	Single-ended	—	—	50	pF
Seek/Tune Time ⁶		RCLK tolerance = 100 ppm	—	—	60	ms/channel
Powerup Time ⁶		From powerdown	—	—	110	ms
RSSI Offset ¹⁴		Input levels of 8 and 60 dB μ V at RF Input	-3	—	3	dB

Notes:

1. Additional testing information is available in "AN388: Si470x/1x/2x/3x/4x Evaluation Board Test Procedure." Volume = maximum for all tests. Tested at RF = 98.1 MHz.
2. To ensure proper operation and receiver performance, follow the guidelines in "AN383: Si47xx Antenna, Schematic, Layout, and Design Guidelines." Silicon Laboratories will evaluate schematics and layouts for qualified customers.
3. F_{MOD} = 1 kHz, 75 μ s de-emphasis, MONO = enabled, and L = R unless noted otherwise.
4. $\Delta f = 22.5$ kHz.
5. B_{AF} = 300 Hz to 15 kHz, A-weighted.
6. Guaranteed by characterization.
7. V_{EMF} = 1 mV.
8. $|f_2 - f_1| > 2$ MHz, f₀ = 2 x f₁ - f₂. AGC is disabled.
9. $\Delta f = 75$ kHz.
10. At L_{OUT} and R_{OUT} pins.
11. Analog audio output mode.
12. Blocker Amplitude = 100 dB μ V
13. Sensitivity measured at (S+N)/N = 26 dB.
14. At temperature (25°C).

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Table 10. 64–75.9 MHz Input Frequency FM Receiver Characteristics^{1,2,6}

($V_{DD} = 2.7$ to 5.5 V, $V_{IO} = 1.85$ to 3.6 V, $T_A = -20$ to 85 °C)

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Input Frequency	f_{RF}		64	—	75.9	MHz
Sensitivity with Headphone Network ^{3,4,5}		(S+N)/N = 26 dB	—	4.0	—	μ V EMF
LNA Input Resistance ⁷			3	4	5	k Ω
LNA Input Capacitance ⁷			4	5	6	pF
Input IP3 ⁸			100	105	—	dB μ V EMF
AM Suppression ^{3,4,7}		m = 0.3	40	50	—	dB
Adjacent Channel Selectivity		± 200 kHz	—	50	—	dB
Alternate Channel Selectivity		± 400 kHz	—	70	—	dB
Audio Output Voltage ^{3,4,7}			72	80	90	mV _{RMS}
Audio Output L/R Imbalance ^{3,7,9}			—	—	1	dB
Audio Frequency Response Low		-3 dB	—	—	30	Hz
Audio Frequency Response High		-3 dB	15	—	—	kHz
Audio Mono S/N ^{3,4,5,7,10}			55	63	—	dB
Audio THD ^{3,7,9}			—	0.1	0.5	%
De-emphasis Time Constant		FM_DEEMPHASIS = 2	70	75	80	μ s
		FM_DEEMPHASIS = 1	45	50	54	μ s
Audio Output Load Resistance ¹⁰	R_L	Single-ended	10	—	—	k Ω
Audio Output Load Capacitance ¹⁰	C_L	Single-ended	—	—	50	pF
Seek/Tune Time		RCLK tolerance = 100 ppm	—	—	60	ms/channel
Powerup Time		From powerdown	—	—	110	ms
RSSI Offset ¹¹		Input levels of 8 and 60 dB μ V EMF	-3	—	3	dB

Notes:

1. Additional testing information is available in “AN388: Si470x/1x/2x/3x/4x Evaluation Board Test Procedure.” Volume = maximum for all tests. Tested at RF = 98.1 MHz.
2. To ensure proper operation and receiver performance, follow the guidelines in “AN383: Si47xx Antenna, Schematic, Layout, and Design Guidelines.” Silicon Laboratories will evaluate schematics and layouts for qualified customers.
3. $F_{MOD} = 1$ kHz, 75 μ s de-emphasis, MONO = enabled, and L = R unless noted otherwise.
4. $\Delta f = 22.5$ kHz.
5. $B_{AF} = 300$ Hz to 15 kHz, A-weighted.
6. Guaranteed by characterization.
7. $V_{EMF} = 1$ mV.
8. $|f_2 - f_1| > 2$ MHz, $f_0 = 2 \times f_1 - f_2$. AGC is disabled.
9. $\Delta f = 75$ kHz.
10. At L_{OUT} and R_{OUT} pins.
11. At temperature (25 °C).

Table 11. WB Receiver Characteristics¹ $(V_{DD} = 2.7$ to 5.5 V, $V_{IO} = 1.85$ to 3.6 V, $T_A = 25$ °C)

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Input Frequency	f_R		162.4	—	162.55	MHz
Sensitivity ^{2,3}		SINAD = 12 dB	—	0.9	—	μ V EMF
Adjacent Channel Selectivity		± 25 kHz	—	52	—	dB
Audio S/N ^{2,3,4,5}		Mono	—	45	—	dB
Audio Frequency Response Low ⁶		-3 dB	—	—	300	Hz
Audio Frequency Response High ⁶		-3 dB	3	—	—	kHz

Notes:

- To ensure proper operation and receiver performance, follow the guidelines in “AN383: Si47xx Antenna, Schematic, Layout, and Design Guidelines.” Silicon Laboratories will evaluate schematics and layouts for qualified customers.
- $F_{MOD} = 1$ kHz.
- $\Delta f = 3$ kHz.
- $V_{EMF} = 1$ mV.
- A-weighted.
- Guaranteed by characterization

Table 12. AM Receiver Characteristics^{1,2} $(V_{DD} = 2.7$ to 5.5 V, $V_{IO} = 1.85$ to 3.6 V, $T_A = -20$ to 85 °C)

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Input Frequency	f_{RF}		520	—	1710	kHz
Sensitivity ^{3,4,5,6}		(S+N)/N = 26 dB	—	25	35	μ V EMF
Large Signal Voltage Handling ^{4,6,7}		THD < 8%	—	300	—	mV _{RMS}
Power Supply Rejection Ratio ⁶		$\Delta V_{DD} = 100$ mV _{RMS} , 100 Hz	—	40	—	dB
Audio Output Voltage ^{3,4,8}			54	60	67	mV _{RMS}
Audio S/N ^{3,4,5,8}			50	56	—	dB
Audio THD ^{3,4,8}			—	0.1	0.5	%

Notes:

- Additional testing information is available in “AN388: Si470x/1x/2x/3x/4x Evaluation Board Test Procedure.” Volume = maximum for all tests. Tested at RF = 520 kHz.
- To ensure proper operation and receiver performance, follow the guidelines in “AN383: Si47xx Antenna, Schematic, Layout, and Design Guidelines.” Silicon Laboratories will evaluate schematics and layouts for qualified customers.
- $F_{MOD} = 1$ kHz, 30% modulation, 2 kHz channel filter.
- Analog audio output mode.
- $B_{AF} = 300$ Hz to 15 kHz, A-weighted.
- Guaranteed by characterization.
- See “AN388: Si470x/1x/2x/3x/4x Evaluation Board Test Procedure” for evaluation method.
- $V_{IN} = 5$ mV_{rms}.
- Stray capacitance on antenna and board must be < 10 pF to achieve full tuning range at higher inductance levels.

Si4736/37/38/39-C40

Table 12. AM Receiver Characteristics^{1,2} (Continued)

($V_{DD} = 2.7$ to 5.5 V, $V_{IO} = 1.85$ to 3.6 V, $T_A = -20$ to 85 °C)

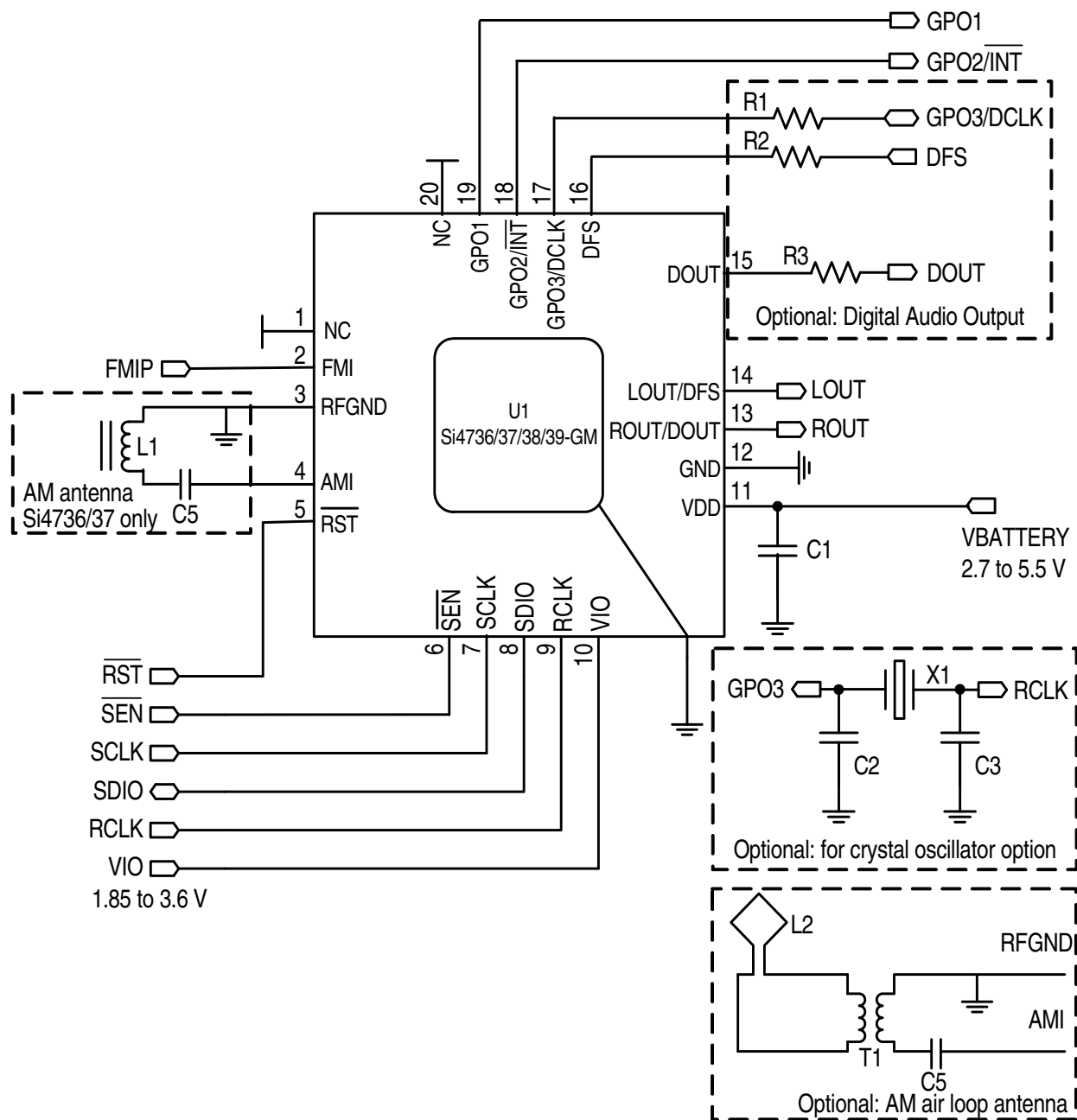
Antenna Inductance ^{6,9}			180	—	450	μH
Powerup Time ⁶		From powerdown	—	—	110	ms
Notes:						
<ol style="list-style-type: none"> Additional testing information is available in “AN388: Si470x/1x/2x/3x/4x Evaluation Board Test Procedure.” Volume = maximum for all tests. Tested at RF = 520 kHz. To ensure proper operation and receiver performance, follow the guidelines in “AN383: Si47xx Antenna, Schematic, Layout, and Design Guidelines.” Silicon Laboratories will evaluate schematics and layouts for qualified customers. FMOD = 1 kHz, 30% modulation, 2 kHz channel filter. Analog audio output mode. $B_{AF} = 300$ Hz to 15 kHz, A-weighted. Guaranteed by characterization. See “AN388: Si470x/1x/2x/3x/4x Evaluation Board Test Procedure” for evaluation method. $V_{IN} = 5$ mVrms. Stray capacitance on antenna and board must be < 10 pF to achieve full tuning range at higher inductance levels. 						

Table 13. Reference Clock and Crystal Characteristics

($V_{DD} = 2.7$ to 5.5 V, $V_{IO} = 1.85$ to 3.6 V, $T_A = -20$ to 85 °C)

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Reference Clock						
RCLK Supported Frequencies ¹			31.130	32.768	40,000	kHz
RCLK Frequency Tolerance ²			-50	—	50	ppm
REFCLK_PRESCALE			1	—	4095	
REFCLK			31.130	32.768	34.406	kHz
Crystal Oscillator						
Crystal Oscillator Frequency			—	32.768	—	kHz
Crystal Frequency Tolerance ²			-50	—	50	ppm
Board Capacitance			—	—	3.5	pF
Notes:						
<ol style="list-style-type: none"> The Si4736/37/38/39 divides the RCLK input by REFCLK_PRESCALE to obtain REFCLK. There are some RCLK frequencies between 31.130 kHz and 40 MHz that are not supported. For more details, see Table 6 of “AN332: Si47xx Programming Guide”. A frequency tolerance of ±50 ppm is required for FM seek/tune using 50 kHz channel spacing and WB tune. 						

2. Typical Application Schematic (QFN)

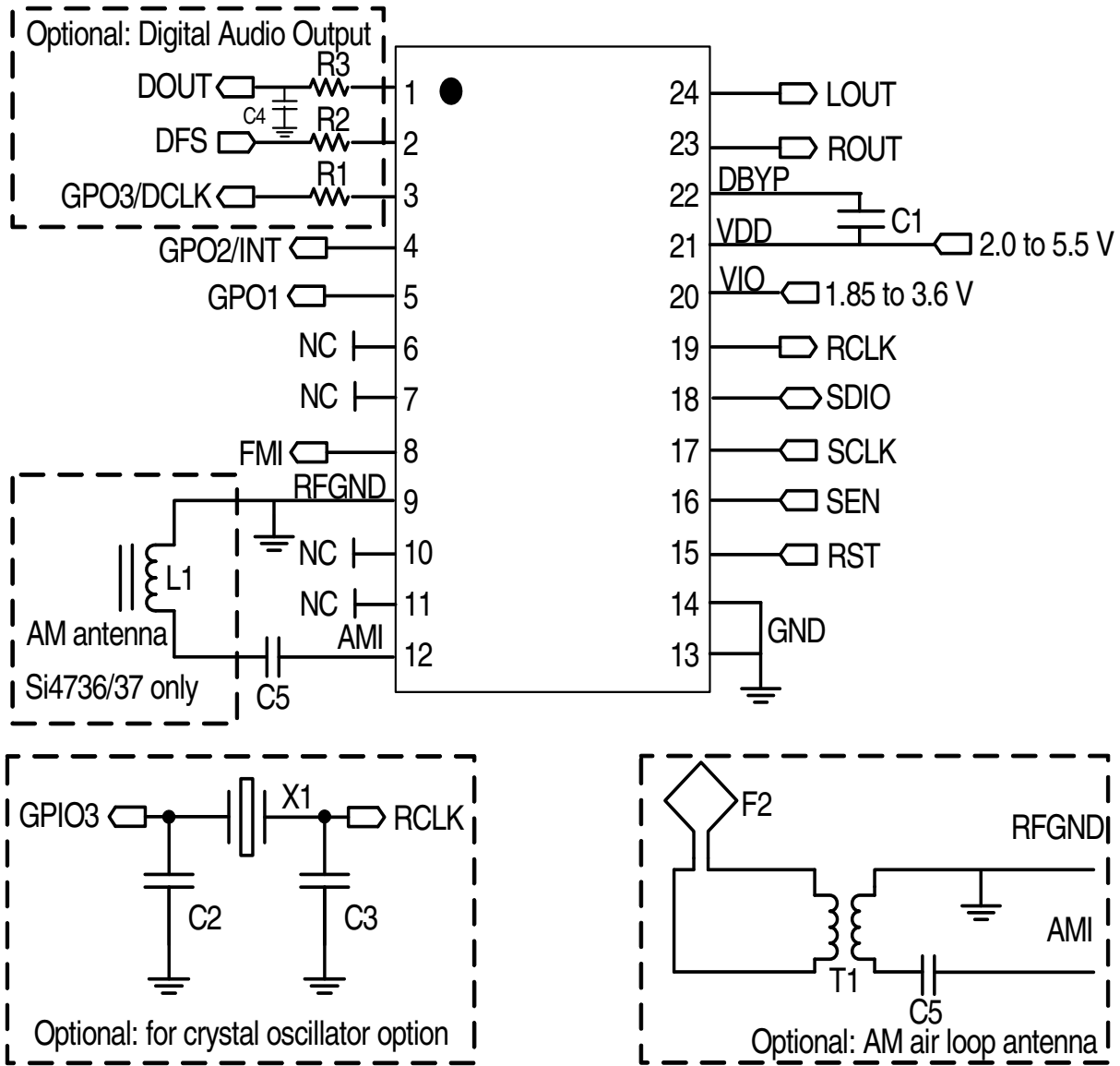


Notes:

1. Place C1 close to V_{DD} pin.
2. All grounds connect directly to GND plane on PCB.
3. Pins 1 and 20 are no connects, leave floating.
4. To ensure proper operation and receiver performance, follow the guidelines in “AN383: Si47xx Antenna, Schematic, Layout, and Design Guidelines.” Silicon Laboratories will evaluate schematics and layouts for qualified customers.
5. Pin 2 connects to the FM antenna interface, and pin 4 connects to the AM antenna interface.
6. Place Si4736/37/38/39 as close as possible to antenna and keep the FMI and AMI traces as short as possible.

Si4736/37/38/39-C40

3. Typical Application Schematic (SSOP)



Notes:

1. Place C1 close to V_{DD} and DBYP pins.
2. All grounds connect directly to GND plane on PCB.
3. Pins 6 and 7 are no connects, leave floating.
4. Pins 10 and 11 are unused. Tie these pins to GND.
5. To ensure proper operation and receiver performance, follow the guidelines in "AN383: Si47xx Antenna, Schematic, Layout, and Design Guidelines." Silicon Laboratories will evaluate schematics and layouts for qualified customers.
6. Pin 8 connects to the FM antenna interface, and pin 12 connects to the AM antenna interface.
7. Place Si4736/37/38/39 as close as possible to antenna and keep the FMI and AMI traces as short as possible.

4. Bill of Materials (QFN/SSOP)

Component(s)	Value/Description	Supplier
C1	Supply bypass capacitor, 22 nF, $\pm 20\%$, Z5U/X7R	Murata
C5	Coupling capacitor, 0.47 μF , $\pm 20\%$, Z5U/X7R	Murata
L1	Ferrite loop stick, 180–450 μH	Jiaxin
U1	Si4736/37/38/39 AM/FM Radio Tuner	Silicon Laboratories
Optional Components		
T1	Transformer, 1–5 turns ratio	Jiaxin, UMEC
L2	Air loop antenna, 10–20 μH	Various
C2, C3	Crystal load capacitors, 22 pF, $\pm 5\%$, COG (Optional for crystal oscillator option)	Venkel
C4	Noise mitigating capacitor, 2~5 pF (Optional for digital audio)	Murata
X1	32.768 kHz crystal (Optional for crystal oscillator option)	Epson
R1	Resistor, 2 k Ω (Optional for digital audio)	Venkel
R2	Resistor, 2 k Ω (Optional for digital audio)	Venkel
R3	Resistor, 600 Ω (Optional for digital audio)	Venkel

5. Functional Description

5.1. Overview

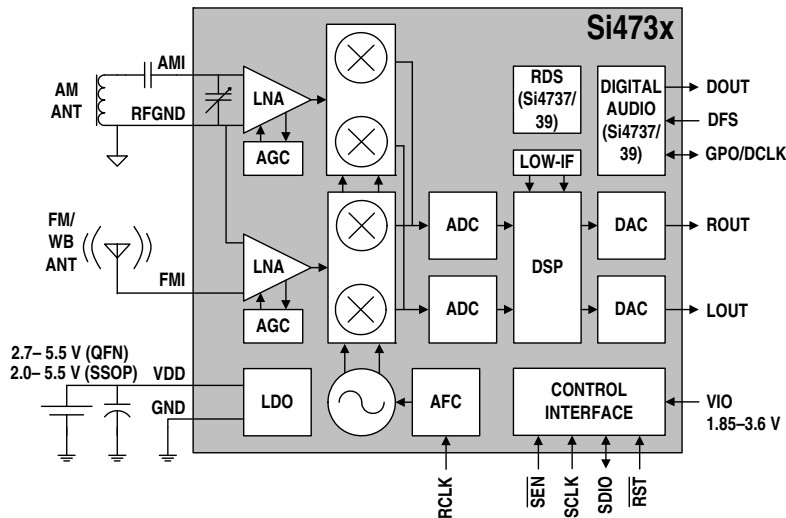


Figure 9. Functional Block Diagram

The Si4736/37 and Si4738/39 are the industry's first fully integrated, 100% CMOS AM/FM/WB and FM/WB radio receiver ICs. Offering unmatched integration and PCB space savings, the Si4736/37/38/39 requires only two external components and less than 15 mm² of board area, excluding the antenna inputs. The Si4736/37/38/39 AM/FM/WB radio provides the space savings and low power consumption necessary for portable devices while delivering the high performance and design simplicity desired for all AM/FM/WB solutions.

Leveraging Silicon Laboratories' proven and patented Si4700/01 FM tuner's digital low intermediate frequency (low-IF) receiver architecture, the Si4736/37/38/39 delivers superior RF performance and interference rejection in both AM and FM bands. The high integration and complete system production test simplifies design-in, increases system quality, and improves manufacturability.

The Si4736/37/38/39 is a feature-rich solution including 1050 Hz tone detection, advanced seek algorithms, soft mute, auto-calibrated digital tuning, and FM stereo processing. In addition, the Si4736/37/38/39 provides analog and digital audio outputs and a programmable reference clock. The device supports I²C-compatible, 2-wire control interface, SPI, and a Si4700/01 backwards-compatible, 3-wire control interface.

The Si4736/37/38/39 utilizes digital processing to achieve high fidelity, optimal performance, and design flexibility. The chip provides excellent pilot rejection, selectivity, and unmatched audio performance, and

offers both the manufacturer and the end-user extensive programmability and flexibility in listening experience.

The Si4737/39 incorporates a digital processor for the European Radio Data System (RDS) and the North American Radio Broadcast Data System (RBDS), and includes all required symbol decoding, block synchronization, error detection, and error correction functions. Using this feature, the Si4737/39 enables broadcast data such as station identification and song name to be displayed to the user.

5.2. Operating Modes

The Si4736/37/38/39 operates in an FM receive, an AM receive, or a weather band receive mode. In FM mode and WB mode, radio signals are received on FMI and processed by the FM front-end circuitry. In AM mode, radio signals are received on AMI and processed by the AM front-end circuitry. In addition to the receiver mode, there is a clocking mode to choose to clock the Si4736/37/38/39 from a reference clock or crystal. On the Si4731, there is an audio output mode to choose between an analog and/or digital audio output. In the analog audio output mode, ROUT and LOUT are used for the audio output pins. In the digital audio mode, DOUT, DFS, and DCLK pins are used. Concurrent analog/digital audio output mode is also available requiring all five pins. The receiver mode and the audio output mode are set by the POWER_UP command listed in Table 15, "Selected Si473x Commands," on page 27.

5.3. FM Receiver

The Si4736/37/38/39 FM receiver is based on the proven Si4700/01 FM tuner. The receiver uses a digital low-IF architecture allowing the elimination of external components and factory adjustments. The Si4736/37/38/39 integrates a low noise amplifier (LNA) supporting the worldwide FM broadcast band (64 to 108 MHz). An AGC circuit controls the gain of the LNA to optimize sensitivity and rejection of strong interferers. An image-reject mixer downconverts the RF signal to low-IF. The quadrature mixer output is amplified, filtered, and digitized with high resolution analog-to-digital converters (ADCs). This advanced architecture allows the Si4736/37/38/39 to perform channel selection, FM demodulation, and stereo audio processing to achieve superior performance compared to traditional analog architectures.

5.4. AM Receiver

The highly-integrated Si4736/37/38/39 supports worldwide AM band reception from 520 to 1710 kHz using a digital low-IF architecture with a minimum number of external components and no manual alignment required. This digital low-IF architecture allows for high-precision filtering offering excellent selectivity and SNR with minimum variation across the AM band. The DSP also provides adjustable channel step sizes in 1 kHz increments, AM demodulation, soft mute, seven different channel bandwidth filters, and additional features, such as a programmable automatic volume control (AVC) maximum gain allowing users to adjust the level of background noise. Similar to the FM receiver, the integrated LNA and AGC optimize sensitivity and rejection of strong interferers allowing better reception of weak stations.

The Si4736/37/38/39 provides highly-accurate digital AM tuning without factory adjustments. To offer maximum flexibility, the receiver supports a wide range of ferrite loop sticks from 180–450 μH . An air loop antenna is supported by using a transformer to increase the effective inductance from the air loop. Using a 1:5 turn ratio inductor, the inductance is increased by 25 times and easily supports all typical AM air loop antennas which generally vary between 10 and 20 μH .

5.5. Weather Band Receiver

The Si4736/37/38/39 supports weather band reception from 162.4 to 162.55 MHz. The highly integrated Si4736/37/38/39 meets NOAA specification, receives all seven NOAA specified frequencies, implements narrow-band FM de-emphasis, and supports 1050 Hz alert tone detection. In addition, the Si4736/37/38/39 provides advanced features not available on conventional radios, such as an AFC and a dynamic channel bandwidth filter.

The AFC locks on to the strongest signal within a narrow, adjustable frequency range to compensate for any potential frequency errors such as crystal tolerance or transmit frequency errors. The AFC ensures the channel filter is always centered on the desired channel providing optimal reception. The dynamic channel bandwidth feature utilizes a wide filter in strong signal conditions to provide best sound quality and a narrower filter in weak conditions to provide best sensitivity.

5.6. Digital Audio Interface (Si4737/39 Only)

The digital audio interface operates in slave mode and supports three different audio data formats:

- I²S
- Left-Justified
- DSP Mode

5.6.1. Audio Data Formats

In I²S mode, by default the MSB is captured on the second rising edge of DCLK following each DFS transition. The remaining bits of the word are sent in order, down to the LSB. The left channel is transferred first when the DFS is low, and the right channel is transferred when the DFS is high.

In Left-Justified mode, by default the MSB is captured on the first rising edge of DCLK following each DFS transition. The remaining bits of the word are sent in order, down to the LSB. The left channel is transferred first when the DFS is high, and the right channel is transferred when the DFS is low.

In DSP mode, the DFS becomes a pulse with a width of 1DCLK period. The left channel is transferred first, followed right away by the right channel. There are two options in transferring the digital audio data in DSP mode: the MSB of the left channel can be transferred on the first rising edge of DCLK following the DFS pulse or on the second rising edge.

In all audio formats, depending on the word size, DCLK frequency and sample rates, there may be unused DCLK cycles after the LSB of each word before the next DFS transition and MSB of the next word. In addition, if preferred, the user can configure the MSB to be captured on the falling edge of DCLK via properties.

The number of audio bits can be configured for 8, 16, 20, or 24 bits.

5.6.2. Audio Sample Rates

The device supports a number of industry-standard sampling rates including 32, 40, 44.1, and 48 kHz. The digital audio interface enables low-power operation by eliminating the need for redundant DACs on the audio baseband processor.

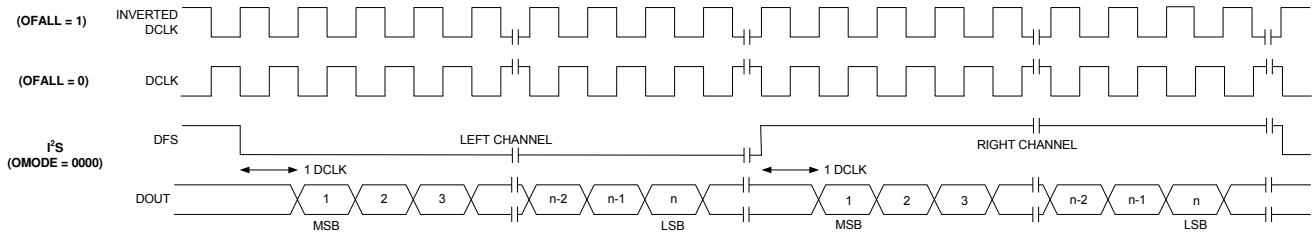


Figure 10. I²S Digital Audio Format

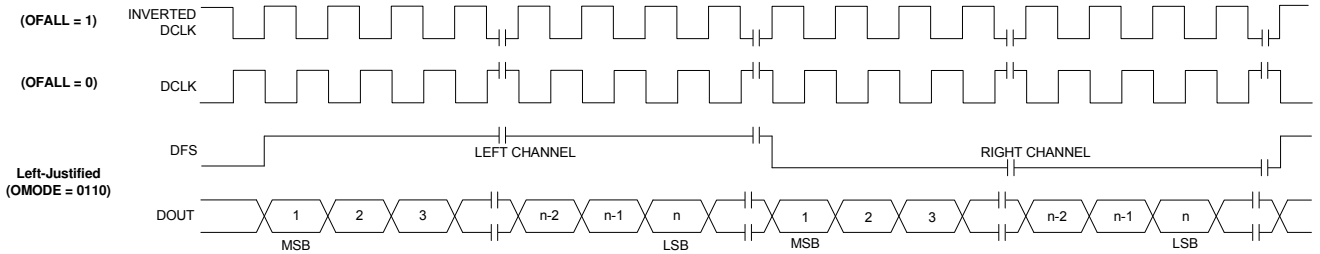


Figure 11. Left-Justified Digital Audio Format

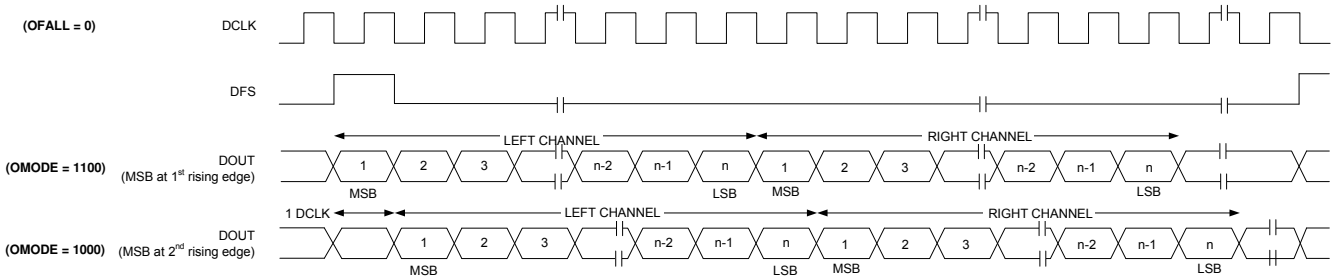


Figure 12. DSP Digital Audio Format

5.7. Stereo Audio Processing

The output of the FM demodulator is a stereo multiplexed (MPX) signal. The MPX standard was developed in 1961, and is used worldwide. Today's MPX signal format consists of left + right (L+R) audio, left – right (L–R) audio, a 19 kHz pilot tone, and RDS/RBDS data as shown in Figure 13 below.

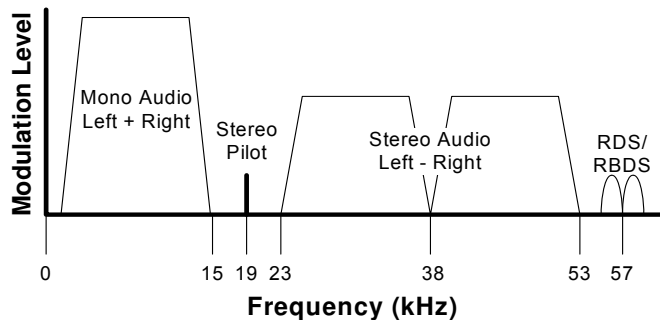


Figure 13. MPX Signal Spectrum

5.7.1. Stereo Decoder

The Si4736/37/38/39's integrated stereo decoder automatically decodes the MPX signal using DSP techniques. The 0 to 15 kHz (L+R) signal is the mono output of the FM tuner. Stereo is generated from the (L+R), (L–R), and a 19 kHz pilot tone. The pilot tone is used as a reference to recover the (L–R) signal. Output left and right channels are obtained by adding and subtracting the (L+R) and (L–R) signals respectively. The Si4731 uses frequency information from the 19 kHz stereo pilot to recover the 57 kHz RDS/RBDS signal.

5.7.2. Stereo-Mono Blending

Adaptive noise suppression is employed to gradually combine the stereo left and right audio channels to a mono (L+R) audio signal as the signal quality degrades to maintain optimum sound fidelity under varying reception conditions. Stereo/mono status can be monitored with the FM_RSQ_STATUS command. Mono operation can be forced with the FM_BLEND_MONO_THRESHOLD property.

5.8. De-emphasis

Pre-emphasis and de-emphasis is a technique used by FM broadcasters to improve the signal-to-noise ratio of FM receivers by reducing the effects of high-frequency interference and noise. When the FM signal is transmitted, a pre-emphasis filter is applied to accentuate the high audio frequencies. The Si4736/37/38/39 incorporates a de-emphasis filter which attenuates high frequencies to restore a flat frequency response. Two time constants are used in various regions. The de-emphasis time constant is programmable to 50 or 75 μ s and is set by the FM_DEEMPHASIS property.

5.9. Stereo DAC

High-fidelity stereo digital-to-analog converters (DACs) drive analog audio signals onto the LOUT and ROUT pins. The audio output may be muted. Volume is adjusted digitally with the RX_VOLUME property.

5.10. Soft Mute

The soft mute feature is available to attenuate the audio outputs and minimize audible noise in very weak signal conditions. The softmute attenuation level is adjustable using the FM_SOFT_MUTE_MAX_ATTENUATION and AM_SOFT_MUTE_MAX_ATTENUATION properties.

5.11. RDS/RBDS Processor (Si4737/39 Only)

The Si4737/39 implements an RDS/RBDS* processor for symbol decoding, block synchronization, error detection, and error correction.

The Si4737/39 device is user configurable and provides an optional interrupt when RDS is synchronized, loses synchronization, and/or the user configurable RDS FIFO threshold has been met.

The Si4737/39 reports RDS decoder synchronization status and detailed bit errors in the information word for each RDS block with the FM_RDS_STATUS command. The range of reportable block errors is 0, 1–2, 3–5, or 6+. More than six errors indicates that the corresponding block information word contains six or more non-correctable errors or that the block checksum contains errors.

*Note: RDS/RBDS is referred to only as RDS throughout the remainder of this document.

5.12. Tuning

The tuning frequency is directly programmed using the FM_TUNE_FREQ, WB_TUNE_FREQ, and AM_TUNE_FREQ commands. The Si4736/37/38/39 supports channel spacing steps of 10 kHz in FM mode, 25 kHz in WB mode, and 1 kHz in AM mode.

5.13. Seek

Seek tuning will search up or down for a valid channel. Valid channels are found when the receive signal strength indicator (RSSI) and the signal-to-noise ratio (SNR) values exceed the set threshold. Using the SNR qualifier rather than solely relying on the more traditional RSSI qualifier can reduce false stops and increase the number of valid stations detected. Seek is initiated using the FM_SEEK_START and AM_SEEK_START commands. The RSSI and SNR threshold settings are adjustable using properties (see Table 16).

5.14. Reference Clock

The Si4736/37/38/39 reference clock is programmable, supporting RCLK frequencies in Table 13. Refer to Table 3, "DC Characteristics," on page 5 for switching voltage levels and Table 9, "FM Receiver Characteristics," on page 12 for frequency tolerance information.

An onboard crystal oscillator is available to generate the 32.768 kHz reference when an external crystal and load capacitors are provided. Refer to "2. Typical Application Schematic (QFN)" on page 17. This mode is enabled using the POWER_UP command. Refer to Table 15, "Selected Si473x Commands," on page 27.

The Si4736/37/38/39 performance may be affected by data activity on the SDIO bus when using the integrated internal oscillator. SDIO activity results from polling the tuner for status or communicating with other devices that share the SDIO bus. If there is SDIO bus activity while the Si4736/37/38/39 is performing the seek/tune function, the crystal oscillator may experience jitter, which may result in mistunes, false stops, and/or lower SNR.

For best seek/tune results, Silicon Laboratories recommends that all SDIO data traffic be suspended during Si4736/37/38/39 seek and tune operations. This is achieved by keeping the bus quiet for all other devices on the bus, and delaying tuner polling until the tune or seek operation is complete. The seek/tune complete (STC) interrupt should be used instead of polling to determine when a seek/tune operation is complete.

5.15. Control Interface

A serial port slave interface is provided, which allows an external controller to send commands to the Si4736/37/38/39 and receive responses from the device. The serial port can operate in three bus modes: 2-wire mode, 3-wire mode, or SPI mode. The Si4736/37/38/39 selects the bus mode by sampling the state of the GPO1 and GPO2 pins on the rising edge of

$\overline{\text{RST}}$. The GPO1 pin includes an internal pull-up resistor, which is connected while $\overline{\text{RST}}$ is low, and the GPO2 pin includes an internal pull-down resistor, which is connected while $\overline{\text{RST}}$ is low. Therefore, it is only necessary for the user to actively drive pins which differ from these states. See Table 14.

Table 14. Bus Mode Select on Rising Edge of $\overline{\text{RST}}$

Bus Mode	GPO1	GPO2
2-Wire	1	0
SPI	1	1 (must drive)
3-Wire	0 (must drive)	0

After the rising edge of $\overline{\text{RST}}$, the pins GPO1 and GPO2 are used as general purpose output (O) pins, as described in Section "5.16. GPO Outputs". In any bus mode, commands may only be sent after V_{IO} and V_{DD} supplies are applied.

In any bus mode, before sending a command or reading a response, the user must first read the status byte to ensure that the device is ready (CTS bit is high).

5.15.1. 2-Wire Control Interface Mode

When selecting 2-wire mode, the user must ensure that SCLK is high during the rising edge of $\overline{\text{RST}}$, and stays high until after the first start condition. Also, a start condition must not occur within 300 ns before the rising edge of $\overline{\text{RST}}$.

The 2-wire bus mode uses only the SCLK and SDIO pins for signaling. A transaction begins with the START condition, which occurs when SDIO falls while SCLK is high. Next, the user drives an 8-bit control word serially on SDIO, which is captured by the device on rising edges of SCLK. The control word consists of a 7-bit device address, followed by a read/write bit (read = 1, write = 0). The Si4736/37/38/39 acknowledges the control word by driving SDIO low on the next falling edge of SCLK.

Although the Si4736/37/38/39 will respond to only a single device address, this address can be changed with the $\overline{\text{SEN}}$ pin (note that the $\overline{\text{SEN}}$ pin is not used for signaling in 2-wire mode). When $\overline{\text{SEN}} = 0$, the 7-bit device address is 0010001b. When $\overline{\text{SEN}} = 1$, the address is 1100011b.

For write operations, the user then sends an 8-bit data byte on SDIO, which is captured by the device on rising edges of SCLK. The Si4736/37/38/39 acknowledges each data byte by driving SDIO low for one cycle, on the next falling edge of SCLK. The user may write up to 8 data bytes in a single 2-wire transaction. The first byte is a command, and the next seven bytes are arguments.

For read operations, after the Si4736/37/38/39 has acknowledged the control byte, it will drive an 8-bit data byte on SDIO, changing the state of SDIO on the falling edge of SCLK. The user acknowledges each data byte by driving SDIO low for one cycle, on the next falling edge of SCLK. If a data byte is not acknowledged, the transaction will end. The user may read up to 16 data bytes in a single 2-wire transaction. These bytes contain the response data from the Si4736/37/38/39.

A 2-wire transaction ends with the STOP condition, which occurs when SDIO rises while SCLK is high.

For details on timing specifications and diagrams, refer to Table 5, “2-Wire Control Interface Characteristics” on page 7; Figure 2, “2-Wire Control Interface Read and Write Timing Parameters,” on page 8, and Figure 3, “2-Wire Control Interface Read and Write Timing Diagram,” on page 8.

5.15.2. 3-Wire Control Interface Mode

When selecting 3-wire mode, the user must ensure that a rising edge of SCLK does not occur within 300 ns before the rising edge of $\overline{\text{RST}}$.

The 3-wire bus mode uses the SCLK, SDIO, and $\overline{\text{SEN}}$ pins. A transaction begins when the user drives $\overline{\text{SEN}}$ low. Next, the user drives a 9-bit control word on SDIO, which is captured by the device on rising edges of SCLK. The control word consists of a 9-bit device address (A7:A5 = 101b), a read/write bit (read = 1, write = 0), and a 5-bit register address (A4:A0).

For write operations, the control word is followed by a 16-bit data word, which is captured by the device on rising edges of SCLK.

For read operations, the control word is followed by a delay of one-half SCLK cycle for bus turn-around. Next, the Si4736/37/38/39 will drive the 16-bit read data word serially on SDIO, changing the state of SDIO on each rising edge of SCLK.

A transaction ends when the user sets $\overline{\text{SEN}}$ high, then pulses SCLK high and low one final time. SCLK may either stop or continue to toggle while $\overline{\text{SEN}}$ is high.

In 3-wire mode, commands are sent by first writing each argument to register(s) 0xA1–0xA3, then writing the command word to register 0xA0. A response is retrieved by reading registers 0xA8–0xAF.

For details on timing specifications and diagrams, refer to Table 6, “3-Wire Control Interface Characteristics,” on page 9; Figure 4, “3-Wire Control Interface Write Timing Parameters,” on page 9, and Figure 5, “3-Wire Control Interface Read Timing Parameters,” on page 9.

5.15.3. SPI Control Interface Mode

When selecting SPI mode, the user must ensure that a rising edge of SCLK does not occur within 300 ns before the rising edge of $\overline{\text{RST}}$.

SPI bus mode uses the SCLK, SDIO, and $\overline{\text{SEN}}$ pins for read/write operations. The system controller can choose to receive read data from the device on either SDIO or GPO1. A transaction begins when the system controller drives $\overline{\text{SEN}} = 0$. The system controller then pulses SCLK eight times, while driving an 8-bit control byte serially on SDIO. The device captures the data on rising edges of SCLK. The control byte must have one of five values:

- 0x48 = write a command (controller drives 8 additional bytes on SDIO).
- 0x80 = read a response (device drives 1 additional byte on SDIO).
- 0xC0 = read a response (device drives 16 additional bytes on SDIO).
- 0xA0 = read a response (device drives 1 additional byte on GPO1).
- 0xE0 = read a response (device drives 16 additional bytes on GPO1).

For write operations, the system controller must drive exactly 8 data bytes (a command and seven arguments) on SDIO after the control byte. The data is captured by the device on the rising edge of SCLK.

For read operations, the controller must read exactly 1 byte (STATUS) after the control byte or exactly 16 data bytes (STATUS and RESP1–RESP15) after the control byte. The device changes the state of SDIO (or GPO1, if specified) on the falling edge of SCLK. Data must be captured by the system controller on the rising edge of SCLK.

Keep $\overline{\text{SEN}}$ low until all bytes have transferred. A transaction may be aborted at any time by setting $\overline{\text{SEN}}$ high and toggling SCLK high and then low. Commands will be ignored by the device if the transaction is aborted.

For details on timing specifications and diagrams, refer to Figure 6 and Figure 7 on page 10.

5.16. GPO Outputs

The Si4736/37/38/39 provides three general-purpose output pins. The GPO pins can be configured to output a constant low, constant high, or high-impedance. The GPO pins can be reconfigured as specialized functions. GPO2/INT can be configured to provide interrupts and GPO3 can be configured to provide external crystal support or as DCLK in digital audio output mode.