

DATA SHEET



SAA7377

Digital servo processor and
Compact Disc decoder (CD7)

Product specifications
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Digital servo processor and Compact Disc decoder (CD7)

SAA7377

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1 FEATURES

- Single-speed mode
- Full error correction strategy, $t = 2$ and $e = 4$
- Full CD graphics interface
- All standard decoder functions implemented digitally on chip
- FIFO overflow concealment for rotational shock resistance
- Digital audio interface (EBU), audio only
- 2 and 4 times oversampling integrated digital filter, including f_s mode
- Audio data peak level detection
- Kill interface for DAC deactivation during digital silence
- All TDA1301 (DSIC2) digital servo functions, plus extra high-level functions
- Low focus noise
- Improved playability on ABEX TCD-721R, TCD-725 and TCD-714 discs
- Automatic closed loop gain control available for focus and radial loops
- Pulsed sledge support
- Microcontroller loading LOW
- High-level servo control option
- High-level mechanism monitor
- Communication may be via TDA1301/SAA7345 compatible bus or I²C-bus
- On-chip clock multiplier allows the use of 8.4672 MHz crystal.

2 GENERAL DESCRIPTION

The SAA7377 is a single chip combining the functions of a CD decoder IC and digital servo IC. The decoder part is based on the SAA7345 (CD6) with an improved error correction strategy. The servo part is based on the TDA1301T (DSIC2) with improvements incorporated, extra features have also been added.

Supply of this Compact Disc IC does not convey an implied license under any patent right to use this IC in any Compact Disc application.

3 QUICK REFERENCE DATA

| SYMBOL | PARAMETER | CONDITIONS | MIN. | TYP. | MAX. | UNIT |
|------------|-------------------------------|------------|------|--------|------|------|
| V_{DD} | supply voltage | | 3.4 | 5.0 | 5.5 | V |
| I_{DD} | supply current | | – | 49 | – | mA |
| f_{xtal} | crystal frequency | | 8 | 8.4672 | 35 | MHz |
| T_{amb} | operating ambient temperature | | –40 | – | +85 | °C |
| T_{stg} | storage temperature | | –55 | – | +125 | °C |

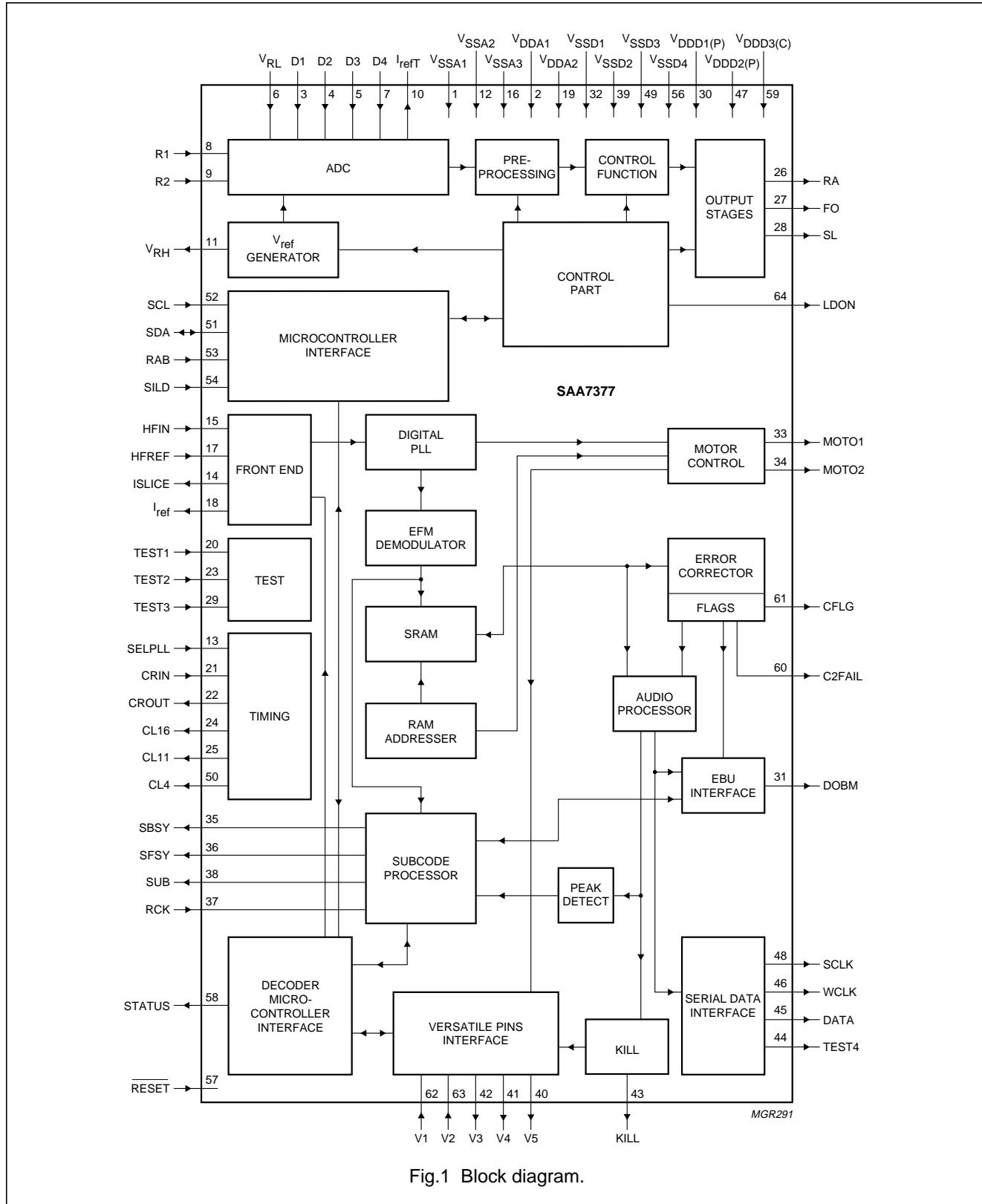
4 ORDERING INFORMATION

| TYPE NUMBER | PACKAGE | | |
|----------------|---------|--|----------|
| | NAME | DESCRIPTION | VERSION |
| SAA7377GP | QFP64 | plastic quad flat package; 64 leads (lead length 1.6 mm); body 14 × 14 × 2.7 mm | SOT393-1 |

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5 BLOCK DIAGRAM



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6 PINNING

| SYMBOL | PIN | DESCRIPTION |
|---------------|-------------------|--|
| V_{SSA1} | 1 ⁽¹⁾ | analog ground 1 |
| V_{DDA1} | 2 ⁽¹⁾ | analog supply voltage 1 |
| D1 | 3 | unipolar current input (central diode signal input) |
| D2 | 4 | unipolar current input (central diode signal input) |
| D3 | 5 | unipolar current input (central diode signal input) |
| V_{RL} | 6 | reference voltage input for ADC |
| D4 | 7 | unipolar current input (central diode signal input) |
| R1 | 8 | unipolar current input (satellite diode signal input) |
| R2 | 9 | unipolar current input (satellite diode signal input) |
| I_{refT} | 10 | current reference output for ADC calibration |
| V_{RH} | 11 | reference voltage output from ADC |
| V_{SSA2} | 12 ⁽¹⁾ | analog ground 2 |
| SELPLL | 13 | selects whether internal clock multiplier PLL is used |
| ISLICE | 14 | current feedback output from data slicer |
| HFIN | 15 | comparator signal input |
| V_{SSA3} | 16 ⁽¹⁾ | analog ground 3 |
| HFREF | 17 | comparator common mode input |
| I_{ref} | 18 | reference current output pin (nominally 0.5V _{DD}) |
| V_{DDA2} | 19 ⁽¹⁾ | analog supply voltage 2 |
| TEST1 | 20 | test control input 1; this pin should be tied LOW |
| CRIN | 21 | crystal/resonator input |
| CROUT | 22 | crystal/resonator output |
| TEST2 | 23 | test control input 2; this pin should be tied LOW |
| CL16 | 24 | 16.9344 MHz system clock output |
| CL11 | 25 | 11.2896 or 5.6448 MHz clock output (3-state) |
| RA | 26 | radial actuator output |
| FO | 27 | focus actuator output |
| SL | 28 | sledge control output |
| TEST3 | 29 | test control input 3; this pin should be tied LOW |
| $V_{DDD1(P)}$ | 30 ⁽¹⁾ | digital supply voltage 1 for periphery |
| DOBM | 31 | bi-phase mark output (externally buffered; 3-state) |
| V_{SSD1} | 32 ⁽¹⁾ | digital ground 1 |
| MOTO1 | 33 | motor output 1; versatile (3-state) |
| MOTO2 | 34 | motor output 2; versatile (3-state) |
| SBSY | 35 | subcode block sync output (3-state) |
| SFSY | 36 | subcode frame sync output (3-state) |
| RCK | 37 | subcode clock input |
| SUB | 38 | P-to-W subcode output bits (3-state) |
| V_{SSD2} | 39 ⁽¹⁾ | digital ground 2 |
| V5 | 40 | versatile output pin 5 |

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| SYMBOL | PIN | DESCRIPTION |
|----------------------|-------------------|---|
| V4 | 41 | versatile output pin 4 |
| V3 | 42 | versatile output pin 3 (open-drain) |
| KILL | 43 | kill output (programmable; open-drain) |
| TEST4 | 44 | test output pin; this pin should be left unconnected |
| DATA | 45 | serial data output (3-state) |
| WCLK | 46 | word clock output (3-state) |
| V _{DDD2(P)} | 47 ⁽¹⁾ | digital supply voltage 2 for periphery |
| SCLK | 48 | serial bit clock output (3-state) |
| V _{SSD3} | 49 ⁽¹⁾ | digital ground 3 |
| CL4 | 50 | 4.2336 MHz microcontroller clock output |
| SDA | 51 | microcontroller interface data I/O line (open-drain output) |
| SCL | 52 | microcontroller interface clock line input |
| RAB | 53 | microcontroller interface R/W and load control line input (4-wire bus mode) |
| SILD | 54 | microcontroller interface R/W and load control line input (4-wire-bus mode) |
| n.c. | 55 | not connected |
| V _{SSD4} | 56 ⁽¹⁾ | digital ground 4 |
| RESET | 57 | power-on reset input (active LOW) |
| STATUS | 58 | servo interrupt request line/decoder status register output (open-drain) |
| V _{DDD3(C)} | 59 ⁽¹⁾ | digital supply voltage 3 for core |
| C2FAIL | 60 | indication of correction failure output (open-drain) |
| CFLG | 61 | correction flag output (open-drain) |
| V1 | 62 | versatile input pin 1 |
| V2 | 63 | versatile input pin 2 |
| LDON | 64 | laser drive on output (open-drain) |

Note

1. All supply pins must be connected to the same external power supply voltage.

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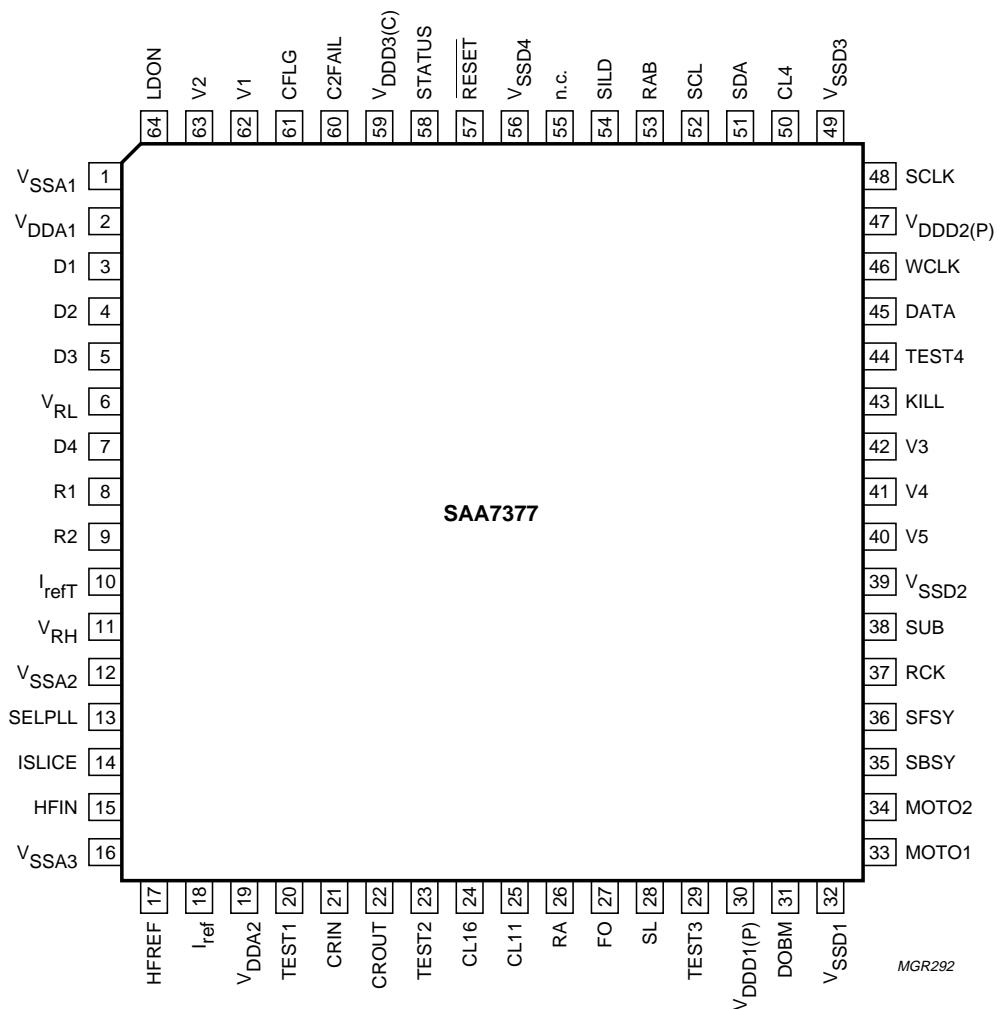


Fig.2 Pin configuration.

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7 FUNCTIONAL DESCRIPTION

7.1 Decoder part

7.1.1 PRINCIPLE OPERATIONAL MODES OF THE DECODER

The decoding part operates at single-speed and supports a full audio specification.

A simplified data flow through the decoder part is illustrated in Fig.6.

7.1.2 CRYSTAL FREQUENCY SELECTION

The SAA7377, which has an internal phase-locked loop clock multiplier, can be used with 33.8688, 16.9344 or 8.4672 MHz crystal frequencies by setting register B and SELPLL as shown in Table 1. The internal clock multiplier, controlled by SELPLL, should only be used if a 8.4672 MHz crystal, ceramic resonator or external clock is present. It should be noted that the CL11 output is a 5.6448 MHz clock if a 16.9344 MHz external clock is used.

Table 1 Crystal frequency selection

| REGISTER B | SELPLL | CRYSTAL FREQUENCY (MHz) |
|------------|--------|-------------------------|
| 00xx | 0 | 33.8688 |
| 00xx | 1 | 8.4672 |
| 01xx | 0 | 16.9344 |

7.1.3 STANDBY MODES

The SAA7377 may be placed in two standby modes selected by register B (it should be noted that the device core is still active)

Standby 1: "CD-STOP" mode. Most I/O functions are switched off.

Standby 2: "CD-PAUSE" mode. Audio output features are switched off, but the motor loop, the motor output and the subcode interfaces remain active. This is also called a "Hot Pause".

In the standby modes the various pins will have the following values:

MOTO1 and MOTO2: put in high-impedance, PWM mode (standby 1 and RESET, operating in standby 2). Put in high-impedance, PDM mode (standby 1 and RESET, operating in standby 2).

SCL, SDA, SILD and RAB: no interaction. Normal operation continues.

SCLK, WCLK, DATA, CL11 and DOBM: 3-state in both standby modes. Normal operation continues after reset.

CRIN, CROUT, CL16 and CL4: no interaction. Normal operation continues.

V1, V2, V3, V4, V5, CFLG and C2FAIL: no interaction. Normal operation continues.

7.2 Crystal oscillator

The crystal oscillator is a conventional 2 pin design operating between 8 and 35 MHz. This oscillator is capable of operating with ceramic resonators and also with both fundamental and third overtone crystals. External components should be used to suppress the fundamental output of the third overtone crystals as shown in Figs 3 and 4. Typical oscillation frequencies required are 8.4672, 16.9344 or 33.8688 MHz depending on the internal clock settings used and whether or not the clock multiplier is enabled.

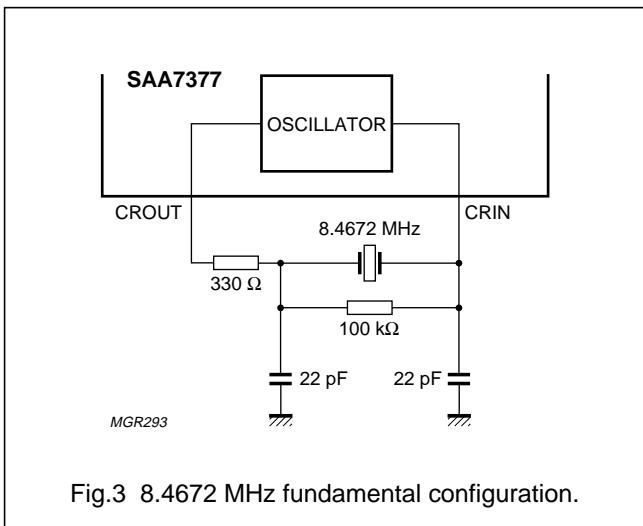


Fig.3 8.4672 MHz fundamental configuration.

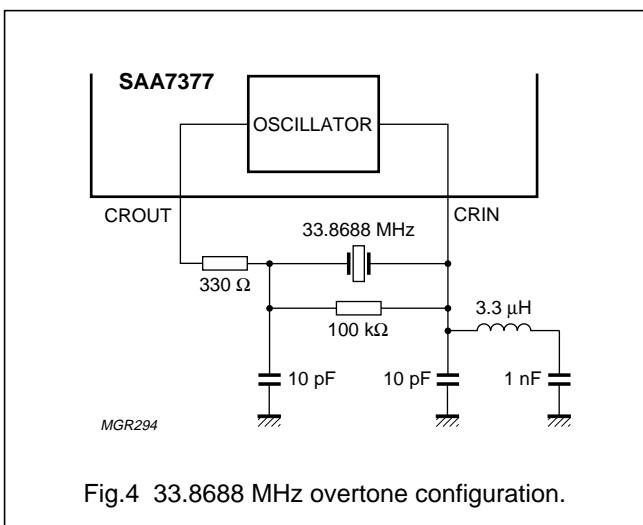


Fig.4 33.8688 MHz overtone configuration.

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7.3 Data slicer and clock regenerator

The SAA7377 has an integrated slice level comparator which can be clocked by the crystal frequency clock, or 8 times the crystal frequency clock (if SELPLL is set HIGH while using an 8.4672 MHz crystal, and register 4 is set to 0xxx). The slice level is controlled by an internal current source applied to an external capacitor under the control of the Digital Phase-Locked Loop (DPLL).

Regeneration of the bit clock is achieved with an internal fully digital PLL. No external components are required and the bit clock is not output. The PLL has two registers (8 and 9) for selecting bandwidth and equalization.

For certain applications an off-track input is necessary. This is internally connected from the servo part (its polarity can be changed by the foc_parm1 parameter), but may be input via the V1 pin if selected by register C. If this flag is HIGH, the SAA7377 will assume that its servo part is following on the wrong track and will flag all incoming HF data as incorrect.

7.4 Demodulator

7.4.1 FRAME SYNC PROTECTION

A double timing system is used to protect the demodulator from erroneous sync patterns in the serial data.

The master counter is only reset if:

- A sync coincidence detected; sync pattern occurs 588 ± 1 EFM clocks after the previous sync pattern
- A new sync pattern is detected within ± 6 EFM clocks of its expected position.

The sync coincidence signal is also used to generate the PLL lock signal, which is active HIGH after 1 sync coincidence found, and reset LOW if, during 61 consecutive frames, no sync coincidence is found. The PLL lock signal can be accessed via the SDA or STATUS pins selected by register 2 and 7.

Also incorporated in the demodulator is a Run Length 2 (RL2) correction circuit. Every symbol detected as RL2 will be pushed back to RL3. To do this, the phase error of both edges of the RL2 symbol are compared and the correction is executed at the side with the highest error probability.

7.4.2 EFM DEMODULATION

The 14-bit EFM data and subcode words are decoded into 8-bit symbols.

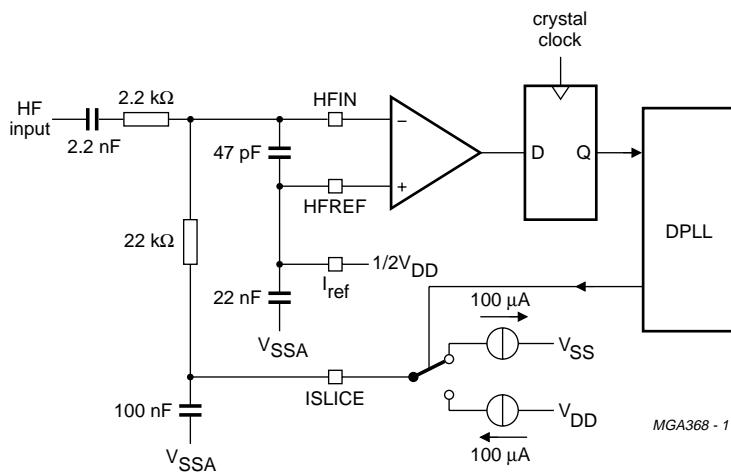


Fig.5 Data slicer showing typical application components.

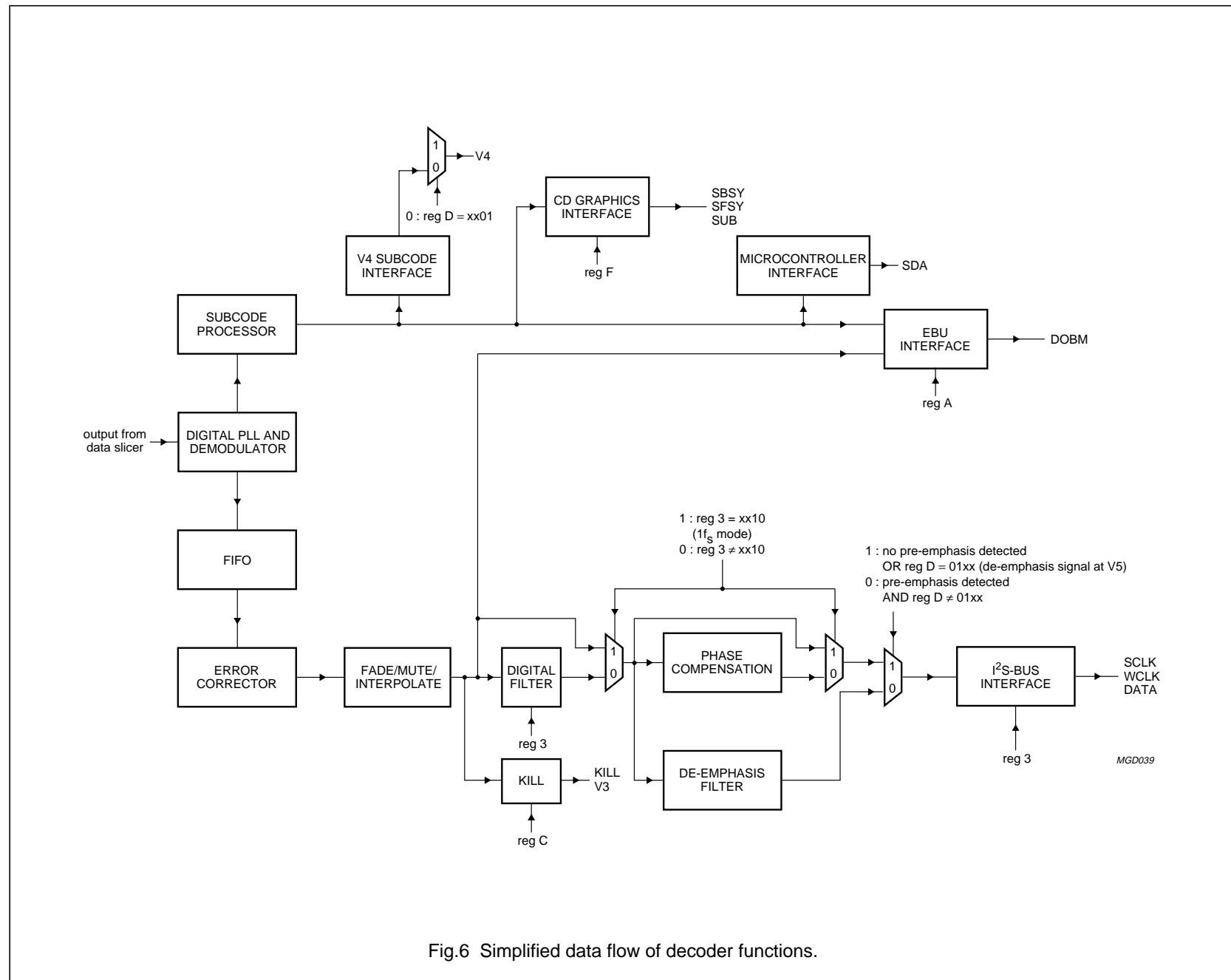


Fig.6 Simplified data flow of decoder functions.

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7.5 Subcode data processing

7.5.1 Q-CHANNEL PROCESSING

The 96-bit Q-channel word is accumulated in an internal buffer. The last 16 bits are used internally to perform a Cyclic Redundancy Check (CRC). If the data is good, the SUBQREADY-I signal will go LOW. SUBQREADY-I can be read via the SDA or STATUS pins, selected via register 2. Good Q-channel data may be read from SDA.

7.5.2 EIAJ 3 AND 4-WIRE SUBCODE (CD GRAPHICS) INTERFACES

Data from all the subcode channels (P-to-W) may be read via the subcode interface, which conforms to EIAJ CP-2401. The interface is enabled and configured as either a 3-wire or 4-wire interface via register F. The subcode interface output formats are illustrated in Fig.7, where the RCK signal is supplied by another device such as a CD graphics decoder.

7.5.3 V4 SUBCODE INTERFACE

Data of subcode channels, Q-to-W, may be read via pin V4 if selected via register D. The format is similar to RS232 and is illustrated in Fig.8. The subcode sync word is formed by a pause of 200 µs minimum. Each subcode byte starts with a logic 1 followed by 7 bits (Q-to-W). The gap between bytes is variable between 11.3 µs and 90 µs.

The subcode data is also available in the EBU output (DOBM) in a similar format.

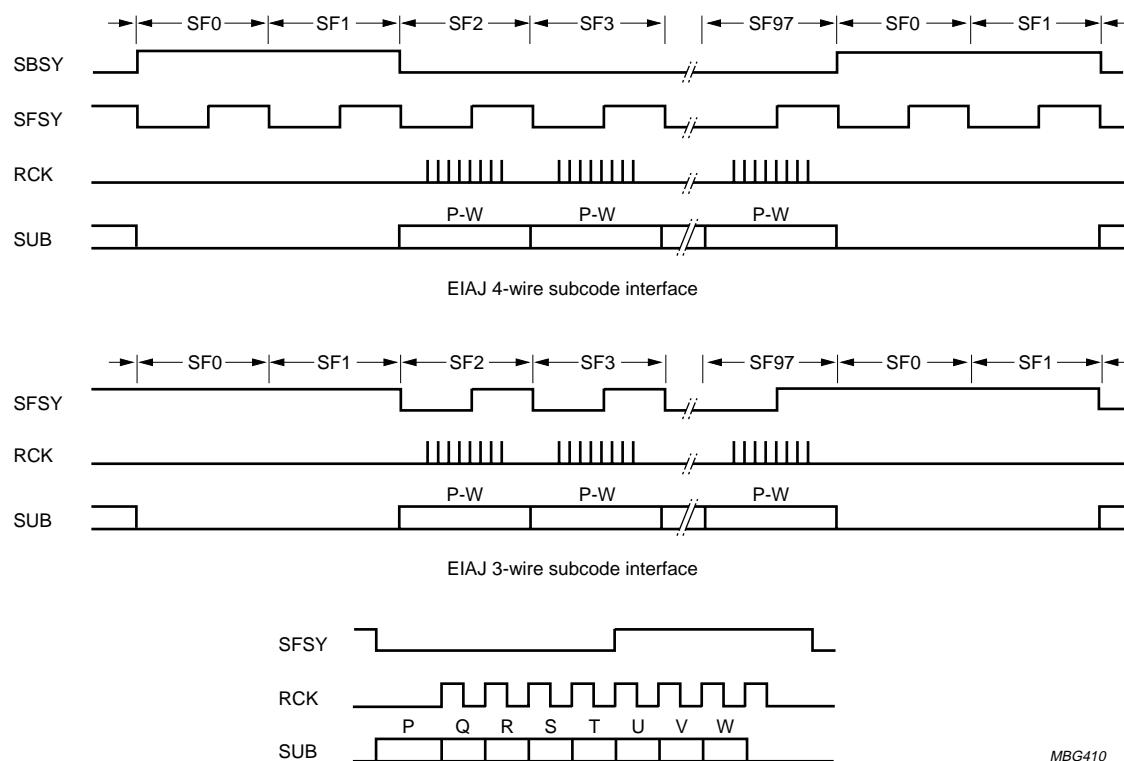


Fig.7 EIAJ subcode (CD graphics) interface format.

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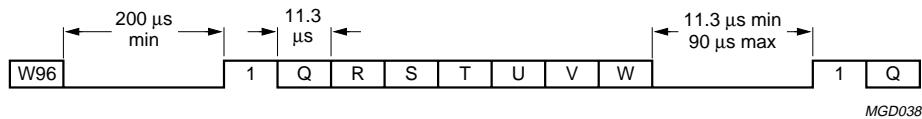


Fig.8 Subcode format and timing on pin V4.

7.6 FIFO and error corrector

The SAA7377 has a ± 8 frame FIFO. The error corrector is a $t = 2$, $e = 4$ type, with error corrections on both C1 (32 symbol) and C2 (28 symbol) frames. Four symbols are used from each frame as parity symbols. This error corrector can correct up to two errors on the C1 level and up to four errors on the C2 level.

The error corrector also contains a flag processor. Flags are assigned to symbols when the error corrector cannot ascertain if the symbols are definitely good. C1 generates output flags which are read after (de-interleaving) by C2, to help in the generation of C2 output flags.

The C2 output flags are used by the interpolator for concealment of uncorrectable errors. They are also output via the EBU signal (DOBM).

7.6.1 FLAGS OUTPUT (CFLG)

The flags output pin CFLG (open-drain) shows the status of the error corrector and interpolator and is updated every frame (7.35 kHz). In the SAA7377 chip a 1-bit flag is present on the CFLG pin as illustrated in Fig.9. This signal shows the status of the error corrector and interpolator.

The first flag bit, F1, is the absolute time sync signal, the FIFO-passed subcode sync and relates the position of the subcode sync to the audio data (DAC output). This flag may also be used in a super FIFO or in the synchronization of different players. The output flags can be made available at bit 4 of the EBU data format (LSB of the 24-bit data word), if selected by register A.

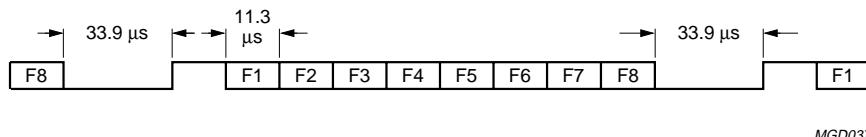


Fig.9 Flag output timing diagram.

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Table 2 Output flags

| F1 | F2 | F3 | F4 | F5 | F6 | F7 | F8 | DESCRIPTION |
|----|----|----|----|----|----|----|----|--|
| 0 | x | x | x | x | x | x | x | no absolute time sync |
| 1 | x | x | x | x | x | x | x | absolute time sync |
| x | 0 | 0 | x | x | x | x | x | C1 frame contained no errors |
| x | 0 | 1 | x | x | x | x | x | C1 frame contained 1 error |
| x | 1 | 0 | x | x | x | x | x | C1 frame contained 2 errors |
| x | 1 | 1 | x | x | x | x | x | C1 frame uncorrectable |
| x | x | x | 0 | 0 | x | x | 0 | C2 frame contained no errors |
| x | x | x | 0 | 0 | x | x | 1 | C2 frame contained 1 error |
| x | x | x | 0 | 1 | x | x | 0 | C2 frame contained 2 errors |
| x | x | x | 0 | 1 | x | x | 1 | C2 frame contained 3 errors |
| x | x | x | 1 | 0 | x | x | 0 | C2 frame contained 4 errors |
| x | x | x | 1 | 1 | x | x | 1 | C2 frame uncorrectable |
| x | x | x | x | x | 0 | 0 | x | no interpolations |
| x | x | x | x | x | 0 | 1 | x | at least one 1 sample interpolation |
| x | x | x | x | x | 1 | 0 | x | at least one hold and no interpolations |
| x | x | x | x | x | 1 | 1 | x | at least one hold and one 1 sample interpolation |

7.6.2 C2FAIL

The C2FAIL pin indicates that invalid data has occurred on the I²S-bus interface. However, due to the structure of the corrector it is impossible to determine which byte has failed. C2FAIL will go LOW for 140 µs when invalid data is detected, this data may then occur 15 ms before or after the pin is activated.

7.7 Audio functions

7.7.1 DE-EMPHASIS AND PHASE LINEARITY

When pre-emphasis is detected in the Q-channel subcode, the digital filter automatically includes a de-emphasis filter section. When de-emphasis is not required, a phase compensation filter section controls the phase of the digital oversampling filter to $\leq \pm 1^\circ$ within the band 0 to 16 kHz. With de-emphasis the filter is not phase linear.

If the de-emphasis signal is set to be available at V5, selected via register D, then the de-emphasis filter is bypassed.

7.7.2 DIGITAL OVERSAMPLING FILTER

The SAA7377 contains a 2 to 4 times oversampling IIR filter. The filter specification of the 4 times oversampling filter is given in Table 3.

These attenuations do not include the sample-and-hold at the external DAC output or the DAC post filter. When using the oversampling filter, the output level is scaled -0.5 dB down, to avoid overflow on full-scale sine wave inputs (0 to 20 kHz).

Table 3 Filter specification

| PASS BAND | STOP BAND | ATTENUATION |
|--------------|--------------|-----------------|
| 0 to 9 kHz | — | ≤ 0.001 dB |
| 19 to 20 kHz | — | ≤ 0.03 dB |
| — | 24 kHz | ≥ 25 dB |
| — | 24 to 27 kHz | ≥ 38 dB |
| — | 27 to 35 kHz | ≥ 40 dB |
| — | 35 to 64 kHz | ≥ 50 dB |
| — | 64 to 68 kHz | ≥ 31 dB |
| — | 68 kHz | ≥ 35 dB |
| — | 69 to 88 kHz | ≥ 40 dB |

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7.7.3 CONCEALMENT

A 1-sample linear interpolator becomes active if a single sample is flagged as erroneous but cannot be corrected. The erroneous sample is replaced by a level midway between the preceding and following samples. Left and right channels have independent interpolators. If more than one consecutive non-correctable sample is found, the last good sample is held. A 1-sample linear interpolation is then performed before the next good sample (see Fig.10).

7.7.4 MUTE, FULL SCALE, ATTENUATION AND FADE

A digital level controller is present on the SAA7377 which performs the functions of soft mute, full scale, attenuation and fade; these are selected via register 0:

Mute: signal reduced to 0 in a maximum of 128 steps; 3 ms.

Attenuate: signal scaled by -12 dB.

Full scale: ramp signal back to 0 dB level. From mute takes 3 ms.

Fade: activates a 128 stage counter which allows the signal to be scaled up/down by 0.07 dB steps

128 = full scale.

120 = -0.5 dB (i.e. full scale if oversampling filter used).

32 = -12 dB.

0 = mute.

7.7.5 PEAK DETECTOR

The peak detector measures the highest audio level (absolute value) on positive peaks for left and right channels. The 8 most significant bits are output in the Q-channel data in place of the CRC bits. Bits 81 to 88 contain the left peak value (bit 88 = MSB) and bits 89 to 96 contain the right peak value (bit 96 = MSB). The values are reset after reading Q-channel data via SDA.

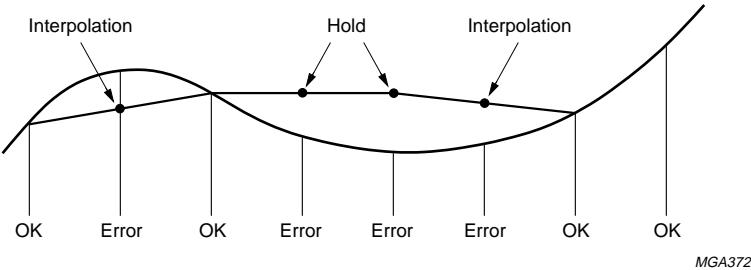


Fig.10 Concealment mechanism.

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7.8 DAC interface

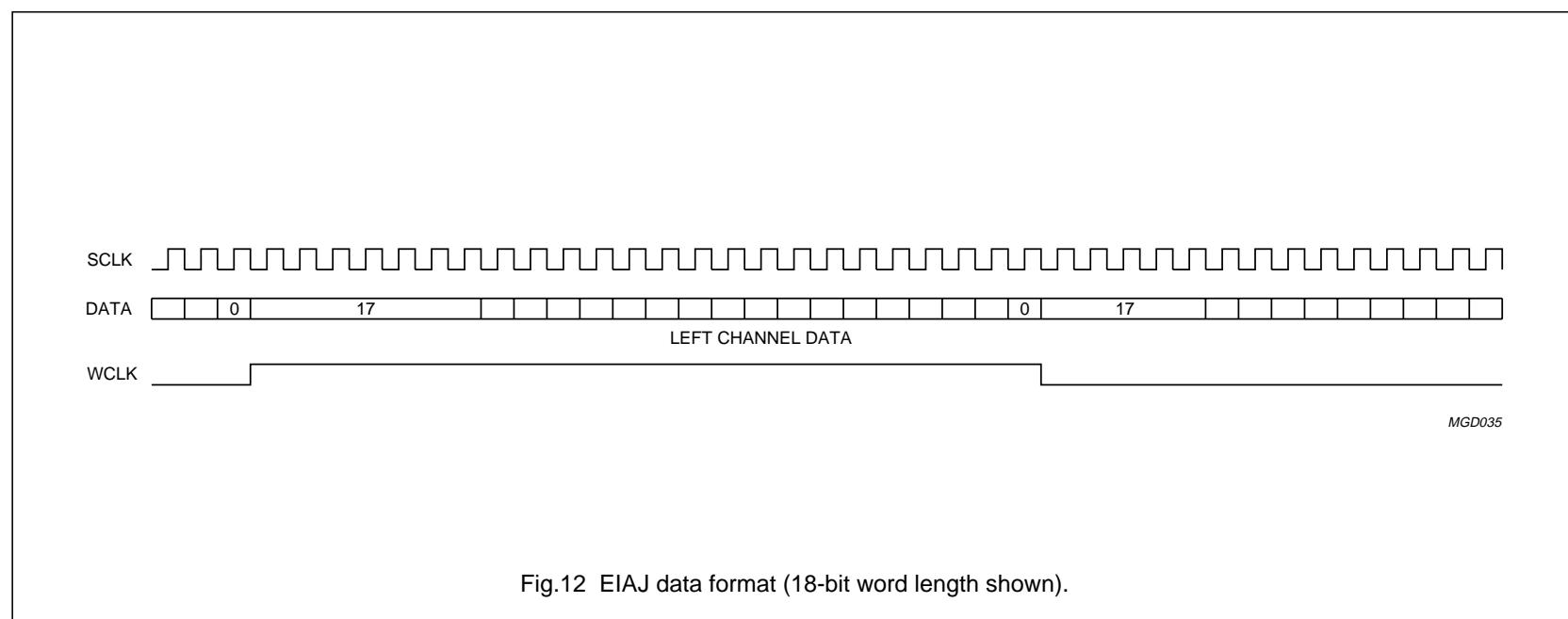
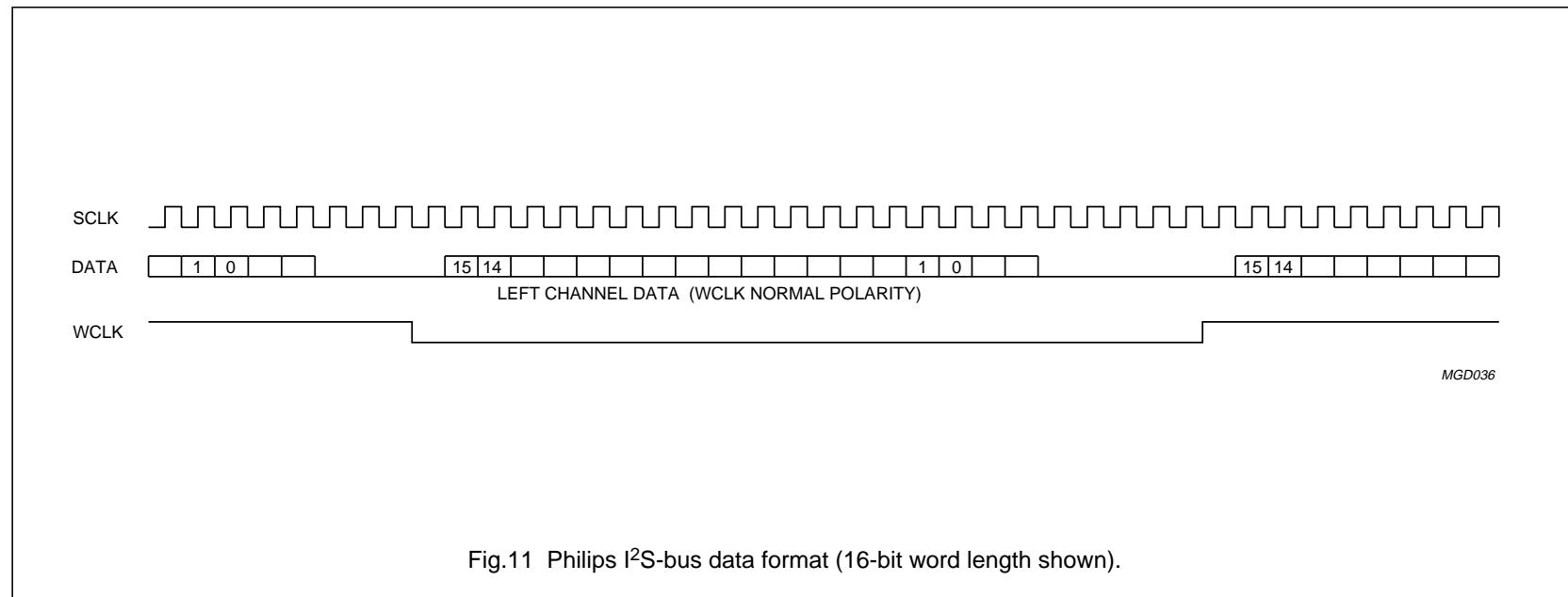
The SAA7377 is compatible with a wide range of digital-to-analog converters (DACs). Nine formats are supported and are given in Table 4. Figures 11 and 12 show the Philips I²S-bus and the EIAJ data formats respectively. All formats are MSB first and f_s is 44.1 kHz. The polarity of the WCLK and the data can be inverted; selectable by register 7.

Table 4 DAC interface formats

| REGISTER 3 | SAMPLE FREQUENCY | NUMBER OF BITS | SCLK (MHz) | FORMAT | INTERPOLATION |
|------------|------------------|----------------------|------------|---|---------------|
| 1110 | f_s | 16/18 ⁽¹⁾ | 2.1168 | Philips I ² S-bus; 16/18 bits ⁽¹⁾ | yes |
| 0010 | f_s | 16 | 2.1168 | EIAJ 16 bits | yes |
| 0110 | f_s | 18 | 2.1168 | EIAJ 18 bits | yes |
| 0000 | $4f_s$ | 16 | 8.4672 | EIAJ 16 bits | yes |
| 0100 | $4f_s$ | 18 | 8.4672 | EIAJ 18 bits | yes |
| 1100 | $4f_s$ | 18 | 8.4672 | Philips I ² S-bus; 18 bits | yes |
| 0011 | $2f_s$ | 16 | 4.2336 | EIAJ 16 bits | yes |
| 0111 | $2f_s$ | 18 | 4.2336 | EIAJ 18 bits | yes |
| 1111 | $2f_s$ | 18 | 4.2336 | Philips I ² S-bus; 18 bits | yes |

Note

1. In this mode the first 16 bits contain data, but if any of the fade, attenuate or de-emphasis filter functions are activated then the first 18 bits contain data.



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7.9 EBU interface

The bi-phase mark digital output signal at pin DOBM is in accordance with the format defined by the IEC958 specification. The DOBM pin can be held LOW and selected via register A.

7.9.1 FORMAT

The digital audio output consists of 32-bit words ('subframes') transmitted in bi-phase mark code (two transitions for a logic 1 and one transition for a logic 0). Words are transmitted in blocks of 384. Table 5 gives the formats.

Table 5 Format

| FUNCTION | BITS | DESCRIPTION |
|----------------|---------|---|
| Sync | 0 to 3 | – |
| Auxiliary | 4 to 7 | not used; normally zero |
| Error flags | 4 | CFLG error and interpolation flags when selected by register A |
| Audio sample | 8 to 27 | first 4 bits not used (always zero). 2's compliment. LSB = bit 12, MSB = bit 27 |
| Validity flag | 28 | valid = logic 0 |
| User data | 29 | used for subcode data (Q-to-W) |
| Channel status | 30 | control bits and category code |
| Parity bit | 31 | even parity for bits 4 to 30 |

Table 6 Description of Table 5

| FUNCTION | DESCRIPTION |
|----------------|--|
| Sync | The sync word is formed by violation of the bi-phase rule and therefore does not contain any data. Its length is equivalent to 4 data bits. The 3 different sync patterns indicate the following situations: sync B: start of a block (384 words), word contains left sample; sync M: word contains left sample (no block start) and sync W: word contains right sample. |
| Audio sample | Left and right samples are transmitted alternately. |
| Validity flag | Audio samples are flagged (bit 28 = 1) if an error has been detected but was uncorrectable. This flag remains the same even if data is taken after concealment. |
| User data | Subcode bits Q-to-W from the subcode section are transmitted via the user data bit. This data is asynchronous with the block rate. |
| Channel status | The channel status bit is the same for left and right words. Therefore a block of 384 words contains 192 channel status bits. The category code is always CD. The bit assignment is given in Table 7. |

Table 7 Bit assignment

| FUNCTION | BITS | DESCRIPTION |
|----------------|------------------------|---|
| Control | 0 to 3 | copy of CRC checked Q-channel control bits 0 to 3; bit 2 is logic 1 when copy permitted; bit 3 is logic 1 when recording has pre-emphasis |
| Reserved mode | 4 to 7 | always zero |
| Category code | 8 to 15 | CD: bit 8 = logic 1, all other bits = logic 0 |
| Clock accuracy | 28 to 29 | set by register A; 10 = level I; 00 = level II; 01 = level III |
| Remaining | 16 to 27 and 30 to 191 | always zero |

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7.10 KILL circuit

The KILL circuit detects digital silence by testing for an all-zero or all-ones data word in the left or right channel before the digital filter. The output is switched active LOW when silence has been detected for at least 250 ms, or if mute is active. Two modes are available which can be selected by register C:

1 pin kill: KILL active LOW indicates silence detected on both left and right channels.

2 pin kill: KILL active LOW indicates silence detected on left channel. V3 active LOW indicates silence detected on right channel.

7.11 The VIA interface

The SAA7377 has five pins that can be reconfigured for different applications (see Table 8).

Table 8 Pin applications

| PIN NAME | PIN NUMBER | TYPE | CONTROL REGISTER ADDRESS | CONTROL REGISTER DATA | FUNCTION |
|----------|------------|--------|--------------------------|-----------------------|---|
| V1 | 62 | input | 1100 | xxx1 | external off-track signal input |
| | | | – | xxx0 | internal off-track signal used, input may be read via decoder status bit; selected via register 2 |
| V2 | 63 | input | – | – | input may be read via decoder status bit; selected via register 2 |
| V3 | 42 | output | 1100 | xx0x | KILL output for right channel |
| | | | – | x01x | output = 0 |
| | | | – | x11x | output = 1 |
| V4 | 41 | output | 1101 | 0000 | 4-line motor drive (using V4 and V5) |
| | | | – | xx01 | Q-to-W subcode output |
| | | | – | xx10 | output = 0 |
| | | | – | xx11 | output = 1 |
| V5 | 40 | output | 1101 | 01xx | de-emphasis output (active HIGH) |
| | | | – | 10xx | output = 0 |
| | | | – | 11xx | output = 1 |

7.12 Spindle motor control

7.12.1 MOTOR OUTPUT MODES

The spindle motor speed is controlled by a fully integrated digital servo. Address information from the internal ± 8 frame FIFO and disc speed information are used to calculate the motor control output signals. Several output modes, selected by register 6, are supported:

- Pulse density, 2-line (true complement output), 1 MHz sample frequency
- PWM output, 2-line, 22.05 kHz modulation frequency
- PWM output, 4-line, 22.05 kHz modulation frequency
- CDV motor mode.

7.12.1.1 Pulse density output mode

In the pulse density mode the motor output pin (MOTO1) is the pulse density modulated motor output signal. A 50% duty factor corresponds with the motor not actuated, higher duty factors mean acceleration, lower mean braking. In this mode, the MOTO2 signal is the inverse of the MOTO1 signal. Both signals change state only on the edges of a 1 MHz internal clock signal. Possible application diagrams are illustrated in Fig.13.

7.12.1.2 PWM output mode (2-line)

In the PWM mode the motor acceleration signal is put in pulse-width modulation form on the MOTO1 output. The motor braking signal is pulse-width modulated on the MOTO2 output. The timing is illustrated in Fig.14. A typical application diagram is illustrated in Fig.15.

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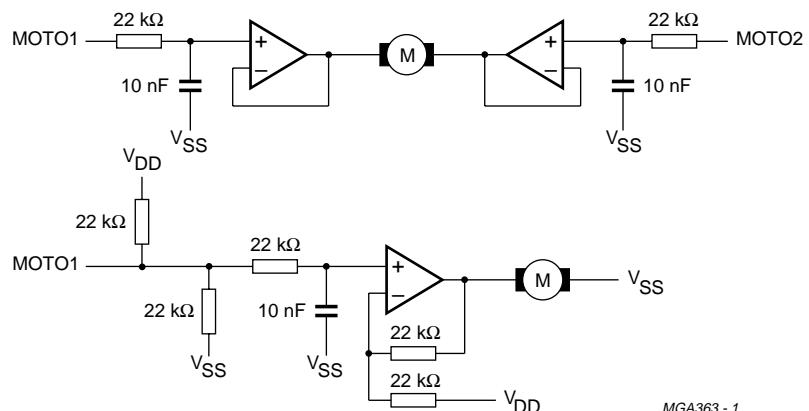


Fig.13 Motor pulse density application diagrams.

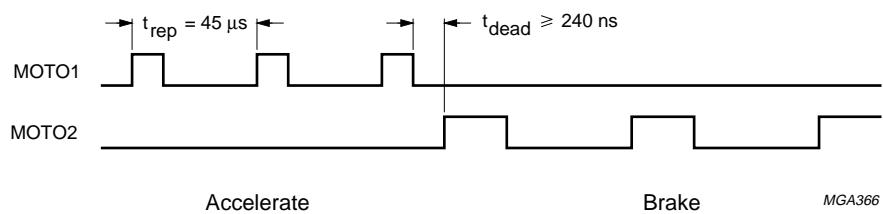


Fig.14 2-line PWM mode timing.

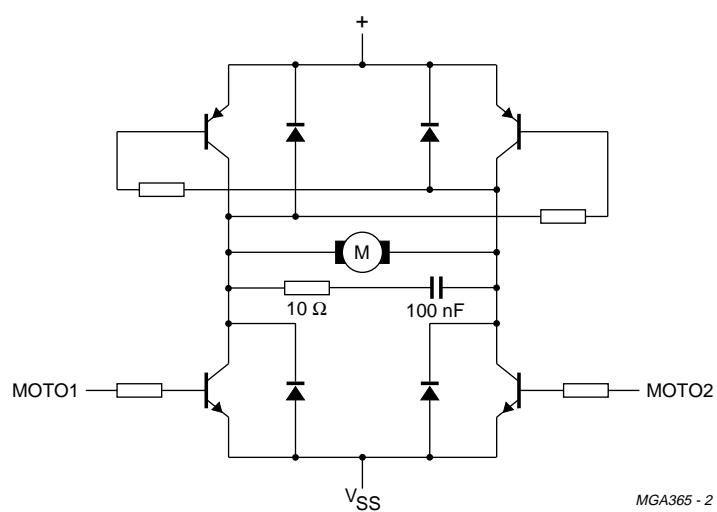


Fig.15 Motor 2-line PWM mode application diagram.

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7.12.1.3 PWM output mode (4-line)

Using two extra outputs from the versatile pins interface, it is possible to use the SAA7377 with a 4-input motor bridge. The timing is illustrated in Fig.16. A typical application diagram is illustrated in Fig.17.

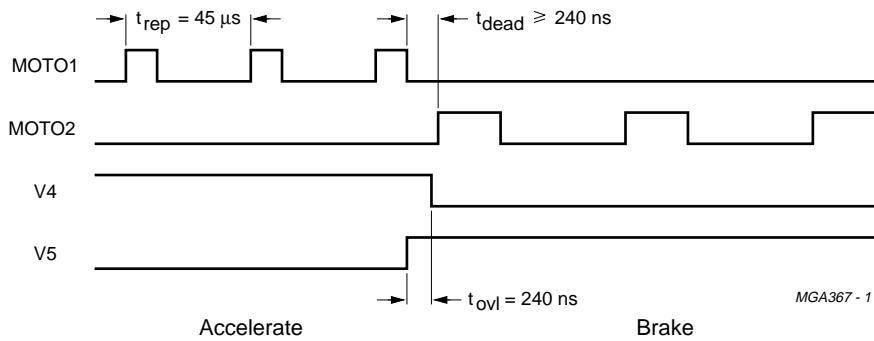


Fig.16 4-line PWM mode timing.

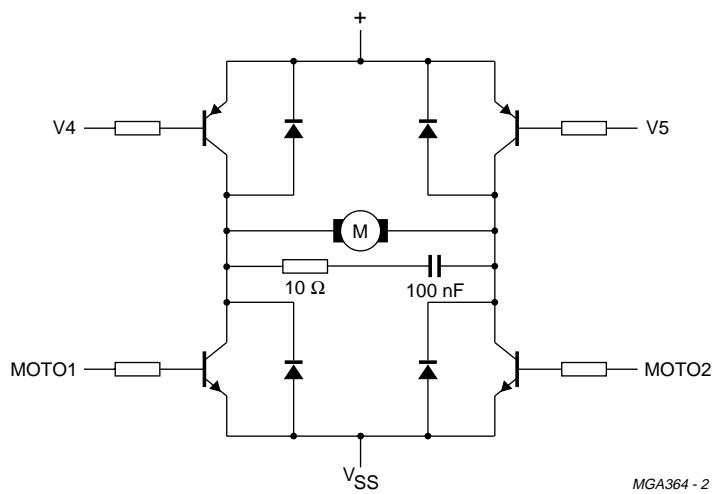


Fig.17 Motor 4-line PWM mode application diagram.

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7.12.1.4 CDV/CAV output mode

In the CDV motor mode, the FIFO position will be put in pulse-width modulated form on the MOTO1 pin (carrier frequency = 300 Hz). The PLL frequency signal will be put in pulse-density modulated form (carrier frequency = 4.23 MHz) on the MOTO2 pin. The integrated motor servo is disabled in this mode.

The PWM signal on MOTO1 corresponds to a total memory space of 20 frames, therefore the nominal FIFO position (half full) will result in a PWM output of 60%.

7.12.2 SPINDLE MOTOR OPERATING MODES

The operation modes of the motor servo is controlled by register 1 (see Table 9).

In the SAA7377 decoder there is an anti-wind-up mode for the motor servo, selected via register 1. When the anti-wind-up mode is activated the motor servo integrator will hold if the motor output saturates.

7.12.2.1 Power limit

In start mode 1, start mode 2, stop mode 1 and stop mode 2, a fixed positive or negative voltage is applied to the motor.

This voltage can be programmed as a percentage of the maximum possible voltage, via register 6, to limit current drain during start and stop. The following power limits are possible;

100% (no power limit), 75%, 50%, or 37% of maximum.

7.12.3 LOOP CHARACTERISTICS

The gain and crossover frequencies of the motor control loop can be programmed via registers 4 and 5. The following parameter values are possible;

Gains: 3.2, 4.0, 6.4, 8.0, 12.8, 16, 25.6 and 32

Crossover frequency f_4 : 0.5 Hz, 0.7 Hz, 1.4 Hz, 2.8 Hz

Crossover frequency f_3 : 0.85 Hz, 1.71 Hz, 3.42 Hz.

7.12.4 FIFO OVERFLOW

If FIFO overflow occurs during Play mode (e.g. as a result of motor rotational shock), the FIFO will be automatically reset to 50% and the audio interpolator tries to conceal as much as possible to minimise the effect of data loss.

Table 9 Operating modes

| MODE | DESCRIPTION |
|--------------|--|
| Start mode 1 | The disc is accelerated by applying a positive voltage to the spindle motor. No decisions are involved and the PLL is reset. No disc speed information is available for the microcontroller. |
| Start mode 2 | The disc is accelerated as in start mode 1, however the PLL will monitor the disc speed. When the disc reaches 75% of its nominal speed, the controller will switch to jump mode. The motor status signals selectable via register 2 are valid. |
| Jump mode | Motor servo enabled but FIFO kept reset at 50%, integrator is held. The audio is muted but it is possible to read the subcode. |
| Jump mode 1 | Similar to jump mode but motor integrator is kept at zero. Used for long jumps where there is a large change in disc speed. |
| Play mode | FIFO released after resetting to 50%. Audio mute released. |
| Stop mode 1 | Disc is braked by applying a negative voltage to the motor. No decisions are involved. |
| Stop mode 2 | The disc is braked as in stop mode 1 but the PLL will monitor the disc speed. As soon as the disc reaches 12% (or 6%, depending on the programmed brake percentage, via register E) of its nominal speed, the MOTSTOP status signal will go HIGH and switch the motor servo to Off mode. |
| Off mode | Motor not steered. |

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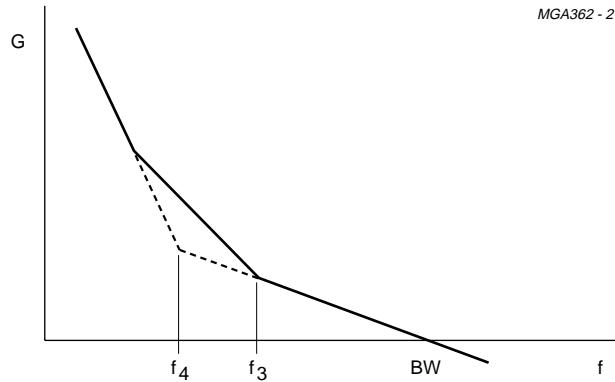


Fig.18 Motor servo mode diagram.

7.13 Servo part

7.13.1 DIODE SIGNAL PROCESSING

The photo detector in conventional two-stage three-beam compact disc systems normally contains six discrete diodes. Four of these diodes (three for single Foucault systems) carry the central aperture signal (CA) while the other two diodes (satellite diodes) carry the radial tracking information. The CA signal is processed into an HF signal (for the decoder function) and LF signal (information for the focus servo loop) before it is supplied to the SAA7377.

The analog signals from the central and satellite diodes are converted into a digital representation using analog-to-digital converters (ADCs). The ADCs are designed to convert unipolar currents into a digital code. The dynamic range of the input currents is adjustable within a given range, which is dependent on the value of the external resistor connected to pin I_{refT} . The maximum current for the central diodes and satellite diodes is given in the following formulae;

$$I_{in(max, central)} = \left(\frac{2.4 \times 10^6}{R_{refT}} \right) \mu\text{A}$$

$$I_{in(max, satellite)} = \left(\frac{1.2 \times 10^6}{R_{refT}} \right) \mu\text{A}$$

The V_{RH} voltage is internally generated by control circuitry which ensures that the V_{RH} voltage is adjusted depending on the spread of internal capacitors, using the reference

current generated by the external resistor on I_{refT} . In the application V_{RL} is connected to V_{SSA1} . The maximum input currents for a range of resistors is given Table 10.

Table 10 Maximum current input

| R_{refT} (k Ω) | DIODE INPUT CURRENT RANGE | |
|--------------------------|----------------------------|-----------------------------|
| | D1 TO D4 (μA) | R1 AND R2 (μA) |
| 220 | 10.909 | 5.455 |
| 240 | 10.000 | 5.000 |
| 270 | 8.889 | 4.444 |
| 300 | 8.000 | 4.000 |
| 330 | 7.273 | 3.636 |
| 360 | 6.667 | 3.333 |
| 390 | 6.154 | 3.077 |
| 430 | 5.581 | 2.791 |
| 470 | 5.106 | 2.553 |
| 510 | 4.706 | 2.353 |
| 560 | 4.286 | 2.143 |
| 620 | 3.871 | 1.935 |

This mode of V_{RH} automatic adjustment can be selected by the preset latch command.

Alternatively, the dynamic range of the input currents can be made dependent on the ADC reference voltages V_{RL} and V_{RH} . The maximum current for the central diodes and satellite diodes is given in the following formulae;

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$$I_{in(max, central)} = f_{sys} \times (V_{RH} - V_{RL}) \times 1.0 \times 10^{-6} \mu A$$

$$I_{in(max, satellite)} = f_{sys} \times (V_{RH} - V_{RL}) \times 0.5 \times 10^{-6} \mu A$$

Where $f_{sys} = 4.2336$ MHz.

V_{RH} is generated internally, and there are 32 levels which can be selected under software control via the preset latch command. With this command the V_{RH} voltage can be set to 2.5 V then modified, decremented one level or incremented, by re-sending the command the required number of times. In the application V_{RL} is connected to V_{SSA1} .

7.13.2 SIGNAL CONDITIONING

The digital codes retrieved from the ADCs are applied to logic circuitry to obtain the various control signals. The signals from the central aperture diodes are processed to obtain a normalised focus error signal.

$$FE_n = \frac{D1 - D2}{D1 + D2} - \frac{D3 - D4}{D3 + D4}$$

where the detector set-up is assumed as shown in Fig.19.

In the event of single Foucault focusing method, the signal conditioning can be switched under software control such that the signal processing is as follows;

$$FE_n = 2 \times \frac{D1 - D2}{D1 + D2}$$

The error signal, FE_n , is further processed by a proportional integral and differential (PID) filter section.

A Focus OK (FOK) flag is generated by means of the central aperture signal and an adjustable reference level. This signal is used to provide extra protection for the track-loss (TL) generation, the focus start-up procedure and the drop out detection.

The radial or tracking error signal is generated by the satellite detector signals R1 and R2. The radial error signal can be formulated as follows;

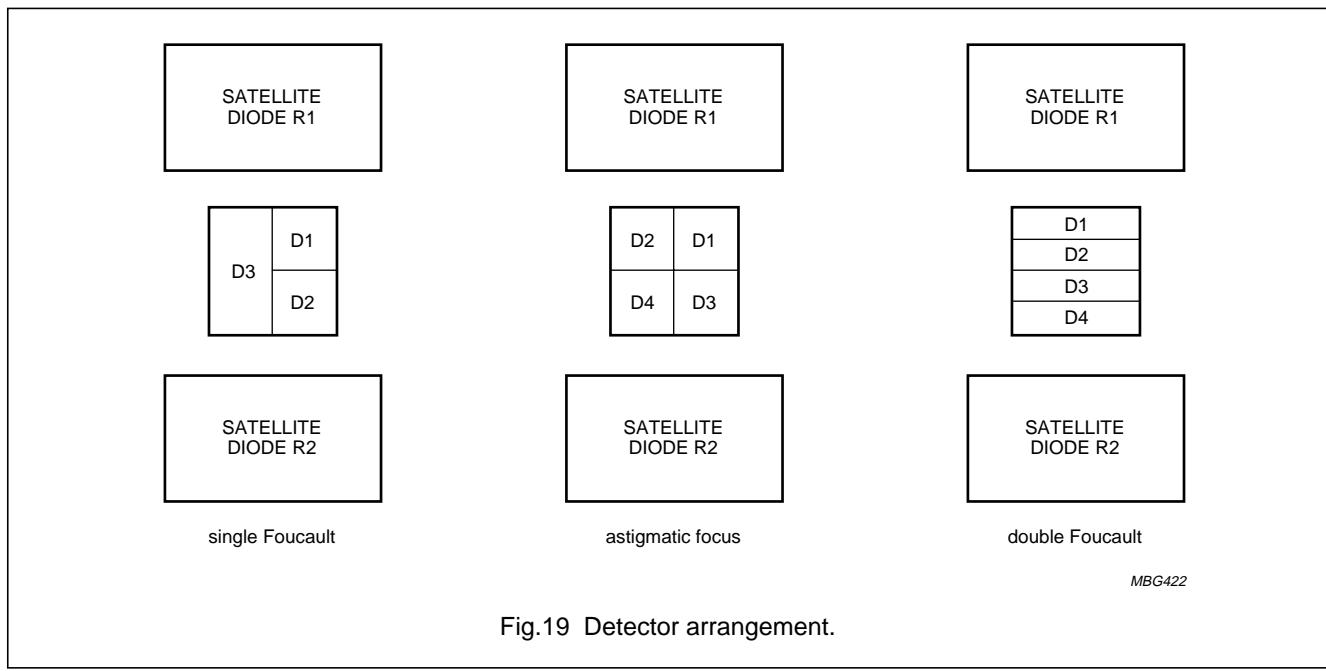
$$RE_s = (R1 - R2) \times re_gain + (R1 - R2) \times re_offset$$

where the index 's' indicates the automatic scaling operation which is performed on the radial error signal. This scaling is necessary to avoid non-optimum dynamic range usage in the digital representation and reduces the radial bandwidth spread. Furthermore, the radial error signal will be made free from offset during start up of the disc.

The four signals from the central aperture detectors, together with the satellite detector signals generate a track position signal (TPI) which can be formulated as follows;

$$TPI = \text{sign} [(D1 + D2 + D3 + D4) - (R1 + R2) \times \text{sum_gain}]$$

Where the weighting factor sum_gain is generated internally by the SAA7377 during initialization.



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7.13.3 FOCUS SERVO SYSTEM

7.13.3.1 *Focus start-up*

Five initially loaded coefficients influence the start-up behaviour of the focus controller. The automatically generated triangle voltage can be influenced by 3 parameters; for height (ramp_height) and DC offset (ramp_offset) of the triangle and its steepness (ramp_incr).

For protection against false focus point detections two parameters are available which are an absolute level on the CA-signal (CA_start) and a level on the FE_n signal (FE_start). When this CA level is reached the FOK signal becomes true.

If the FOK signal is true and the level on the FE_n signal is reached, the focus PID is enabled to switch on when the next zero crossing is detected in the FE_n signal.

7.13.3.2 *Focus position control loop*

The focus control loop contains a digital PID controller which has 5 parameters which are available to the user. These coefficients influence the integrating (foc_int), proportional (foc_lead_length, part of foc_parm3) and differentiating (foc_pole_lead, part of foc_parm1) action of the PID and a digital low-pass filter (foc_pole_noise, part of foc_parm2) following the PID. The fifth coefficient foc_gain influences the loop gain.

7.13.3.3 *Drop-out detection*

This detector can be influenced by one parameter (CA_drop). The FOK signal will become false and the integrator of the PID will hold if the CA signal drops below this programmable absolute CA level. When the FOK signal becomes false it is assumed, initially, to be caused by a black dot.

7.13.3.4 *Focus loss detection and fast restart*

Whenever FOK is false for longer than approximately 3 ms, it is assumed that the focus point is lost. A fast restart procedure is initiated which is capable of restarting the focus loop within 200 to 300 ms depending on the programmed coefficients of the microcontroller.

7.13.3.5 *Focus loop gain switching*

The gain of the focus control loop (foc_gain) can be multiplied by a factor of 2 or divided by a factor of 2 during normal operation. The integrator value of the PID is corrected accordingly. The differentiating (foc_pole_lead)

action of the PID can be switched at the same time as the gain switching is performed.

7.13.3.6 *Focus automatic gain control loop*

The loop gain of the focus control loop can be corrected automatically to eliminate tolerances in the focus loop. This gain control injects a signal into the loop which is used to correct the loop gain. Since this decreases the optimum performance, the gain control should only be activated for a short time (for example, when starting a new disc).

7.13.4 RADIAL SERVO SYSTEM

7.13.4.1 *Level initialization*

During start-up an automatic adjustment procedure is activated to set the values of the radial error gain (re_gain), offset (re_offset) and satellite sum gain (sum_gain) for TPI level generation. The initialization procedure runs in a radial open loop situation and is ≤ 300 ms. This start-up time period may coincide with the last part of the motor start-up time period.

Automatic gain adjustment: as a result of this initialization the amplitude of the RE signal is adjusted to within $\pm 10\%$ around the nominal RE amplitude.

Offset adjustment: the additional offset in RE due to the limited accuracy of the start-up procedure is less than ± 50 nm.

TPI level generation: the accuracy of the initialization procedure is such that the duty factor range of TPI becomes $0.4 < \text{duty factor} < 0.6$ (definition of duty factor = TPI HIGH/TPI period).

7.13.4.2 *Sledge control*

The microcontroller can move the sledge in both directions via the steer sledge command.

7.13.4.3 *Tracking control*

The actuator is controlled using a PID loop filter with user defined coefficients and gain. For stable operation between the tracks, the S-curve is extended over ± 0.75 of the track. On request from the microcontroller, S-curve extension over ± 2.25 tracks is used, automatically changing to access control when exceeding those 2.25 tracks.

Both modes of S-curve extension make use of a track-count mechanism. In this mode, track counting results in an 'automatic return-to-zero track', to avoid major music rhythm disturbances in the audio output for improved shock resistance.

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The sledge is continuously controlled, or provided with step pulses to reduce power consumption using the filtered value of the radial PID output. Alternatively, the microcontroller can read the average voltage on the radial actuator and provide the sledge with step pulses to reduce power consumption. Filter coefficients of the continuous sledge control can be preset by the user.

7.13.4.4 Access

The access procedure is divided into two different modes (see Table 11), depending on the requested jump size.

Table 11 Access modes

| ACCESS TYPE | JUMP SIZE ⁽¹⁾ | ACCESS SPEED |
|---------------|--------------------------|--|
| Actuator jump | 1 - brake_distance | decreasing velocity |
| Sledge jump | brake_distance - 32768 | maximum power to sledge ⁽¹⁾ |

Note

1. Microcontroller presettable.

The access procedure makes use of a track counting mechanism, a velocity signal based on a fixed number of tracks passed within a fixed time interval, a velocity set point calculated from the number of tracks to go and a user programmable parameter indicating the maximum sledge performance.

If the number of tracks remaining is greater than the brake_distance then the sledge jump mode should be activated, or, the actuator jump should be performed. The requested jump size together with the required sledge breaking distance at maximum access speed defines the brake_distance value.

During the actuator jump mode, velocity control with a PI controller is used for the actuator. The sledge is then continuously controlled using the filtered value of the radial PID output. All filter parameters (for actuator and sledge) are user programmable.

In the sledge jump mode maximum power (user programmable) is applied to the sledge in the correct direction while the actuator becomes idle (the contents of the actuator integrator leaks to zero just after the sledge jump mode is initiated).

7.13.4.5 Radial automatic gain control loop

The loop gain of the radial control loop can be corrected automatically to eliminate tolerances in the radial loop. This gain control injects a signal into the loop which is used to correct the loop gain. Since this decreases the optimum performance, the gain control should only be activated for a short time (for example, when starting a new disc).

This gain control differs from the level initialization.

The level initialization should be performed first.

The disadvantage of using the level initialization without the gain control is that only tolerances from the front-end are reduced.

7.13.5 OFF-TRACK COUNTING

The track position signal (TPI) is a flag which is used to indicate whether the radial spot is positioned on the track, with a margin of $\pm 1/4$ of the track-pitch. In combination with the radial polarity flag (RP) the relative spot position over the tracks can be determined. These signals are, however, afflicted with some uncertainties caused by;

- Disc defects such as scratches and fingerprints
- The HF information on the disc, which is considered as noise by the detector signals.

In order to determine the spot position with sufficient accuracy, extra conditions are necessary to generate a track loss signal (TL) and an off-track counter value. These extra conditions influence the maximum speed and this implies that, internally, one of the following three counting states is selected;

1. Protected state: used in normal play situations. A good protection against false detection caused by disc defects is important in this state.
2. Slow counting state: used in low velocity track jump situations. In this state a fast response is important rather than the protection against disc defects (if the phase relationship between TL and RP of $1/2\pi$ radians is affected too much, the direction cannot then be determined accurately).
3. Fast counting state: used in high velocity track jump situations. Highest obtainable velocity is the most important feature in this state.

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7.13.6 DEFECT DETECTION

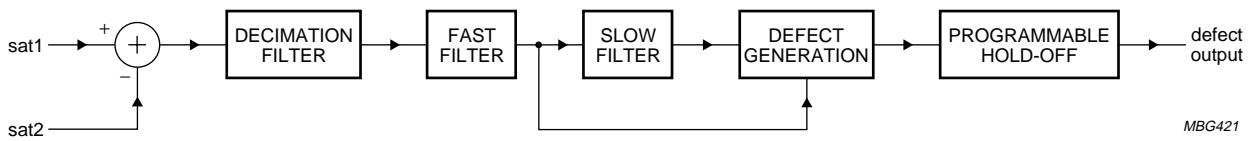


Fig.20 Block diagram of defect detector.

A defect detection circuit is incorporated into the SAA7377. If a defect is detected, the radial and focus error signals may be zeroed, resulting in better playability. The defect detector can be switched off, applied only to focus control or applied to both focus and radial controls under software control (part of foc_parm1).

The defect detector (see Fig.20) has programmable set points selectable by the parameter defect_parm.

7.13.7 OFF-TRACK DETECTION

During active radial tracking, off-track detection has been realised by continuously monitoring the off-track counter value. The off-track flag becomes valid whenever the off-track counter value is not equal to zero. Depending on the type of extended S-curve, the off-track counter is reset after 0.75 extend or at the original track in the 2.25 track extend mode.

7.13.8 HIGH-LEVEL FEATURES

7.13.8.1 Interrupt mechanism and STATUS pin

The STATUS pin is an output which is active LOW, its output is selected by register 7 to be either the status bit (active LOW) selected by register 2 (only available in 4-wire bus mode) or the interrupt signal generated by the servo part.

8 signals from the interrupt status register are selectable from the servo part via the interrupt_mask parameter. The interrupt is reset by sending the read high-level status command. The 8 signals are as follows:

1. Focus lost: drop out of longer than 3 ms.
2. Subcode ready.
3. Subcode absolute seconds changed.
4. Subcode discontinuity detected: new subcode time before previous subcode time, or more than 10 frames later than the previous subcode time.
5. Radial error: during radial on-track, no new subcode frame occurs within time defined by playwatchtime parameter. During radial jump, less than 4 tracks have

been crossed during time defined by jumpwatchtime parameter.

6. Autosequencer state change.
7. Autosequencer error.
8. Subcode interface blocked: the internal decoder interface is being used.

It should be noted that if the STATUS pin output is selected via register 2 and either the microcontroller writes a different value to register 2 or the decoder interface is enabled then the STATUS output will change.

7.13.8.2 Decoder interface

The decoder interface allows registers 0 to F to be programmed and subcode Q-channel data to be read via servo commands. The interface is enabled/disabled by the preset latch command (and the xtra_preset parameter).

7.13.8.3 Automatic error handling

Three watchdogs are present:

1. Focus: detects focus drop out of longer than 3 ms, sets focus lost interrupt, switches off radial and sledge servos, disables drive to disc motor.
2. Radial play: started when radial servo is on-track mode and a first subcode frame is found. Detects when maximum time between two subcode frames exceeds time set by playwatchtime parameter; then sets radial error interrupt, switches radial and sledge servos off, puts disc motor in jump mode.
3. Radial jump: active when radial servo in long jump or short jump modes. Detects when the off-track counter value decreases by less than 4 tracks between two readings (time interval set by jumpwatchtime parameter); then sets radial jump error, switches radial and sledge servos off to cancel jump.

The focus watchdog is always active, the radial watchdogs are selectable via the radcontrol parameter.

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7.13.8.4 Automatic sequencers and timer interrupts

Two automatic sequencers are implemented (and must be initialized after power-on):

1. Autostart sequencer: controls the start-up of focus, radial and motor.
2. Autostop sequencer: brakes the disc and shuts down servos.

When the automatic sequencers are not used it is possible to generate timer interrupts, defined by the time_parameter coefficient.

7.13.8.5 High-level status

The read high-level status command can be used to obtain the interrupt, decoder, autosequencer status registers and the motor start time. Use of the read high-level status command clears the interrupt status register, and re-enables the subcode read via a servo command.

7.13.9 DRIVER INTERFACE

The control signals (pins RA, FO and SL) for the mechanism actuators are pulse density modulated. The modulating frequency can be set to either 1.0584 MHz (DSD mode) or 2.1168 MHz; controlled via the xtra_preset parameter. An analog representation of the output signals can be achieved by connecting a first-order low-pass filter to the outputs.

During reset (i.e. RESET pin is held LOW) the RA, FO and SL pins are high impedance.

7.13.10 LASER INTERFACE

The LDON pin (open-drain output) is used to switch the laser off and on. When the laser is on the output is high impedance. The action of the LDON pin is controlled by the xtra_preset parameter; the pin is automatically driven if the focus control loop is active.

7.13.11 RADIAL SHOCK DETECTOR

The shock detector (see Fig.21) can be switched on during normal track following, and detects within an adjustable frequency whether disturbances in the radial spot position relative to the track exceed an adjustable level (controlled by shock_level). Every time the radial tracking error (RE) exceeds this level the radial control bandwidth is switched to twice its original bandwidth and the loop gain is increased by a factor of 4.

The shock detection level is adjustable in 16 steps from 0 to 100% of the traverse radial amplitude which is sent to an amplitude detection unit via an adjustable band-pass filter (controlled by sledge_parm1); lower corner frequency can be set at either 0 or 20 Hz, and upper corner frequency at 750 or 1850 Hz. The shock detector is switched off automatically during jump mode.

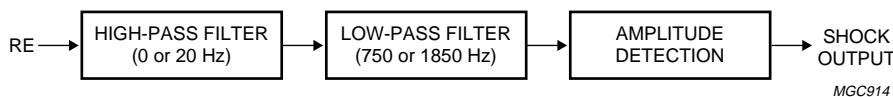


Fig.21 Block diagram of radial shock detector.

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7.14 Microcontroller interface

Communication on the microcontroller interface can be set-up in two different modes:

1. 4-wire bus mode: protocol compatible with SAA7345 (CD6) and TDA1301 (DSIC2) where:
 - a) SCL = serial bit clock
 - b) SDA = serial data
 - c) RAB = $\overline{R/W}$ control and data strobe (active HIGH) for writing to registers 0 to F, reading status bit selected via register 2 and reading Q-channel subcode.
 - d) SILD = $\overline{R/W}$ control and data strobe (active LOW) for servo commands.
2. I²C-bus mode: I²C-bus protocol where SAA7377 behaves as slave device, activated by setting RAB = HIGH and SILD = LOW where:
 - a) I²C-bus slave address (write mode) = 30H.
 - b) I²C-bus slave address (read mode) = 31H.
 - c) Maximum data transfer rate = 400 kbytes/s

It should be noted that only servo commands can be used therefore, writing to registers 0 to F, reading decoder status and reading Q-channel subcode data must be performed by servo commands.

7.14.1 MICROCONTROLLER INTERFACE (4-WIRE BUS MODE)

7.14.1.1 Writing data to registers 0 to F

The sixteen 4-bit programmable configuration registers, 0 to F (see Table 12), can be written to via the microcontroller interface using the protocol shown in Fig.22.

It should be noted that SILD must be held HIGH; A3 to A0 identifies the register number and D3 to D0 is the data; the data is latched into the register on the LOW-to-HIGH transition of RAB.

7.14.1.2 Writing repeated data to registers 0 to F

The same data can be repeated several times (e.g. for a fade function) by applying extra RAB pulses as shown in Fig.23. It should be noted that SCL must stay HIGH between RAB pulses.

7.14.1.3 Reading decoder status information on SDA

There are several internal status signals, selected via register 2, which can be made available on the SDA line;

SUBQREADY-I: LOW if new subcode word is ready in Q-channel register.

MOTSTART1: HIGH if motor is turning at 75% or more of nominal speed.

MOTSTART2: HIGH if motor is turning at 50% or more of nominal speed.

MOTSTOP: HIGH if motor is turning at 12% or less of nominal speed. Can be set to indicate 6% or less (instead of 12% or less) via register E.

PLL Lock: HIGH if sync coincidence signals are found.

V1: follows input on V1 pin.

V2: follows input on V2 pin.

MOTOR-OV: HIGH if the motor servo output stage saturates.

FIFO-OV: HIGH if FIFO overflows.

SHOCK: MOTSTART2 + PLL Lock + MOTOR-OV + FIFO-OV + servo interrupt signal + OTD (HIGH if shock detected).

LA-SHOCK: latched SHOCK signal.

The status read protocol is shown in Fig.24. It should be noted that SILD must be held HIGH.

7.14.1.4 Reading Q-channel subcode

To read the Q-channel subcode direct in the 4-wire bus mode, the SUBQREADY-I signal should be selected as status signal. The subcode read protocol is illustrated in Fig.25.

It should be noted that SILD must be held HIGH; after subcode read starts, the microcontroller may take as long as it wants to terminate the read operation; when enough subcode has been read (1 to 96 bits), terminate reading by pulling RAB LOW.

Alternatively, the Q-channel subcode can be read using a servo command as follows:

- Use the read high-level status command to monitor the subcode ready signal.
- Send the read subcode command, and read the required number of bytes (up to 12).
- Send the read high-level status command; to re-enable the decoder interface.

7.14.1.5 Behaviour of the SUBQREADY-I signal

When the CRC of the Q-channel word is good, and no subcode is being read, the SUBQREADY-I status signal will react as shown in Fig.26.

When the CRC is good and the subcode is being read, the timing in Fig.27 applies.

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If t_1 (SUBQREADY-I status LOW to end of subcode read) is below 2.6 ms, then $t_2 = 13.1$ ms (i.e. the microcontroller can read all subcode frames if it completes the read operation within 2.6 ms after the subcode is ready). If this criterion is not met, it is only possible to guarantee that t_3 will be below 26.2 ms (approximately).

If subcode frames with failed CRCs are present, the t_2 and t_3 times will be increased by 13.1 ms for each defective subcode frame.

7.14.1.6 Write servo commands

A write data command is used to transfer data (a number of bytes) from the microcontroller, using the protocol shown in Fig.28. The first of these bytes is the command byte and the following are data bytes; the number (between 1 and 7) depends on the command byte.

It should be noted that RAB must be held LOW; the command or data is interpreted by the SAA7377 after the HIGH-to-LOW transition of SILD; there must be a minimum time of 70 μ s between SILD pulses.

7.14.1.7 Writing repeated data in servo commands

The same data byte can be repeated by applying extra SILD pulses as shown in Fig.29. SCL must stay HIGH between the SILD pulses.

7.14.1.8 Read servo commands

A read data command is used to transfer data (status information) to the microcontroller, using the protocol shown in Fig.30. The first byte written determines the type of command. After this byte a variable number of bytes can be read. It should be noted that RAB must be held LOW; after the end of the command byte (LOW-to-HIGH transition on SILD) there must be a delay of 70 μ s before reading data is started (i.e. the next HIGH-to-LOW transition on SILD); there must be a minimum time of 70 μ s between SILD pulses.

7.14.2 MICROCONTROLLER INTERFACE (I²C-BUS MODE)

Bytes are transferred over the interface in groups (i.e. servo commands) of which there are two types: write data commands and read data commands.

The sequence for a write data command (that requires 3 data bytes) is as follows;

- Send START condition
- Send address 30H (write)
- Write command byte
- Write data byte 1
- Write data byte 2.
- Write data byte 3
- Send STOP condition.

It should be noted that more than one command can be sent in one write sequence.

The sequence for a read data command (that reads 2 data bytes) is as follows;

- Send START condition
- Send address 30H (write)
- Write command byte
- Send STOP condition.
- Send START condition
- Send address 31H (read)
- Read data byte 1
- Read data byte 2
- Send STOP condition.

It should be noted that the timing constraints specified for the read and write servo commands must still be adhered to.

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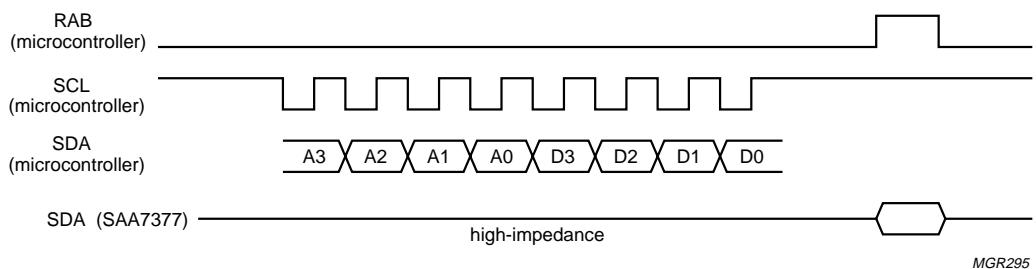


Fig.22 Microcontroller write protocol for registers 0 to F.

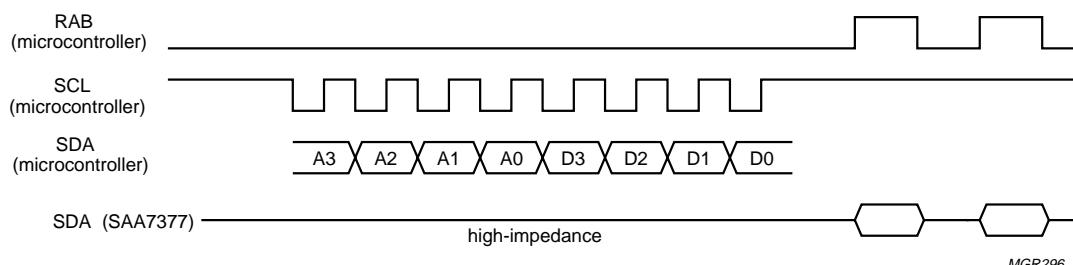


Fig.23 Microcontroller write protocol for registers 0 to F (repeat mode).

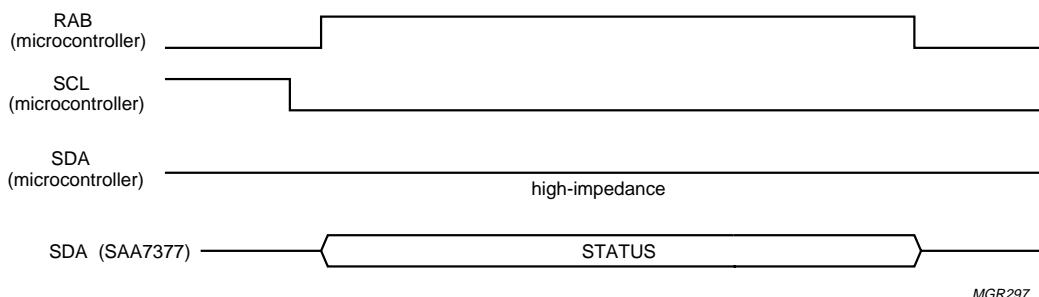


Fig.24 Microcontroller read protocol for decoder status on SDA.

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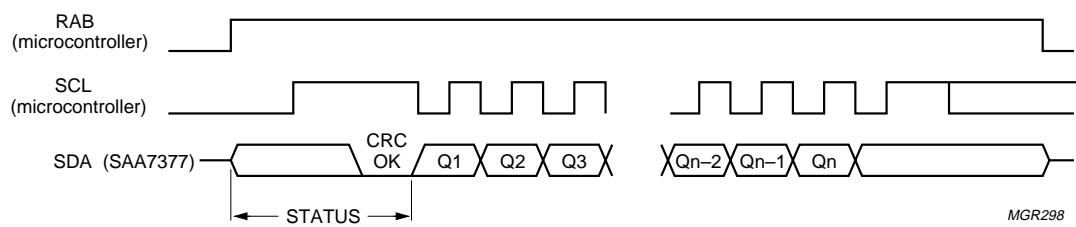


Fig.25 Microcontroller protocol for reading Q-channel subcode.

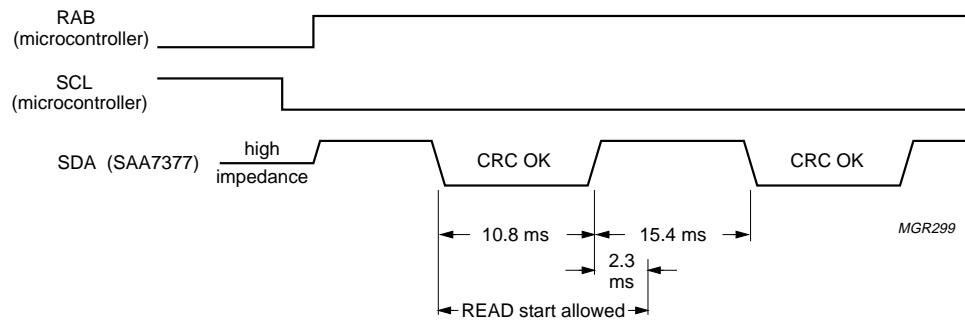


Fig.26 SUBQREADY-I status timing when no subcode is read.

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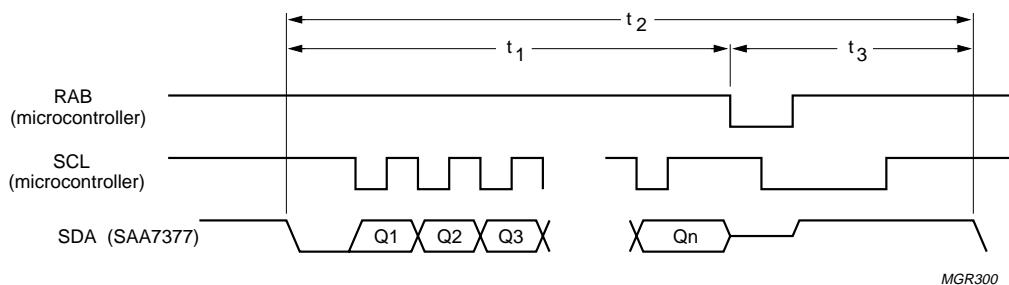


Fig.27 SUBQREADY-I status timing when subcode is read.

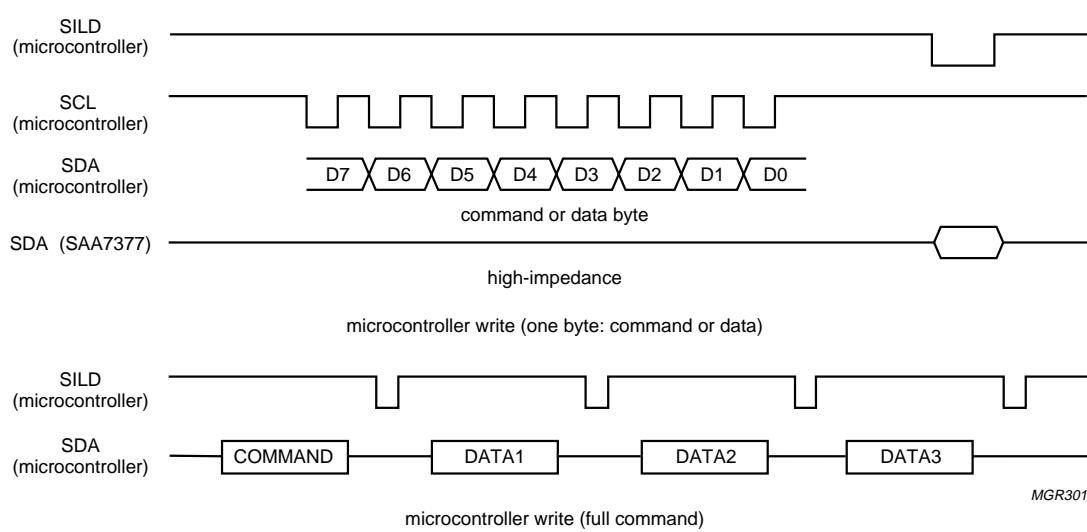


Fig.28 Microcontroller protocol for write servo commands.

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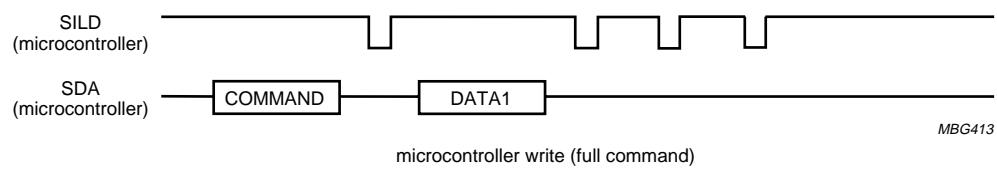


Fig.29 Microcontroller protocol for repeated data in write servo commands.

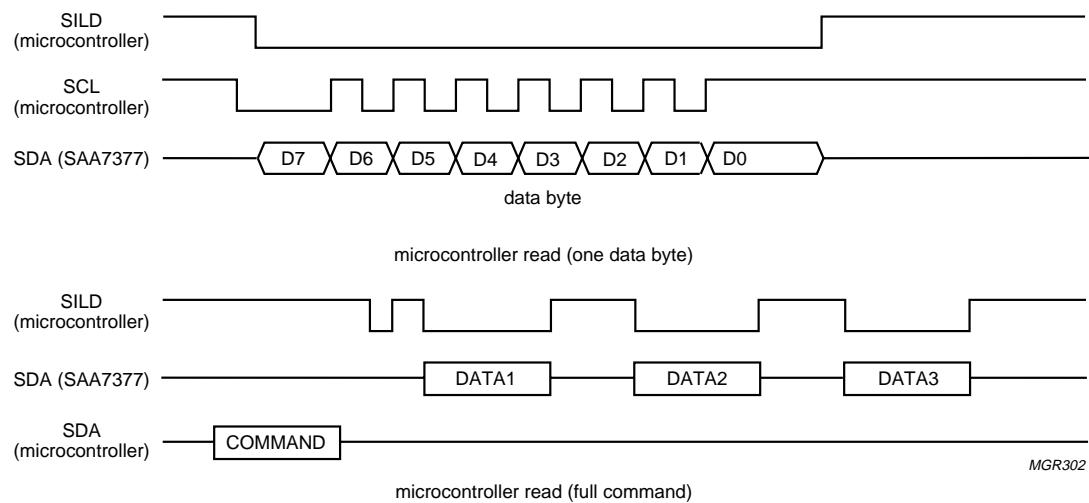


Fig.30 Microcontroller protocol for read servo commands.

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7.14.3 SUMMARY OF FUNCTIONS CONTROLLED BY REGISTERS 0 TO F

Table 12 Registers 0 to F

| REGISTER | ADDRESS | DATA | FUNCTION | INITIAL ⁽¹⁾ |
|-----------------------------|---------|-------|--|------------------------|
| 0 (fade and attenuation) | 0000 | 0000 | mute | reset |
| | | 0010 | attenuate | — |
| | | 0001 | full scale | — |
| | | 0100 | step down | — |
| | | 0101 | step up | — |
| 1 (motor mode) | 0001 | x000 | motor off mode | reset |
| | | x 001 | motor stop mode 1 | — |
| | | x010 | motor stop mode 2 | — |
| | | x011 | motor start mode 1 | — |
| | | x100 | motor start mode 2 | — |
| | | x101 | motor jump mode | — |
| | | x111 | motor play mode | — |
| | | x110 | motor jump mode 1 | — |
| | | 1xxx | anti-windup active | — |
| | | 0xxx | anti-windup off | reset |
| 2 (status control) | 0010 | 0000 | status = SUBQREADY-I | reset |
| | | 0001 | status = MOTSTART1 | — |
| | | 0010 | status = MOTSTART2 | — |
| | | 0011 | status = MOTSTOP | — |
| | | 0100 | status = PLL Lock | — |
| | | 0101 | status = V1 | — |
| | | 0110 | status = V2 | — |
| | | 0111 | status = MOTOR-OV | — |
| | | 1000 | status = FIFO overflow | — |
| | | 1001 | status = shock detect | — |
| | | 1010 | status = latched shock detect | — |
| | | 1011 | status = latched shock detect reset | — |
| 3 (DAC output) | 0011 | 1100 | I ² S-bus; 18-bit; 4f _s mode | reset |
| | | 1111 | I ² S-bus; 18-bit; 2f _s mode | — |
| | | 1110 | I ² S-bus; 16-bit; f _s mode | — |
| | | 0000 | EIAJ; 16-bit; 4f _s | — |
| | | 0011 | EIAJ; 16-bit; 2f _s | — |
| | | 0010 | EIAJ; 16-bit; f _s | — |
| | | 0100 | EIAJ; 18-bit; 4f _s | — |
| | | 0111 | EIAJ; 18-bit; 2f _s | — |
| | | 0110 | EIAJ; 18-bit; f _s | — |

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| REGISTER | ADDRESS | DATA | FUNCTION | INITIAL ⁽¹⁾ |
|---|---------|------|---|------------------------|
| 4 (motor gain) | 0100 | x000 | motor gain G = 3.2 | reset |
| | | x001 | motor gain G = 4.0 | — |
| | | x010 | motor gain G = 6.4 | — |
| | | x011 | motor gain G = 8.0 | — |
| | | x100 | motor gain G = 12.8 | — |
| | | x101 | motor gain G = 16.0 | — |
| | | x110 | motor gain G = 25.6 | — |
| | | x111 | motor gain G = 32.0 | — |
| | | 0xxx | disable comparator clock divider | reset |
| | | 1xxx | enable comparator clock divider; only if SELLPLL set HIGH | — |
| 5 (motor bandwidth) | 0101 | xx00 | motor f4 = 0.5 Hz | reset |
| | | xx01 | motor f4 = 0.7 Hz | — |
| | | xx10 | motor f4 = 1.4 Hz | — |
| | | xx11 | motor f4 = 2.8 Hz | — |
| | | 00xx | motor f3 = 0.85 Hz | reset |
| | | 01xx | motor f3 = 1.71 Hz | — |
| | | 10xx | motor f3 = 3.42 Hz | — |
| 6 (motor output configuration) | 0110 | xx00 | motor power maximum 37% | reset |
| | | xx01 | motor power maximum 50% | — |
| | | xx10 | motor power maximum 75% | — |
| | | xx11 | motor power maximum 100% | — |
| | | 00xx | MOTO1, MOTO2 pins 3-state | reset |
| | | 01xx | motor PWM mode | — |
| | | 10xx | motor PDM mode | — |
| | | 11xx | motor CDV mode | — |
| 7 (DAC output and status control) | 0111 | xx00 | interrupt signal from servo at STATUS pin | reset |
| | | xx10 | status bit from decoder status register at STATUS pin | — |
| | | x0xx | DAC data normal value | reset |
| | | x1xx | DAC data inverted value | — |
| | | 0xxx | left channel first at DAC (WCLK normal) | reset |
| | | 1xxx | right channel first at DAC (WCLK inverted) | — |
| 8 (PLL loop filter bandwidth) | | | see Table 13 | |
| 9 (PLL equalization) | 1001 | 0011 | PLL loop filter equalization | reset |
| | | 0001 | PLL 30 ns over-equalization | — |
| | | 0010 | PLL 15 ns over-equalization | — |
| | | 0100 | PLL 15 ns under-equalization | — |
| | | 0101 | PLL 30 ns under-equalization | — |

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| REGISTER | ADDRESS | DATA | FUNCTION | INITIAL ⁽¹⁾ |
|------------------------------------|---------|------|---|------------------------|
| A (EBU output) | 1010 | x010 | level II clock accuracy (<1000 ppm) | reset |
| | | x011 | level I clock accuracy (<50 ppm) | — |
| | | x110 | level III clock accuracy (>1000 ppm) | — |
| | | x111 | EBU off - output LOW | — |
| | | 0xxx | flags in EBU off | reset |
| | | 1xxx | flags in EBU on | — |
| B (speed control) | 1011 | 00xx | 33.8688 MHz crystal present, or 8.4672 MHz crystal with SELPLL set HIGH | reset |
| | | 01xx | 16.9344 MHz crystal present | — |
| | | xx00 | standby 1:'CD-STOP' mode | reset |
| | | xx10 | standby 2:'CD-PAUSE' mode | — |
| | | xx11 | operating mode | — |
| C (versatile pins interface) | 1100 | xxx1 | external off-track signal input at V1 | — |
| | | xxx0 | internal off-track signal used (V1 may be read via STATUS) | reset |
| | | xx0x | kill-L at KILL output, kill-R at V3 output | — |
| | | 001x | V3 = 0; single KILL output | reset |
| | | 011x | V3 = 1; single KILL output | — |
| D (versatile pins interface) | 1101 | 0000 | 4-line motor (using V4 and V5) | — |
| | | xx01 | Q-to-W subcode at V4 | — |
| | | xx10 | V4 = 0 | — |
| | | xx11 | V4 = 1 | reset |
| | | 01xx | de-emphasis signal at V5, no internal de-emphasis filter | — |
| | | 10xx | V5 = 0 | — |
| | | 11xx | V5 = 1 | reset |
| E | 1110 | 0100 | motor brakes to 12% | reset |
| | | 0101 | motor brakes to 6% | — |
| F (subcode interface) | 1111 | x000 | subcode interface off | reset |
| | | x100 | subcode interface on | — |
| | | 0xxx | 4-wire subcode | reset |
| | | 1xxx | 3-wire subcode | — |

Note

1. The initial column shows the power-on reset state.

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Table 13 Loop filter bandwidth

| REGISTER | ADDRESS | DATA | FUNCTION | | | INITIAL ⁽¹⁾ |
|-------------------------------------|---------|------|---------------------------|-------------------------------|-------------------------------|------------------------|
| | | | LOOP BANDWIDTH (Hz) | INTERNAL BANDWIDTH (Hz) | LOW-PASS BANDWIDTH (Hz) | |
| 8 (PLL loop filter bandwidth) | 1000 | 0000 | 1640 | 525 | 8400 | — |
| | | 0001 | 3279 | 263 | 16800 | — |
| | | 0010 | 6560 | 131 | 33600 | — |
| | | 0100 | 1640 | 1050 | 8400 | — |
| | | 0101 | 3279 | 525 | 16800 | — |
| | | 0110 | 6560 | 263 | 33600 | — |
| | | 1000 | 1640 | 2101 | 8400 | — |
| | | 1001 | 3279 | 1050 | 16800 | reset |
| | | 1010 | 6560 | 525 | 33600 | — |
| | | 1100 | 1640 | 4200 | 8400 | — |
| | | 1101 | 3279 | 2101 | 16800 | — |
| | | 1110 | 6560 | 1050 | 33600 | — |

Note

1. The initial column shows the power-on reset state.

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7.14.4 SUMMARY OF SERVO COMMANDS

A list of the servo commands are given in Table 14. It should be noted that these are not fully backwards compatible with DSIC2.

Table 14 CD7 servo commands

| COMMANDS | CODE | BYTES | PARAMETERS |
|------------------------------------|------|----------|--|
| Write commands | | | |
| Write_focus_coefs1 | 17H | 7 | <foc_parm3> <foc_int> <ramp_incr> <ramp_height> <ramp_offset> <FE_start> <foc_gain> |
| Write_focus_coefs2 | 27H | 7 | <defect_parm> <rad_parm_jump> <vel_parm2> <vel_parm1> <foc_parm1> <foc_parm2> <CA_drop> |
| Write_focus_command | 33H | 3 | <foc_mask> <foc_stat> <shock_level> |
| Focus_gain_up | 42H | 2 | <foc_gain> <foc_parm1> |
| Focus_gain_down | 62H | 2 | <foc_gain> <foc_parm1> |
| Write_radial_coefs | 57H | 7 | <rad_length_lead> <rad_int> <rad_parm_play> <rad_pole_noise> <rad_gain> <sledge_parm2> <sledge_parm_1> |
| Preset_Latch | 81H | 1 | <chip_init> |
| Radial_off | C1H | 1 | '1CH' |
| Radial_init | C1H | 1 | '3CH' |
| Short_jump | C3H | 3 | <tracks_hi> <tracks_lo> <rad_stat> |
| Long_jump | C5H | 5 | <brake_dist> <sledge_U_max> <tracks_hi> <tracks_lo> <rad_stat> |
| Steer_sledge | B1H | 1 | <sledge_level> |
| Preset_init | 93H | 3 | <re_offset> <re_gain> <sum_gain> |
| Write_decoder_reg ⁽¹⁾ | D1H | 1 | <decoder_reg_data> |
| Write_parameter | A2H | 2 | <param_ram_addr> <param_data> |
| Read commands | | | |
| Read_Q_subcode ⁽¹⁾⁽²⁾ | 0H | up to 12 | <Q_sub1..10> <peak_l> <peak_r> |
| Read_status | 70H | up to 5 | <foc_stat> <rad_stat> <rad_int_lpf> <tracks_hi> <tracks_lo> |
| Read_hilevel_status ⁽³⁾ | E0H | up to 4 | <intreq> <dec_stat> <seq_stat> <motor_start_time> |
| Read_aux_status | F0H | up to 3 | <re_offset> <re_gain> <sum_gain> |

Notes

1. These commands only available when internal decoder interface is enabled.
2. <peak_l> and <peak_r> bytes are clocked out LSB first.
3. Decoder status flag information in <dec_stat> is only valid when the internal decoder interface is enabled.

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7.14.5 SUMMARY OF SERVO COMMAND PARAMETERS

Table 15 Servo command parameters

| PARAMETER | RAM ADDRESS | AFFECTS | POR VALUE | DETERMINES |
|-------------------|-------------|-----------------|-----------|---|
| foc_parm_1 | – | focus PID | – | end of focus lead |
| | | | | defect detector enabling |
| foc_parm_2 | – | focus PID | – | focus low-pass |
| | | | | focus error normalising |
| foc_parm_3 | – | focus PID | – | focus lead length |
| | | | | minimum light level |
| foc_int | 14H | focus PID | – | focus integrator crossover frequency |
| foc_gain | 15H | focus PID | 70H | focus PID loop gain |
| CA_drop | 12H | focus PID | – | sensitivity of drop-out detector |
| ramp_offset | 16H | focus ramp | – | asymmetry of focus ramp |
| ramp_height | 18H | focus ramp | – | peak-to-peak value of ramp voltage |
| ramp_incr | – | focus ramp | – | slope of ramp voltage |
| FE_start | 19H | focus ramp | – | minimum value of focus error |
| rad_parm_play | 28H | radial PID | – | end of radial lead |
| rad_pole_noise | 29H | radial PID | – | radial low-pass |
| rad_length_lead | 1CH | radial PID | – | length of radial lead |
| rad_int | 1EH | radial PID | – | radial integrator crossover frequency |
| rad_gain | 2AH | radial PID | 70H | radial loop gain |
| rad_parm_jump | 27H | radial jump | – | filter during jump |
| vel_parm1 | 1FH | radial jump | – | PI controller crossover frequencies |
| vel_parm2 | 32H | radial jump | – | jump pre-defined profile |
| speed_threshold | 48H | radial jump | – | maximum speed in fastrad mode |
| hold_mult | 49H | radial jump | 00H | sledge bandwidth during jump |
| brake_dist_max | 21H | radial jump | – | maximum sledge distance allowed in fast actuator steered mode |
| sledge_long_brake | 58H | radial jump | 7FH | brake distance of sledge |
| sledge_Umax | – | sledge | – | voltage on sledge during long jump |
| sledge_level | – | sledge | – | voltage on sledge when steered |
| sledge_parm_1 | 36H | sledge | – | sledge integrator crossover frequency |
| sledge_parm_2 | 17H | sledge | – | sledge low-pass frequencies |
| | | | | sledge gain |
| | | | | sledge operation mode |
| sledge_pulse1 | 46H | pulsed sledge | – | pulse width |
| sledge_pulse2 | 64H | pulsed sledge | – | pulse height |
| defect_parm | – | defect detector | – | defect detector setting |
| shock_level | – | shock detector | – | shock detector operation |
| playwatchtime | 54H | watchdog | – | radial on-track watchdog time |
| jumpwatchtime | 57H | watchdog | – | radial jump watchdog time-out |

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| PARAMETER | RAM ADDRESS | AFFECTS | POR VALUE | DETERMINES |
|-------------------|-------------|-------------------|-----------|---|
| radcontrol | 59H | watchdog | – | enable/disable automatic radial off feature |
| chip_init | – | set-up | – | V_{RH} level setting |
| | | | | enable/disable decoder interface |
| xtra_preset | 4AH | set-up | 38H | laser on/off |
| | | | | RA, FO and SL PDM modulating frequency |
| | | | | microcontroller communication to decoder part |
| cd6cmd | 4DH | decoder interface | – | decoder part commands |
| interrupt_mask | 53H | STATUS pin | – | enabled interrupts |
| seq_control | 42H | autosequencer | – | autosequencer control |
| focus_start_time | 5EH | autosequencer | – | focus start time |
| motor_start_time1 | 5FH | autosequencer | – | motor start 1 time |
| motor_start_time2 | 60H | autosequencer | – | motor start 2 time |
| radial_init_time | 61H | autosequencer | – | radial initialization time |
| brake_time | 62H | autosequencer | – | brake time |
| RadCmdByte | 63H | autosequencer | – | radial command byte |
| osc_inc | 68H | focus/radial AGC | – | AGC control |
| | | | | frequency of injected signal |
| phase_shift | 67H | focus/radial AGC | – | phase shift of injected signal |
| level1 | 69H | focus/radial AGC | – | amplitude of signal injected |
| level2 | 6AH | focus/radial AGC | – | amplitude of signal injected |
| agc_gain | 6CH | focus/radial AGC | – | focus/radial gain |

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8 LIMITING VALUES

In accordance with the Absolute Maximum Rating System (IEC 134).

| SYMBOL | PARAMETER | CONDITIONS | MIN. | MAX. | UNIT |
|--------------|--|------------|-------|----------------|------|
| V_{DD} | supply voltage | note 1 | -0.5 | +6.5 | V |
| $V_{I(max)}$ | maximum Input voltage (any input) | | -0.5 | $V_{DD} + 0.5$ | V |
| V_O | output voltage (any output) | | -0.5 | +6.5 | V |
| V_{DDdiff} | difference between V_{DDA} and V_{DDD} | | - | ± 0.25 | V |
| I_O | output current (continuous) | | - | ± 20 | mA |
| I_{IK} | DC input diode current (continuous) | | - | ± 20 | mA |
| T_{amb} | operating ambient temperature | | -40 | +85 | °C |
| T_{stg} | storage temperature | | -55 | +125 | °C |
| V_{es} | electrostatic handling | note 2 | -2000 | +2000 | V |
| | | note 3 | -200 | +200 | V |

Notes

1. All V_{DD} and V_{SS} connections must be made externally to the same power supply.
2. Equivalent to discharging a 100 pF capacitor via a 1.5 kΩ series resistor with a rise time of 15 ns.
3. Equivalent to discharging a 200 pF capacitor via a 2.5 μH series inductor.

9 OPERATING CHARACTERISTICS

$V_{DD} = 3.4$ to 5.5 V; $V_{SS} = 0$ V; $T_{amb} = -10$ to $+70$ °C; unless otherwise specified.

| SYMBOL | PARAMETER | CONDITIONS | MIN. | TYP. | MAX. | UNIT |
|--|----------------------------------|----------------|------|-------------|----------------|------|
| Supply | | | | | | |
| V_{DD} | supply voltage | | 3.4 | 5.0 | 5.5 | V |
| I_{DD} | supply current | $V_{DD} = 5$ V | - | 49 | - | mA |
| Decoder analog front-end ($V_{DDA} = 5$ V; $V_{SSA} = 0$ V; $T_{amb} = 25$ °C) | | | | | | |
| COMPARATOR INPUTS: HFIN AND HFREF | | | | | | |
| f_{clk} | clock frequency | note 1 | 8 | - | 70 | MHz |
| $V_{th(sw)}$ | switching voltage threshold | | 1.2 | - | $V_{DD} - 0.8$ | V |
| V_{tpt} | HFIN input voltage level | | - | 1.0 | - | V |
| REFERENCE GENERATOR: I_{ref} | | | | | | |
| V_{ref} | reference voltage level (pin 18) | | - | $0.5V_{DD}$ | - | V |

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| SYMBOL | PARAMETER | CONDITIONS | MIN. | TYP. | MAX. | UNIT |
|---|--|--------------------------------|---------------|--------------------------|----------------|------|
| Servo analog part ($V_{DDA} = 5$ V; $V_{SSA} = 0$ V; $T_{amb} = 25$ °C) | | | | | | |
| PINS D1 TO D4, R1, R2, V_{RH} , V_{RL} AND I_{refT} | | | | | | |
| I_{refT} | input reference current | | 1.935 | — | 5.45 | µA |
| R_{IrefT} | external resistor on pin 10 | | 220 | — | 620 | kΩ |
| V_{IrefT} | voltage on reference current input | | — | 1.2 | — | V |
| $I_{D(max)}$ | maximum input current for central diode input signal | note 2 | 3.871 | — | 10.9 | µA |
| $I_{R(max)}$ | maximum input current for satellite diode input signal | note 2 | 1.935 | — | 5.45 | µA |
| V_{RL} | LOW level reference voltage | | 0 | 0 | 0 | V |
| V_{RH} | HIGH level reference voltage | output state 0; note 3 | — | 0.5 | — | V |
| | | output state v; note 3 | —30% | $0.5 \times 10^{v/44.4}$ | +30% | V |
| | | output state 31; note 3 | — | 2.5 | — | V |
| (THD+N)/S | total harmonic distortion plus noise | at 0 dB; note 4 | — | —50 | —45 | dB |
| S/N | signal-to-noise ratio | | — | 55 | — | dB |
| PSRR | power supply ripple rejection at V_{DDA2} | note 5 | — | 45 | — | dB |
| G_{tol} | gain tolerance | note 6 | —12 | 0 | +12 | % |
| ΔG_v | variation of gain between channels | | — | — | 2 | % |
| α_{cs} | channel separation | | — | 60 | — | dB |
| Digital inputs | | | | | | |
| INPUTS: $\overline{\text{RESET}}$, V1, V2, SELPLL (CMOS INPUT WITH PULL-UP RESISTOR AND HYSTERESIS) | | | | | | |
| $V_{thr(sw)}$ | switching voltage threshold rising | | — | — | 0.8 V_{DDD} | V |
| $V_{thf(sw)}$ | switching voltage threshold falling | | 0.2 V_{DDD} | — | — | V |
| V_{hys} | hysteresis voltage | | — | 0.33 V_{DDD} | — | V |
| $R_{I(pu)}$ | input pull-up resistance | $V_i = 0$ V | — | 50 | — | kΩ |
| C_{in} | input capacitance | | — | — | 10 | pF |
| t_{resL} | reset pulse width (active LOW) | $\overline{\text{RESET}}$ only | 1 | — | — | µs |
| INPUTS: SCL, RAB, SILD AND RCK (CMOS INPUT) | | | | | | |
| V_{IL} | LOW level input voltage | | —0.3 | — | 0.3 V_{DD} | V |
| V_{IH} | HIGH level input voltage | | 0.7 V_{DD} | — | $V_{DD} + 0.3$ | V |
| I_{LI} | input leakage current | $V_i = 0 - V_{DD}$ | —10 | — | +10 | µA |
| C_{in} | input capacitance | | — | — | 10 | pF |

Digital servo processor and Compact Disc decoder (CD7)

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| SYMBOL | PARAMETER | CONDITIONS | MIN. | TYP. | MAX. | UNIT |
|---|---------------------------|---|-----------------|------|-----------|------|
| Digital outputs | | | | | | |
| OUTPUT: CL4 | | | | | | |
| V_{OL} | LOW level output voltage | $I_{OL} = 1 \text{ mA}$ | 0 | — | 0.4 | V |
| V_{OH} | HIGH level output voltage | $I_{OH} = -1 \text{ mA}$ | $V_{DDD} - 0.4$ | — | V_{DDD} | V |
| C_L | load capacitance | | — | — | 25 | pF |
| t_r | output rise time | $C_L = 20 \text{ pF};$ 0.8 to $(V_{DDD} - 0.8)$ | — | — | 20 | ns |
| t_f | output fall time | $C_L = 20 \text{ pF};$ $(V_{DDD} - 0.8)$ to 0.8 | — | — | 20 | ns |
| OUTPUT: CL16 | | | | | | |
| V_{OL} | LOW level output voltage | $I_{OL} = 1 \text{ mA}$ | 0 | — | 0.4 | V |
| V_{OH} | HIGH level output voltage | $I_{OH} = -1 \text{ mA}$ | $V_{DDD} - 0.4$ | — | V_{DDD} | V |
| C_L | load capacitance | | — | — | 50 | pF |
| t_r | output rise time | $C_L = 20 \text{ pF};$ 0.8 – $(V_{DDD} - 0.8)$ | — | — | 15 | ns |
| t_f | output fall time | $C_L = 20 \text{ pF};$ $(V_{DDD} - 0.8) - 0.8$ | — | — | 15 | ns |
| OUTPUTS: V4 AND V5 | | | | | | |
| V_{OL} | LOW level output voltage | $V_{DDD} = 4.5 \text{ to } 5.5 \text{ V};$ $I_{OL} = 10 \text{ mA}$ | 0 | — | 1.0 | V |
| | | $V_{DDD} = 3.4 \text{ to } 5.5 \text{ V};$ $I_{OL} = 5 \text{ mA}$ | 0 | — | 1.0 | V |
| V_{OH} | HIGH level output voltage | $V_{DDD} = 4.5 \text{ to } 5.5 \text{ V};$ $I_{OH} = -10 \text{ mA}$ | $V_{DDD} - 1$ | — | V_{DDD} | V |
| | | $V_{DDD} = 3.4 \text{ to } 5.5 \text{ V};$ $I_{OH} = -5 \text{ mA}$ | $V_{DDD} - 1$ | — | V_{DDD} | V |
| C_L | load capacitance | | — | — | 50 | pF |
| t_r | output rise time | $C_L = 20 \text{ pF};$ 0.8 – $(V_{DDD} - 0.8)$ | — | — | 10 | ns |
| t_f | output fall time | $C_L = 20 \text{ pF};$ $(V_{DDD} - 0.8) - 0.8$ | — | — | 10 | ns |
| Open-drain outputs | | | | | | |
| OUTPUTS: CFLG, C2FAIL, STATUS, KILL, V3 AND LDON (OPEN-DRAIN OUTPUT WITH PROTECTION DIODE TO V_{DD}) | | | | | | |
| V_{OL} | LOW level output voltage | $I_{OL} = 1 \text{ mA}$ | 0 | — | 0.4 | V |
| I_{OL} | LOW level output current | | — | — | 2 | mA |
| C_L | load capacitance | | — | — | 25 | pF |
| t_f | output fall time | $C_L = 20 \text{ pF};$ $(V_{DDD} - 0.8) - 0.8$ | — | — | 30 | ns |

Digital servo processor and Compact Disc decoder (CD7)

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| SYMBOL | PARAMETER | CONDITIONS | MIN. | TYP. | MAX. | UNIT |
|---|---|--|----------------|------|----------|---------------|
| 3-state outputs | | | | | | |
| OUTPUTS: CLK, WCLK, DATA AND CL11 | | | | | | |
| V_{OL} | LOW level output voltage | $I_{OL} = 1 \text{ mA}$ | 0 | — | 0.4 | V |
| V_{OH} | HIGH level output voltage | $I_{OH} = -1 \text{ mA}$ | $V_{DD} - 0.4$ | — | V_{DD} | V |
| C_L | load capacitance | | — | — | 50 | pF |
| t_r | output rise time | $C_L = 20 \text{ pF};$ $0.8 - (V_{DD} - 0.8)$ | — | — | 15 | ns |
| t_f | output fall time | $C_L = 20 \text{ pF};$ $(V_{DD} - 0.8) - 0.8$ | — | — | 15 | ns |
| I_{ZO} | output 3-state leakage current | $V_i = 0 - V_{DD}$ | -10 | — | +10 | μA |
| OUTPUT: CL11 | | | | | | |
| t_H | output HIGH time (relative to clock period) | $V_o = 1.5 \text{ V}$ | 45 | 50 | 55 | % |
| OUTPUTS: RA, FO, SL, SBSY, SFSY AND SUB | | | | | | |
| V_{OL} | LOW level output voltage | $I_{OL} = 1 \text{ mA}$ | 0 | — | 0.4 | V |
| V_{OH} | HIGH level output voltage | $I_{OH} = -1 \text{ mA}$ | $V_{DD} - 0.4$ | — | V_{DD} | V |
| C_L | load capacitance | | — | — | 25 | pF |
| t_r | output rise time | $C_L = 20 \text{ pF};$ $0.8 - (V_{DD} - 0.8)$ | — | — | 20 | ns |
| t_f | output fall time | $C_L = 20 \text{ pF};$ $(V_{DD} - 0.8) - 0.8$ | — | — | 20 | ns |
| I_{ZO} | 3-state leakage current | $V_i = 0 - V_{DD}$ | -10 | — | +10 | μA |
| OUTPUTS: MOTO1, MOTO2 AND DOBM | | | | | | |
| V_{OL} | LOW level output voltage | $V_{DD} = 4.5 \text{ to } 5.5 \text{ V};$ $I_{OL} = 10 \text{ mA}$ | 0 | — | 1.0 | V |
| | | $V_{DD} = 3.4 \text{ to } 5.5 \text{ V};$ $I_{OL} = 5 \text{ mA}$ | 0 | — | 1.0 | V |
| V_{OH} | HIGH level output voltage | $V_{DD} = 4.5 \text{ to } 5.5 \text{ V};$ $I_{OL} = -10 \text{ mA}$ | $V_{DD} - 1$ | — | V_{DD} | V |
| | | $V_{DD} = 3.4 \text{ to } 5.5 \text{ V};$ $I_{OL} = -5 \text{ mA}$ | $V_{DD} - 1$ | — | V_{DD} | V |
| C_L | load capacitance | | — | — | 50 | pF |
| t_r | output rise time | $C_L = 20 \text{ pF};$ $0.8 - (V_{DD} - 0.8)$ | — | — | 10 | ns |
| t_f | output fall time | $C_L = 20 \text{ pF};$ $(V_{DD} - 0.8) - 0.8$ | — | — | 10 | ns |
| I_{ZO} | 3-state leakage current | $V_i = 0 - V_{DD}$ | -10 | — | +10 | μA |

Digital servo processor and Compact Disc decoder (CD7)

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| SYMBOL | PARAMETER | CONDITIONS | MIN. | TYP. | MAX. | UNIT |
|--|----------------------------------|---|---------------------|--------|------------------------|------|
| Digital input/output | | | | | | |
| INPUT/OUTPUT: SDA [CMOS INPUT/OPEN-DRAIN I ² C-BUS OUTPUT (WITH PROTECTION DIODE TO V _{DDD})] | | | | | | |
| V _{IL} | LOW level input voltage | | -0.3 | - | 0.3V _{DDD} | V |
| V _{IH} | HIGH level input voltage | | 0.7V _{DDD} | - | V _{DDD} + 0.3 | V |
| I _{ZO} | 3-state leakage current | V _i = 0 – V _{DDD} | -10 | - | +10 | μA |
| C _{in} | input capacitance | | - | - | 10 | pF |
| V _{OL} | LOW level output voltage | I _{OL} = 2 mA | 0 | - | 0.4 | V |
| I _{OL} | LOW level output current | | - | - | 4 | mA |
| C _L | load capacitance | | - | - | 50 | pF |
| t _f | output fall time | C _L = 20 pF; (V _{DDD} – 0.8) – 0.8 | - | - | 15 | ns |
| Crystal oscillator | | | | | | |
| INPUT: CRIN (EXTERNAL CLOCK) | | | | | | |
| V _{IL} | LOW level input voltage | | -0.3 | - | 0.3V _{DD} | V |
| V _{IH} | HIGH level input voltage | | 0.7V _{DD} | - | V _{DD} + 0.3 | V |
| I _{LI} | input leakage current | | -10 | - | +10 | μA |
| C _{in} | input capacitance | | - | - | 10 | pF |
| OUTPUT: CROUT; see Figs 3 and 4 | | | | | | |
| f _{xtal} | crystal frequency | note 7 | 8 | 8.4672 | 35 | MHz |
| g _m | mutual conductance at 100 kHz | | - | 10 | - | mA/V |
| G _v | small signal voltage gain | G _v = g _m × R _O | - | 18 | - | V/V |
| C _{fb} | feedback capacitance | | - | - | 5 | pF |
| C _{out} | output capacitance | | - | - | 10 | pF |

Notes

1. Highest clock frequency at which data slicer produces 1010 output in analog self-test mode.
2. V_{RL} = 0 V, f_{sys} = 4.2336 MHz. The maximum input current depends on the value of the external resistor connected to I_{refT}:
 - a) For D1 to D4: I_{max} = 2.4/R_{refT} ⇒ 2.4/220 kΩ = 10.9 μA
 - b) For R1 and R2: I_{max} = 1.2/R_{refT} ⇒ 1.2/20 kΩ = 5.45 μA
3. Internal reference source with 32 different output voltages. Selection is achieved during a calibration period or via the serial interface. The values given are for an unloaded V_{RH}.
4. V_{RH} = 2.5 V and V_{RL} = 0 V, measuring bandwidth: 200 Hz to 20 kHz, f_{i(ADC)} = 1 kHz.
5. f_{ripple} = 1 kHz, V_{ripple} = 0.5 V (p-p).
6. Gain of the ADC is defined as G_{ADC} = f_{sys}/I_{max} (counts/μA); thus digital output = I_i × G_{ADC} where;
 - a) Digital output = the number of pulses at the digital output in counts/s and I_i = the DC input current in μA.
 - b) The maximum input current depends on the system frequency (f_{sys} = 4.2336 MHz) and on V_{RH} – V_{RL}.
 - c) The gain tolerance is the deviation from the calculated gain regarding note 2.
7. It is recommended that the series resistance of the crystal or ceramic resonator is ≤60 Ω.

Digital servo processor and Compact Disc decoder (CD7)

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10 OPERATING CHARACTERISTICS (SUBCODE INTERFACE TIMING)

$V_{DD} = 3.4$ to 5.5 V; $V_{SS} = 0$ V; $T_{amb} = -10$ to $+70$ °C; unless otherwise specified.

| SYMBOL | PARAMETER | CONDITIONS | MIN. | TYP. | MAX. | UNIT |
|--|---------------------------------------|------------|------|------|------|------|
| Subcode interface timing; see Fig.31 | | | | | | |
| INPUT: RCK | | | | | | |
| t_H | input clock HIGH time | | 2 | 4 | 6 | μs |
| t_L | input clock LOW time | | 2 | 4 | 6 | μs |
| t_r | input clock rise time | | — | — | 80 | ns |
| t_f | input clock fall time | | — | — | 80 | ns |
| t_{dC} | delay time SFSY to RCK | | 10 | — | 20 | μs |
| OUTPUTS: SBSY, SFSY AND SUB ($C_L = 20$ pF) | | | | | | |
| t_{Bcy} | block cycle | | 12.0 | 13.3 | 14.7 | ms |
| t_{BW} | SBSY pulse width | | — | — | 300 | μs |
| t_{Fc_y} | frame cycle | | 122 | 136 | 150 | μs |
| t_{FW} | SFSY pulse width (3-wire mode only) | | — | — | 366 | μs |
| t_{FH} | SFSY HIGH time | | — | — | 66 | μs |
| t_{FL} | SFSY LOW time | | — | — | 84 | μs |
| t_{dPAC} | delay time SFSY to SUB (P data valid) | | — | — | 1 | μs |
| t_{dAC} | delay time RCK falling to SUB | | — | — | 0 | μs |
| t_{hD} | hold time RCK to SUB | | — | — | 0.7 | μs |

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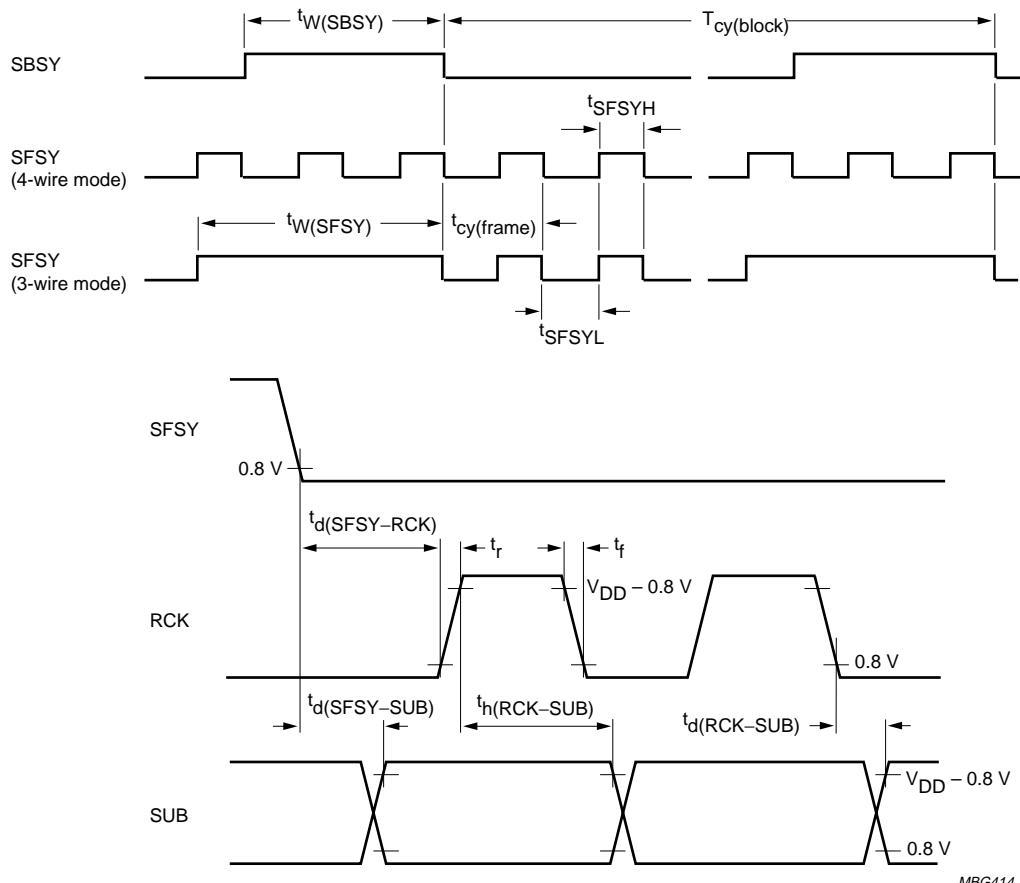


Fig.31 Subcode interface timing diagram.

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11 OPERATING CHARACTERISTICS (I²S-BUS TIMING)

$V_{DD} = 3.4$ to 5.5 V; $V_{SS} = 0$ V; $T_{amb} = -10$ to $+70$ °C; unless otherwise specified

| SYMBOL | PARAMETER | CONDITIONS | MIN. | TYP. | MAX. | UNIT |
|--|---------------------|----------------------|------|-------|------|------|
| I²S-bus timing; see Fig.32 | | | | | | |
| CLOCK OUTPUT: SCLK ($C_L = 20$ pF) | | | | | | |
| T_{cy} | output clock period | sample rate = f_s | — | 472.4 | — | ns |
| | | sample rate = $2f_s$ | — | 236.2 | — | ns |
| | | sample rate = $4f_s$ | — | 118.1 | — | ns |
| t_{CH} | clock HIGH time | sample rate = f_s | 166 | — | — | ns |
| | | sample rate = $2f_s$ | 83 | — | — | ns |
| | | sample rate = $4f_s$ | 42 | — | — | ns |
| t_{CL} | clock LOW time | sample rate = f_s | 166 | — | — | ns |
| | | sample rate = $2f_s$ | 83 | — | — | ns |
| | | sample rate = $4f_s$ | 42 | — | — | ns |
| OUTPUTS: WCLK AND DATA ($C_L = 20$ pF) | | | | | | |
| t_{su} | set-up time | sample rate = f_s | 95 | — | — | ns |
| | | sample rate = $2f_s$ | 48 | — | — | ns |
| | | sample rate = $4f_s$ | 24 | — | — | ns |
| t_h | hold time | sample rate = f_s | 95 | — | — | ns |
| | | sample rate = $2f_s$ | 48 | — | — | ns |
| | | sample rate = $4f_s$ | 24 | — | — | ns |

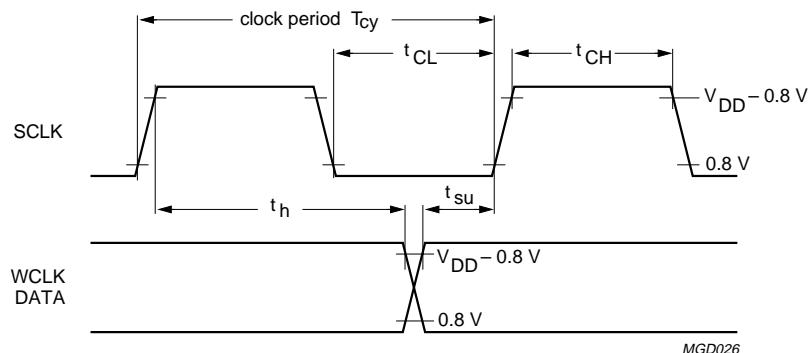


Fig.32 I²S-bus timing diagram.

Digital servo processor and Compact Disc decoder (CD7)

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12 OPERATING CHARACTERISTICS (MICROCONTROLLER INTERFACE TIMING)

$V_{DD} = 3.4$ to 5.5 V; $V_{SS} = 0$ V; $T_{amb} = -10$ to $+70$ °C; unless otherwise specified.

| SYMBOL | PARAMETER | CONDITIONS | MIN. | TYP. | MAX. | UNIT |
|--|---------------------------------------|------------|------|------|------|------|
| Microcontroller interface timing (4-wire bus mode; writing to registers 0 to F; reading Q-channel subcode and decoder status); see Figs 33 and 34 | | | | | | |
| INPUTS SCL AND RAB | | | | | | |
| t_{CL} | input LOW time | | 500 | — | — | ns |
| t_{CH} | input HIGH time | | 500 | — | — | ns |
| t_r | rise time | | — | — | 480 | ns |
| t_f | fall time | | — | — | 480 | ns |
| READ MODE ($C_L = 20$ pF) | | | | | | |
| t_{dRD} | delay time RAB to SDA valid | | — | — | 50 | ns |
| t_{PD} | propagation delay SCL to SDA | | 700 | — | 980 | ns |
| t_{dRZ} | delay time RAB to SDA high-impedance | | — | — | 50 | ns |
| WRITE MODE ($C_L = 20$ pF) | | | | | | |
| t_{suD} | set-up time SDA to SCL | note 1 | 700 | — | — | ns |
| t_{hD} | hold time SCL to SDA | | — | — | 980 | ns |
| t_{suCR} | set-up time SCL to RAB | | 260 | — | — | ns |
| t_{dWZ} | delay time SDA high-impedance to RAB | | 0 | — | — | ns |
| Microcontroller interface timing (4-wire bus mode; servo commands); see Figs 35 and 36 | | | | | | |
| INPUTS SCL AND SILD | | | | | | |
| t_L | input LOW time | | 710 | — | — | ns |
| t_H | input HIGH time | | 710 | — | — | ns |
| t_r | rise time | | — | — | 240 | ns |
| t_f | fall time | | — | — | 240 | ns |
| READ MODE ($C_L = 20$ pF) | | | | | | |
| t_{dLD} | delay time SILD to SDA valid | | — | — | 25 | ns |
| t_{PD} | propagation delay SCL to SDA | | — | — | 950 | ns |
| t_{dLZ} | delay time SILD to SDA high-impedance | | — | — | 50 | ns |
| t_{sCLR} | set-up time SCL to SILD | | 480 | — | — | ns |
| t_{hCLR} | hold time SCL to SILD | | 830 | — | — | ns |
| WRITE MODE ($C_L = 20$ pF) | | | | | | |
| t_{sD} | set-up time SDA to SCL | | 0 | — | — | ns |
| t_{hD} | hold time SCL to SDA | | 950 | — | — | ns |
| t_{sCL} | set-up time SCL to SILD | | 480 | — | — | ns |
| t_{hCL} | hold time SILD to SCL | | 120 | — | — | ns |
| t_{dPLP} | delay between two SILD pulses | | 70 | — | — | μs |
| t_{dWZ} | delay time SDA high-impedance to SILD | | 0 | — | — | ns |

Notes

1. Negative set-up time means that the data may change after clock transition.

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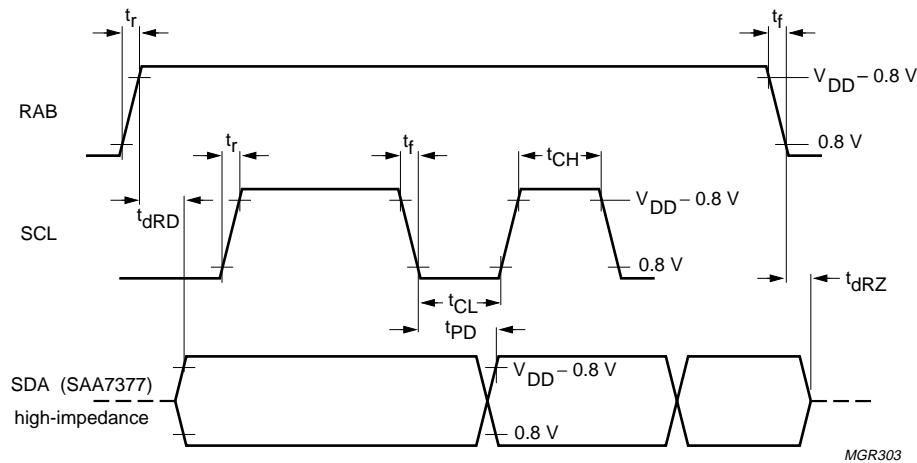


Fig.33 4-wire bus microcontroller timing; read mode (Q-channel subcode and decoder status information).

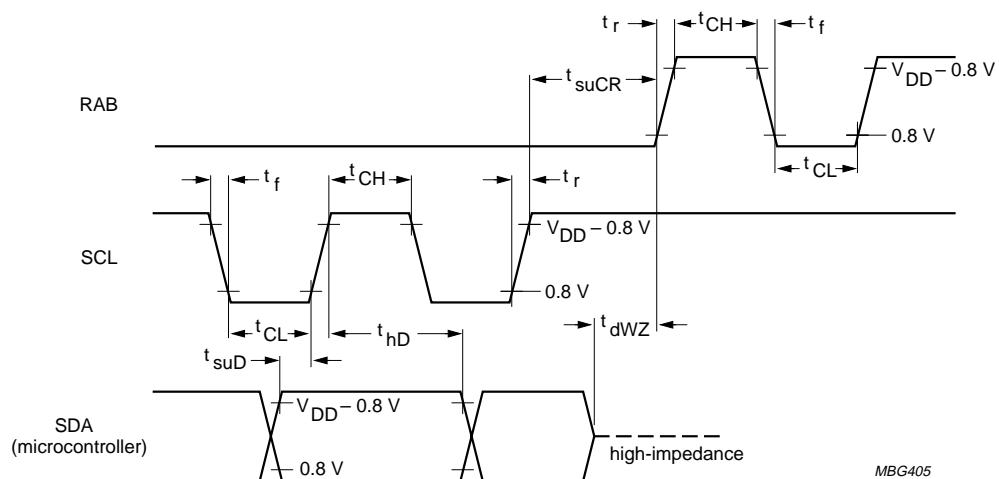


Fig.34 4-wire bus microcontroller timing; write mode (registers 0 to F).

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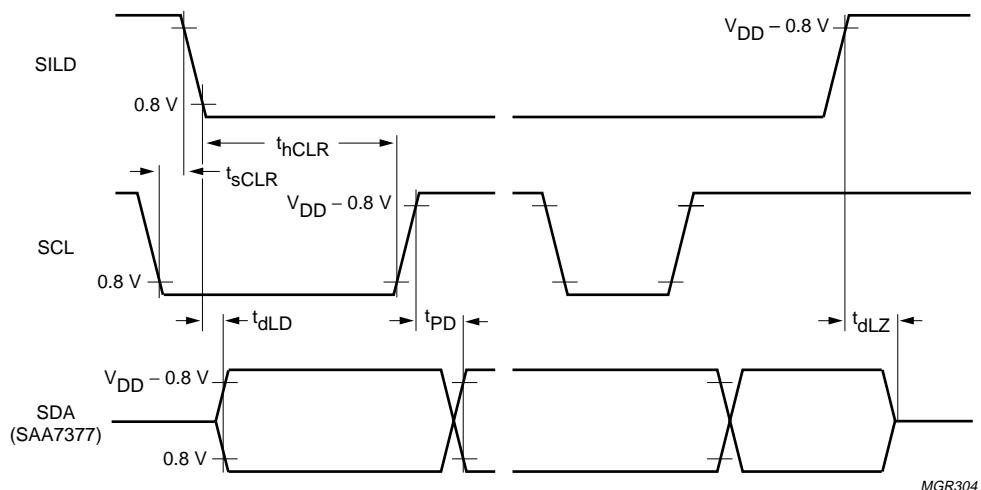


Fig.35 4-wire bus microcontroller timing; read mode (servo commands).

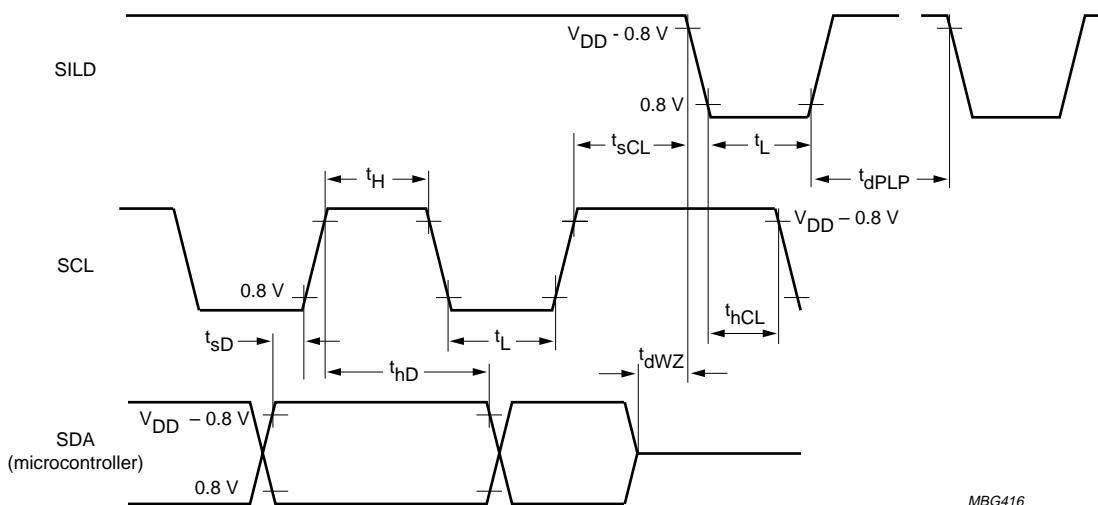


Fig.36 4-wire bus microcontroller timing (servo commands) write mode.

13 APPLICATION INFORMATION

Product specifications

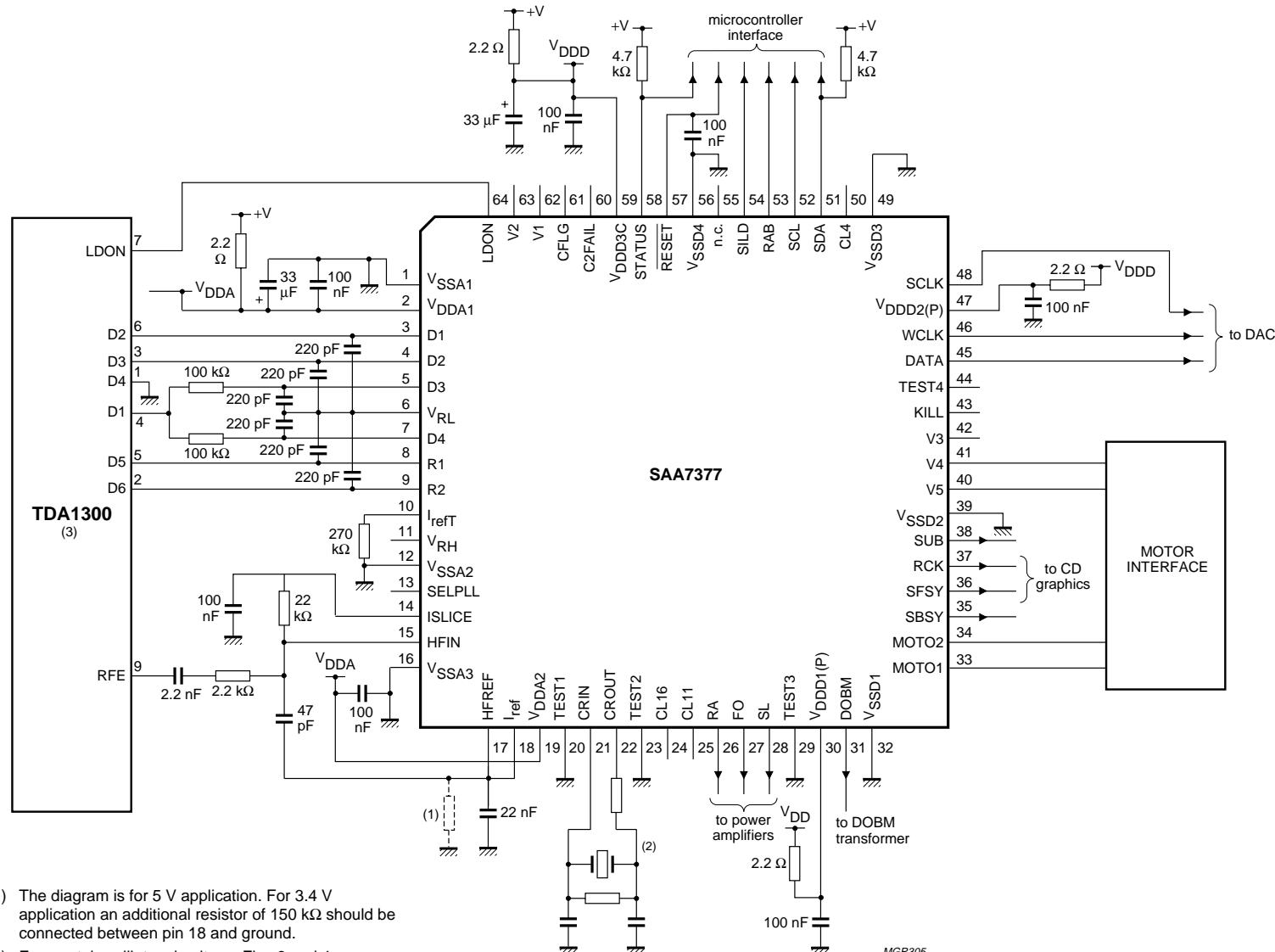


Fig.37 Typical SAA7377 application diagram.

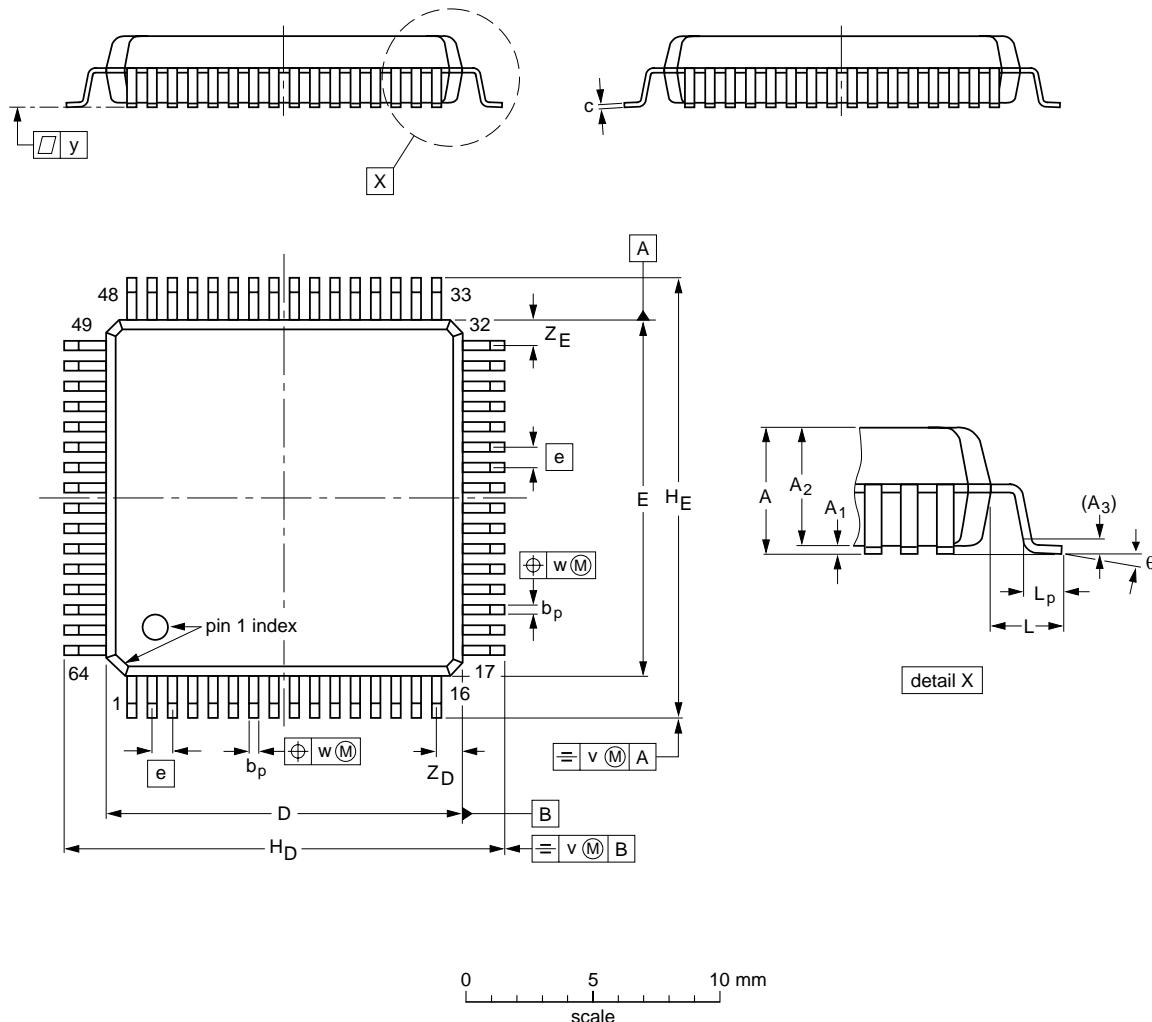
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14 PACKAGE OUTLINE

QFP64: plastic quad flat package; 64 leads (lead length 1.6 mm); body 14 x 14 x 2.7 mm

SOT393-1



DIMENSIONS (mm are the original dimensions)

| UNIT | A max. | A ₁ | A ₂ | A ₃ | b _p | c | D ⁽¹⁾ | E ⁽¹⁾ | e | H _D | H _E | L | L _p | v | w | y | Z _D ⁽¹⁾ | Z _E ⁽¹⁾ | θ |
|------|--------------|----------------|----------------|----------------|----------------|--------------|------------------|------------------|-----|----------------|----------------|------|----------------|------|------|------|-------------------------------|-------------------------------|----------|
| mm | 3.00 0.10 | 0.25 2.55 | 2.75 | 0.25 | 0.45 0.30 | 0.23 0.13 | 14.1 13.9 | 14.1 13.9 | 0.8 | 17.45 16.95 | 17.45 16.95 | 1.60 | 1.03 0.73 | 0.16 | 0.16 | 0.10 | 1.2 0.8 | 1.2 0.8 | 7° 0° |

Note

1. Plastic or metal protrusions of 0.25 mm maximum per side are not included.

| OUTLINE VERSION | REFERENCES | | | | EUROPEAN PROJECTION | ISSUE DATE |
|--------------------|------------|--------|------|--|------------------------|----------------------|
| | IEC | JEDEC | EIAJ | | | |
| SOT393-1 | | MS-022 | | | | 96-05-21 97-08-04 |

Digital servo processor and Compact Disc decoder (CD7)

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15 SOLDERING

15.1 Introduction

There is no soldering method that is ideal for all IC packages. Wave soldering is often preferred when through-hole and surface mounted components are mixed on one printed-circuit board. However, wave soldering is not always suitable for surface mounted ICs, or for printed-circuits with high population densities. In these situations reflow soldering is often used.

This text gives a very brief insight to a complex technology. A more in-depth account of soldering ICs can be found in our "IC Package Databook" (order code 9398 652 90011).

15.2 Reflow soldering

Reflow soldering techniques are suitable for all QFP packages.

The choice of heating method may be influenced by larger plastic QFP packages (44 leads, or more). If infrared or vapour phase heating is used and the large packages are not absolutely dry (less than 0.1% moisture content by weight), vaporization of the small amount of moisture in them can cause cracking of the plastic body. For more information, refer to the Drypack chapter in our "Quality Reference Handbook" (order code 9397 750 00192).

Reflow soldering requires solder paste (a suspension of fine solder particles, flux and binding agent) to be applied to the printed-circuit board by screen printing, stencilling or pressure-syringe dispensing before package placement.

Several methods exist for reflowing; for example, infrared/convection heating in a conveyor type oven. Throughput times (preheating, soldering and cooling) vary between 50 and 300 seconds depending on heating method. Typical reflow peak temperatures range from 215 to 250 °C.

15.3 Wave soldering

Wave soldering is **not** recommended for QFP packages. This is because of the likelihood of solder bridging due to closely-spaced leads and the possibility of incomplete solder penetration in multi-lead devices.

If wave soldering cannot be avoided, for QFP packages with a pitch (e) larger than 0.5 mm, the following conditions must be observed:

- A double-wave (a turbulent wave with high upward pressure followed by a smooth laminar wave) soldering technique should be used.
- The footprint must be at an angle of 45° to the board direction and must incorporate solder thieves downstream and at the side corners.

During placement and before soldering, the package must be fixed with a droplet of adhesive. The adhesive can be applied by screen printing, pin transfer or syringe dispensing. The package can be soldered after the adhesive is cured.

Maximum permissible solder temperature is 260 °C, and maximum duration of package immersion in solder is 10 seconds, if cooled to less than 150 °C within 6 seconds. Typical dwell time is 4 seconds at 250 °C.

A mildly-activated flux will eliminate the need for removal of corrosive residues in most applications.

15.4 Repairing soldered joints

Fix the component by first soldering two diagonally-opposite end leads. Use only a low voltage soldering iron (less than 24 V) applied to the flat part of the lead. Contact time must be limited to 10 seconds at up to 300 °C. When using a dedicated tool, all other leads can be soldered in one operation within 2 to 5 seconds between 270 and 320 °C.

CAUTION

Wave soldering is **NOT** applicable for all QFP packages with a pitch (e) equal or less than 0.5 mm.

Digital servo processor and Compact Disc decoder (CD7)

SAA7377

16 DEFINITIONS

| Data sheet status | |
|---------------------------|--|
| Objective specification | This data sheet contains target or goal specifications for product development. |
| Preliminary specification | This data sheet contains preliminary data; supplementary data may be published later. |
| Product specification | This data sheet contains final product specifications. |
| Short-form specification | The data in this specification is extracted from a full data sheet with the same type number and title. For detailed information see the relevant data sheet or data handbook. |

| Limiting values | |
|---|--|
| Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 134). Stress above one or more of the limiting values may cause permanent damage to the device. These are stress ratings only and operation of the device at these or at any other conditions above those given in the Characteristics sections of the specification is not implied. Exposure to limiting values for extended periods may affect device reliability. | |

| Application information | |
|---|--|
| Where application information is given, it is advisory and does not form part of the specification. | |

17 LIFE SUPPORT APPLICATIONS

These products are not designed for use in life support appliances, devices, or systems where malfunction of these products can reasonably be expected to result in personal injury. Philips customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify Philips for any damages resulting from such improper use or sale.

18 PURCHASE OF PHILIPS I²C COMPONENTS



Purchase of Philips I²C components conveys a license under the Philips' I²C patent to use the components in the I²C system provided the system conforms to the I²C specification defined by Philips. This specification can be ordered using the code 9398 393 40011.

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