THE DATASHEET OF

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DATA SHEET

SAA7826

CD audio decoder, digital servo and filterless DAC with integrated pre-amp and laser control

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Philips Semiconductors

PHILIPS

CD audio decoder, digital servo and filterless DAC with integrated pre-amp and laser control

SAA7826

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CD audio decoder, digital servo and filterless DAC with integrated pre-amp and laser control

SAA7826

1 FEATURES

- Decoder and servo parts are based upon the SAA732X design (the original features are maintained)
- Software compatibility is maintained with the SAA732X by using a similar register structure (new features are controlled from new shadow registers)
- 1×, 2× and 4× speed
- LF (servo) signals converted to digital representations by 6 oversampling bitstream ADCs
- HF part summed from signals D1 to D4 and converted to a digital signal by a data slicer
- On-chip buffering and filtering of the diode signals from the mechanism for signal optimization
- Selectable DC offset cancellation of quiescent mechanism voltages and dark currents
- On-chip laser power control (up to 120 mA)
- Laser on/off control, including ‘soft’ start control (zero to nominal power in 1 ms)
- Monitor control and feedback circuit to maintain nominal output power throughout laser life
- Dynamic element matching DAC with minimum external components
- DAC performance of −80 dB Total Harmonic Distortion + Noise (THD + N) and 90 dB Signal-to-Noise Ratio (S/N) A-weighted
- Separate left and right channel digital silence detection available on the KILL pins
- Digital silence detection on internal data and loopback (external) data
- 5 versatile pins, 2 inputs and 3 outputs

ReWritable CD COMPATIBLE

I²C BUS

- Integrated CD text decoder with separate microcontroller interface
- Dedicated 4 MHz or 12 MHz clock output for microcontroller (configurable)
- Configured for N-sub monitor diode
- On-chip clock multiplier allows the use of an 8.4672 MHz crystal or ceramic resonator
- The M1 version has an EBU mute function which allows independent muting of data being transmitted over the EBU interface whilst maintaining the SPDIF frame structure.

2 GENERAL DESCRIPTION

This document covers versions M0 and M1 of the CD audio decoder IC.

The SAA7826 is a CD audio decoder IC which combines the function of the SAA732X IC with the pre-amplifier and laser control functions previously found in the TZA102X IC. The design is intended to reduce the external component count and hence the Bill Of Material (BOM).

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 ORDERING INFORMATION

TYPE NUMBER	PACKAGE		
	NAME	DESCRIPTION	VERSION
SAA7826HL	LQFP80	plastic low profile quad flat package; 80 leads; body 12 × 12 × 1.4 mm	SOT315-1

4 QUICK REFERENCE DATA

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
V_{DDD}	digital supply voltage		1.65	1.8	1.95	V
V_{DDA}	analog supply voltage		3.0	3.3	3.6	V
I_{DDD}	digital supply current	n = 1 mode	–	38	–	mA
		n = 2 mode	–	39	–	mA
		n = 4 mode	–	40	–	mA
f_{xtal}	crystal frequency		–	8.4672	–	MHz
T_{amb}	ambient temperature		–40	–	+85	°C
T_{stg}	storage temperature		–55	–	+125	°C
S/N_{DAC}	onboard DAC signal-to-noise ratio		–	90	–	dB

5 BLOCK DIAGRAM

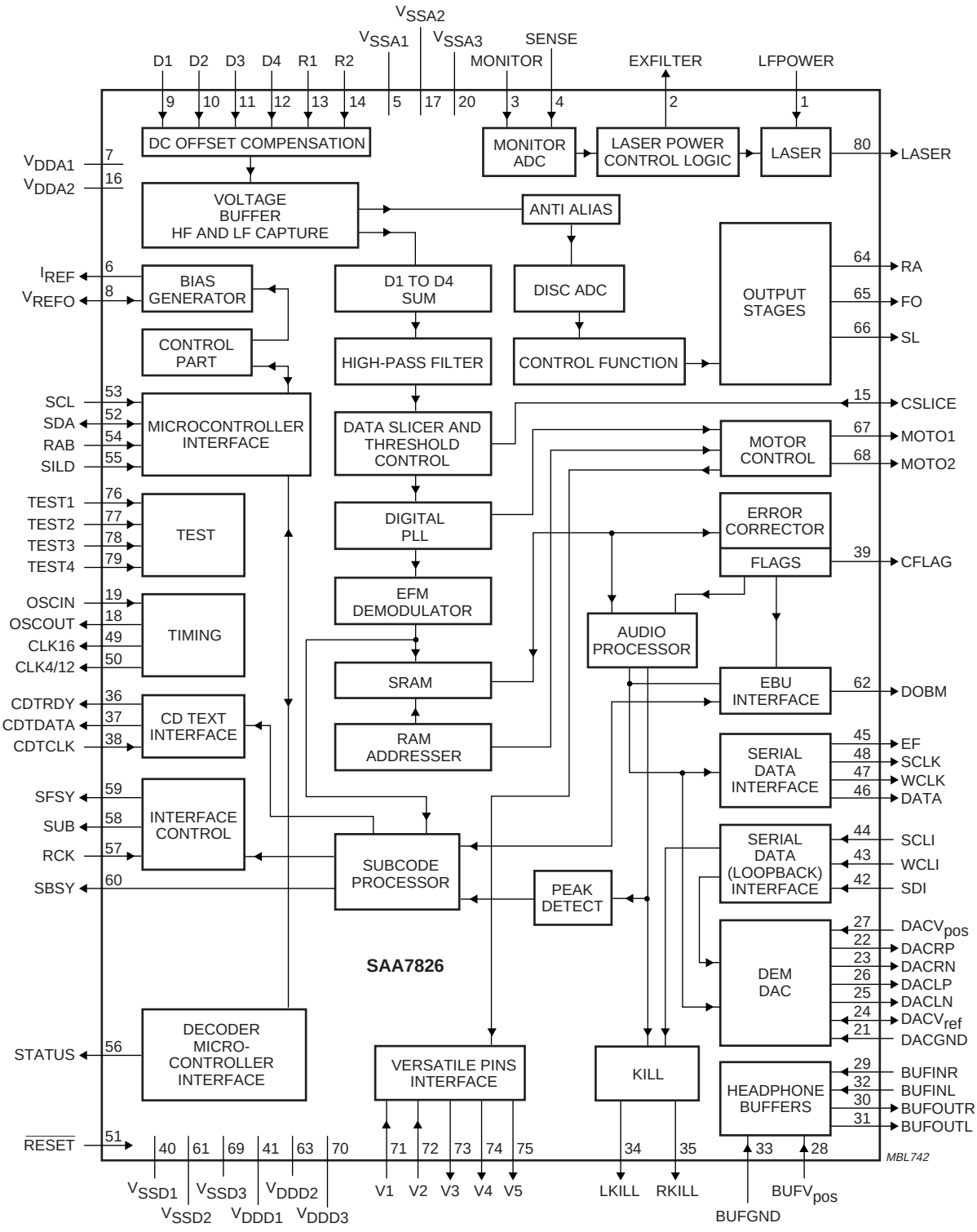


Fig.1 Block diagram.

6 PINNING

SYMBOL	PIN	I/O	DESCRIPTION
LFPOWER	1	I	laser power supply
EXFILTER	2	O	10 nF capacitor for laser start-up control
MONITOR	3	I	laser monitor diode
SENSE	4	I	OPU ground reference point for MONITOR measurement
V_{SSA1}	5	SUP	analog ground 1
I_{REF}	6	O	reference current output (24 kΩ resistor connected to analog ground)
V_{DDA1}	7	SUP	analog supply voltage 1
V_{REFO}	8	I/O	servo reference voltage
D1	9	I	diode voltage/current input (central diode signal input)
D2	10	I	diode voltage/current input (central diode signal input)
D3	11	I	diode voltage/current input (central diode signal input)
D4	12	I	diode voltage/current input (central diode signal input)
R1	13	I	diode voltage/current input (satellite diode signal input)
R2	14	I	diode voltage/current input (satellite diode signal input)
CSLICE	15	I/O	10 nF capacitor for adaptive HF data slicer
V_{DDA2}	16	SUP	analog supply voltage 2
V_{SSA2}	17	SUP	analog ground 2
OSCOUT	18	O	crystal/resonator output
OSCIN	19	I	crystal/resonator input
V_{SSA3}	20	SUP	analog ground 3
DACGND	21	I	audio DAC ground
DACRP	22	O	audio DAC right channel differential positive output
DACRN	23	O	audio DAC right channel differential negative output
$DACV_{ref}$	24	I/O	audio DAC decoupling point (10 μF or 100 nF to ground)
DACLN	25	O	audio DAC left channel differential negative output
DACLP	26	O	audio DAC left channel differential positive output
$DACV_{pos}$	27	I	audio DAC positive supply voltage
$BUFV_{pos}$	28	I	audio buffer positive supply voltage
BUFINR	29	I	audio buffer right input
BUFOUTR	30	O	audio buffer right output
BUFOUTL	31	O	audio buffer left output
BUFINL	32	I	audio buffer left input
BUFGND	33	I	audio buffer ground
LKILL	34	O	KILL output for left channel (configurable as open-drain)
RKILL	35	O	KILL output for right channel (configurable as open-drain)
CDTRDY	36	O	CD text output to microcontroller ready flag
CDTDATA	37	O	CD text output data to microcontroller
CDTCLK	38	I	CD text microcontroller clock input
CFLAG	39	O	correction flag output (open-drain)
V_{SSD1}	40	SUP	digital ground 1

SYMBOL	PIN	I/O	DESCRIPTION
V_{DDD1}	41	SUP	digital supply voltage 1
SDI	42	I	serial data input (loopback)
WCLI	43	I	word clock input (loopback)
SCLI	44	I	serial bit clock input (loopback)
EF	45	O	C2 error flag output
DATA	46	O	serial data output
WCLK	47	O	word clock output
SCLK	48	O	serial clock output
CLK16	49	O	16 MHz clock output
CLK4/12	50	O	configurable 4 MHz or 12 MHz clock output
$\overline{\text{RESET}}$	51	I	power-on reset input (active LOW)
SDA	52	I/O	microcontroller interface data input/output (open-drain)
SCL	53	I	microcontroller interface clock input
RAB	54	I	microcontroller interface R/W and load control input (4-wire)
SILD	55	I	microcontroller interface R/W and load control input (4-wire)
STATUS	56	O	servo interrupt request line/decoder status register/DC offset value readback output
RCK	57	I	subcode clock input
SUB	58	O	P to W subcode output
SFSY	59	O	subcode frame sync output
SBSY	60	O	subcode block sync output
V_{SSD2}	61	SUP	digital ground 2
DOBM	62	O	bi-phase mark output (externally buffered)
V_{DDD2}	63	SUP	digital supply voltage 2
RA	64	O	radial actuator output
FO	65	O	focus actuator output
SL	66	O	sledge actuator output
MOTO1	67	O	motor output 1 output
MOTO2	68	O	motor output 2 output
V_{SSD3}	69	SUP	digital ground 3
V_{DDD3}	70	SUP	digital supply voltage 3
V1	71	I	versatile pin 1 input
V2	72	I	versatile pin 2 input
V3	73	O	versatile pin 3 output
V4	74	O	versatile pin 4 output
V5	75	O	versatile pin 5 output
TEST1	76	I	test pin 1 input
TEST2	77	I	test pin 2 input
TEST3	78	I	test pin 3 input
TEST4	79	I	test pin 4 input
LASER	80	O	laser drive output

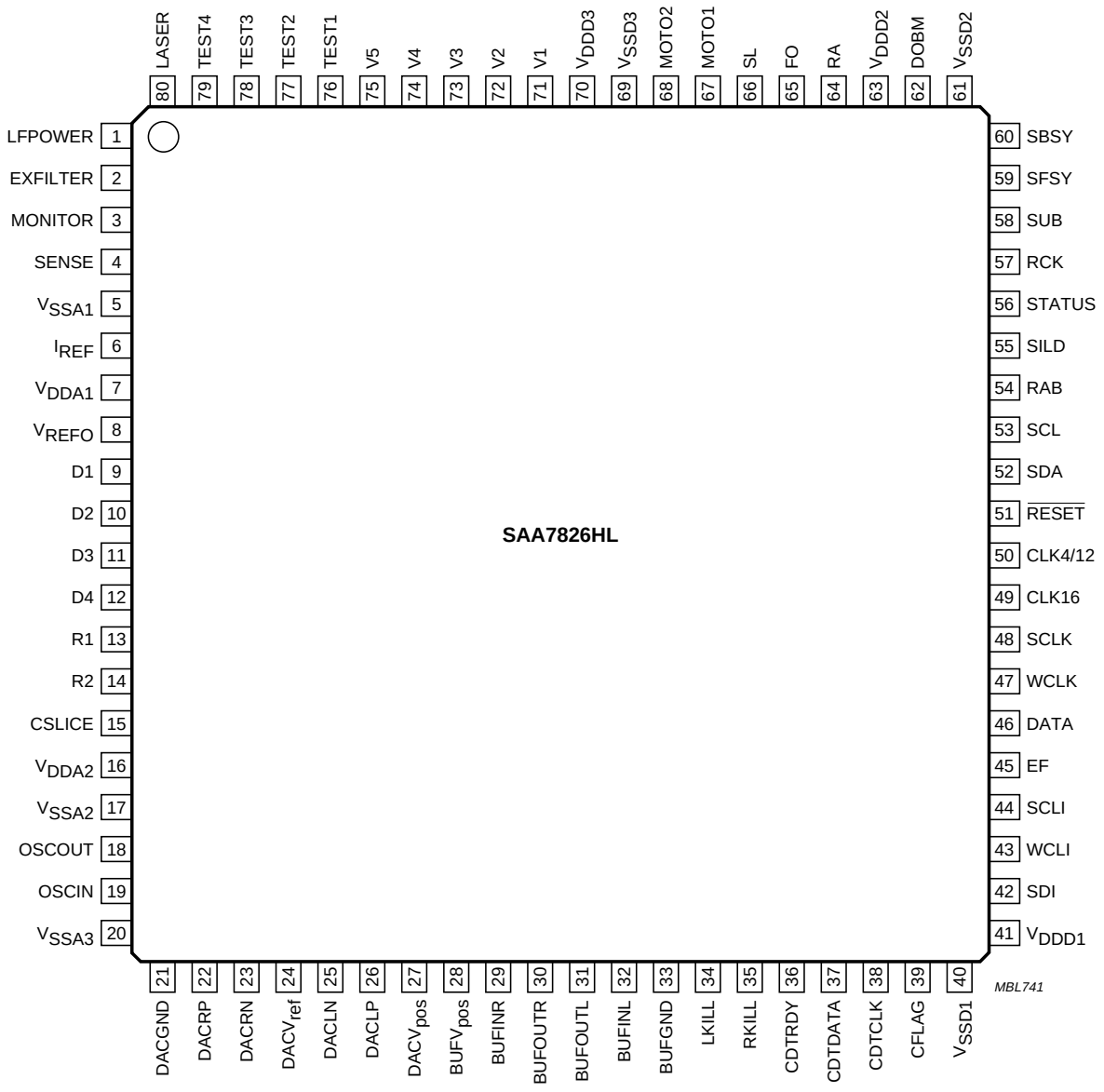


Fig.2 Pin configuration.

7 FUNCTIONAL DESCRIPTION

7.1 Data acquisition and HF data path

The SAA7826 removes the need for an external diode signal pre-amplifier.

A simplified diagram of the HF data path is illustrated in Fig.3. The high-pass filter, equalizing filter, HF gain and adaptive slicer are all register programmable, thus enabling the SAA7826 to be optimized for the intended application.

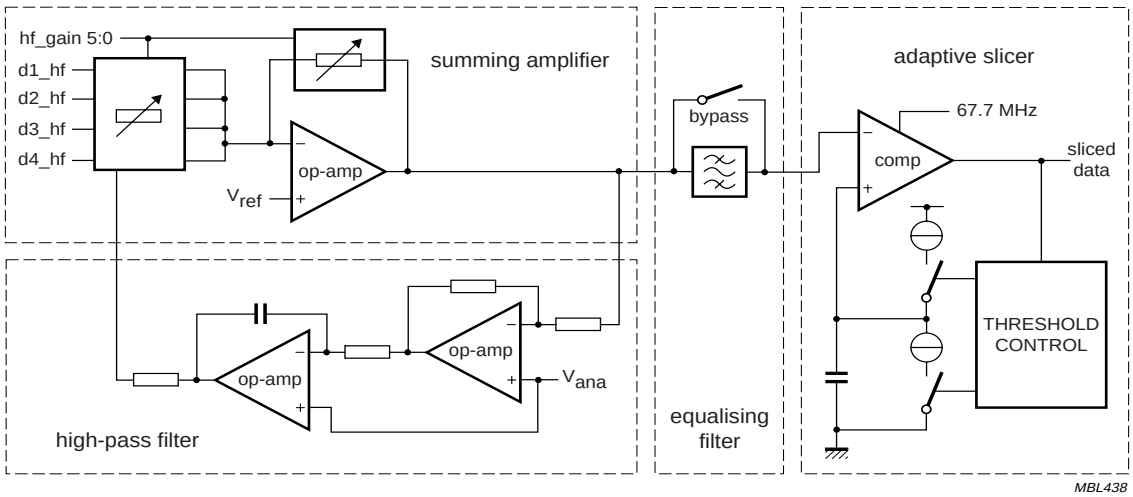


Fig.3 Simplified block diagram of the HF data path and adaptive slicer.

7.2 Decoder part

7.2.1 Principle operating modes of the decoder

The decoding part supports a full audio specification and can operate at single-speed (n = 1), double-speed (n = 2) and quad-speed (n = 4). The factor 'n' is called the overspeed factor. A simplified data flow through the decoder part is illustrated in Fig.7 for the M0 version and Fig.8 for the M1 version.

7.2.2 Decoder speed and crystal frequency

The SAA7826 is a 1×, 2× and 4× (three-speed) decoding device, with an internal Phase-Locked Loop (PLL) clock multiplier. Table 1 gives the playback speeds that are achievable in conjunction with crystal frequency, the mechanism and internal clock settings (selectable via decoder register B).

7.2.3 Lock-to-disc mode

For electronic shock absorption applications, the SAA7826 can be put into lock-to-disc mode. This allows Constant Angular Velocity (CAV) disc playback with varying input data rates from the inside to the outside of the disc.

In the lock-to-disc mode, the FIFO is blocked and the decoder will adjust its output data rate to the disc speed. Hence, the frequency of the I^2S-bus (WCLK and SCLK) clocks are dependent on the disc speed. In the lock-to-disc mode there is a limit on the maximum variation in disc speed that the SAA7826 will follow. Disc speeds must always be within 25% to 100% range of their nominal value. The lock-to-disc mode is enabled or disabled by decoder register E.

7.2.4 STANDBY MODES

The SAA7826 can be placed in two standby modes, selected by decoder 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 to high-impedance, PWM mode (Standby 1 and $\overline{\text{RESET}}$: operating in Standby 2); put in high-impedance, PDM mode (Standby 1 and $\overline{\text{RESET}}$: operating in Standby 2)
- Pins SCL and SDA: no interaction; normal operation continues
- Pins SCLK, WCLK, DATA, EF and DOBM: 3-state in both standby modes; normal operation continues after reset
- Pins OSCIN, OSCOUT, CLK16 and CLK4/12: no interaction; normal operation continues
- Pins V1 to V5 and CFLAG: no interaction; normal operation continues.

Table 1 Playback speeds

REGISTER B	REGISTER E	f_{xtal} = 8.4672 MHz
0XXX	0XXX	n = 1
1XXX	0XXX	n = 2; voltage mode only
0XXX	1XXX	n = 4; voltage mode only

7.3 Crystal oscillator

The crystal oscillator is a conventional 2-pin design which can also operate with ceramic resonators. The external components used around the crystal are illustrated in Fig.4 together with component values (C1 and C2) for a given crystal type in Table 2. The oscillator frequency that can be used with the SAA7826 is 8.4672 MHz.

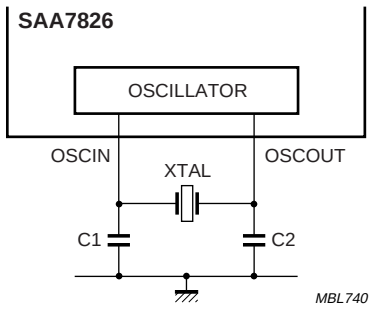


Fig.4 Crystal configuration.

Table 2 External capacitor selection based upon the crystal type

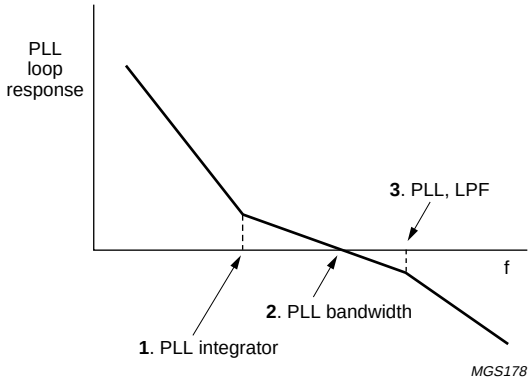
CRYSTAL LOAD CAPACITANCE (C_L)	MAXIMUM SERIES CRYSTAL RESISTANCE (R_S)	EXTERNAL LOAD CAPACITORS	
	8 MHz	C1	C2
10 pF	<300 Ω	8 pF	8 pF
20 pF	<300 Ω	27 pF	27 pF
30 pF	<300 Ω	47 pF	47 pF

7.4 Data slicer and bit clock regenerator

The SAA7826 has an integrated adaptive data slicer which is clocked at 67 MHz. The slice level is controlled by internal current sources which are switched onto and integrated by the external capacitor connected to the CSLICE pin. The currents are switched under the control of a Digital Phase-Locked loop (DPLL).

Regeneration of the bit clock is achieved with an internal fully digital PLL. No external components are required. The bit clock is not output. The PLL has two registers (8 and 9) for selecting bandwidth and equalization. The PLL loop response is illustrated in Fig.5.

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 can be input via pin V1 if selected by register C. If this flag is HIGH, the SAA7826 assumes that its servo part is following the wrong track, and will flag all incoming HF data as incorrect.



Points 1, 2 and 3 are all programmable via decoder register 8.

Fig.5 Digital PLL loop response.

7.5 DC offset cancellation

Unwanted DC offsets can exist within the photo-diode signals and are defined as the DC present in the system when the laser diode is switched off. They arise from various sources of imperfection within the system such as leakage in the photo diodes and offsets in the Optical Pick-Up (OPU) circuitry. The SAA7826 is capable of measuring these offsets and minimizing them.

7.5.1 Offset cancellation

A number of registers are associated with the DC offset cancellation function; these registers are given in Table 3.

The measurement time of the DC offset is regulated by new shadow register C (bank 2). A longer time will yield more accurate results but will result in greater measurement durations.

New shadow register 3 (bank 3) is used to select which diode is to be measured.

7.5.2 Reading back the DC offset value

The microcontroller reads the DC offset measurements in order to calculate the correct cancellation value [for writing back to new shadow register 7 (bank 3)].

This is achieved by using the STATUS pin and setting decoder register 7 to XX10. Shadow register C (bank 3) can then be used to control the STATUS pin output; the register settings are given in Table 20.

Once the measurement time has been set and the diode selected, the STATUS pin should be set to read the DC offset ready flag [new shadow register C (bank 3) = X01X]. This signal toggles HIGH after the prescribed measurement time. Changing the diode selection results in the measurement timer being automatically reset.

The microcontroller can read back the measurement by setting the STATUS pin to output the DC offset value [new shadow register C (bank 3) = X10X].

The offset value is repeatedly streamed out through the STATUS pin and is UART compatible. It should be noted that the MSB is inverted and will require re-inverting after the offset value has been captured. Timing information for this signal is illustrated in Fig.6.

The final DC cancellation value (as calculated by the microcontroller) can then be written to new shadow register 7 (bank 3). This is a multiple write register containing the cancellation values for all six diodes.

Table 3 Registers relating to the DC offset cancellation

SHADEN BITS	SHADOW REGISTER	ADDRESS	DATA	FUNCTION	INITIAL
10 (bank 2)	C DC offset measurement times	1100	XX00	settling time = 354 µs	reset
			XX01	settling time = 1 ms	–
			XX10	settling time = 2 ms	–
			XX11	settling time = 10 ms	–
11 (bank 3)	3 diode selection for DC offset measurement	0011	0000	select D1	reset
			0001	select D1	–
			0010	select D2	–
			0011	select D3	–
			0100	select D4	–
			0101	select R1	–
			0110	select R2	–
			0111	select D1	–
	C STATUS pin control	1100	X00X	STATUS pin outputs decoder status register information	reset
			X01X	STATUS pin outputs DC offset ready flag	–
			X10X	STATUS pin outputs DC offset value	–
	7 DC cancellation levels	0111	multi-write (9 × 4 bits)	DC cancellation values for diodes D1 to D4 and R1 and R2; see Table 20	–

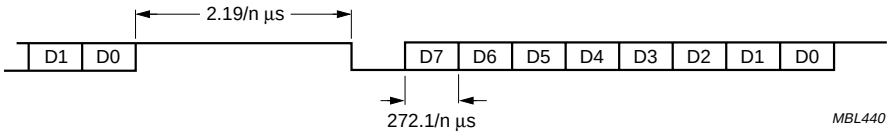


Fig.6 Serial data format for DC offset data.

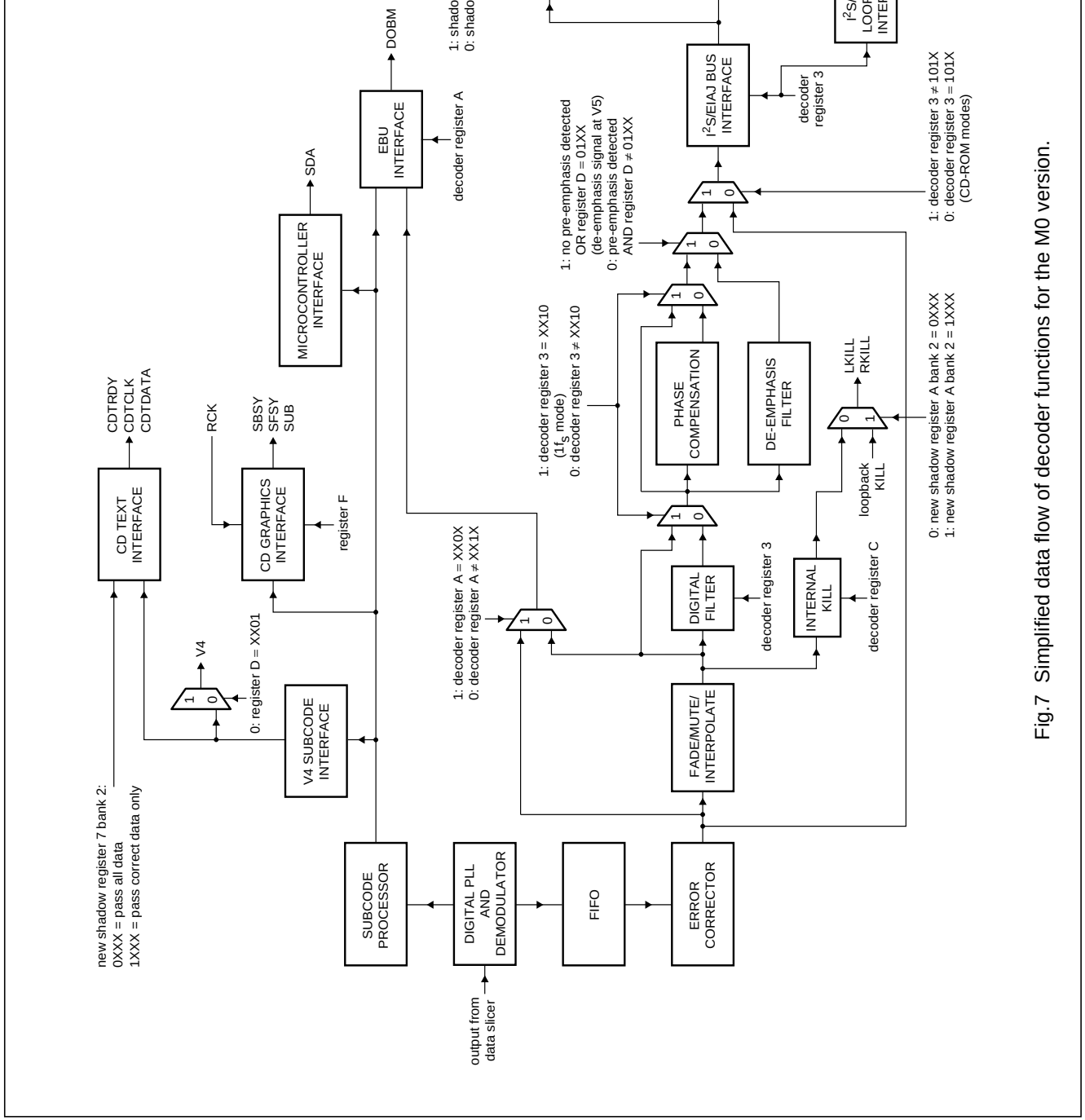


Fig.7 Simplified data flow of decoder functions for the M0 version.

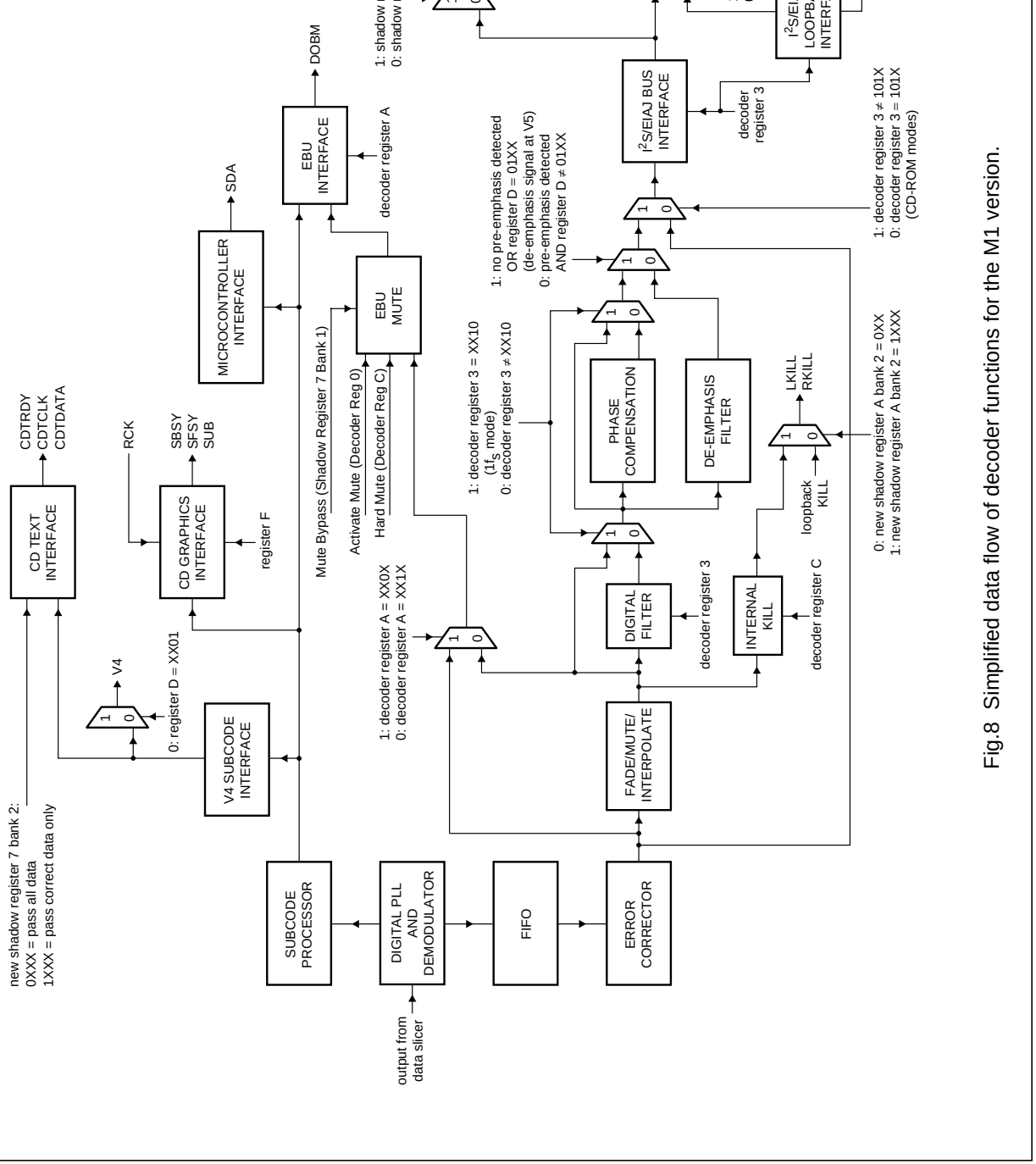


Fig.8 Simplified data flow of decoder functions for the M1 version.

7.6 Demodulator

7.6.1 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 is 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 is 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 decoder registers 2, 7 and new shadow register C (bank 3).

Also incorporated in the demodulator is a Run Length 2 (RL2) correction circuit. Every symbol detected as RL2 is 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.

7.6.2 EFM demodulation

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

7.7 Subcode data processing

7.7.1 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 goes LOW. SUBQREADY-I can be read via the SDA or STATUS pins, selected via decoder registers 2, 7 and new shadow register C (bank 3). Good Q-channel data may be read from pin SDA.

7.7.2 EIAJ 3 and 4-wire subcode (CD graphics) interface

Data from all the subcode channels (P-to-W) can 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 decoder register F.

The subcode interface output formats are illustrated in Fig.9, where the RCK signal is supplied by another device such as a CD graphics decoder.

7.7.3 V4 subcode interface

Data of subcode channels Q-to-W can be read via pin V4 if selected via decoder register D. The format is similar to RS232 and is illustrated in Fig.10. The subcode sync word is formed by a pause of (200/n) 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/n) μs and (90/n) μs.

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

7.7.4 CD text interface

R-to-W subcode data is captured and stored until a complete CD text PACK is formed. The least significant 16 bits of the PACK are used for a CRC.

The behaviour of the CD text interface is controlled by new shadow register 7 (bank 2). The interface can either flag all data (i.e. passed or failed CRC) or it can flag good data only.

The data ready flag is monitored via pin CDTRDY and is active LOW. The pulse width varies from 73/n μs, for the first three packs, to 317/n μs for the fourth pack.

When a PACK becomes available, the initial value of the CDTDATA pin indicates the CRC result (HIGH = passed; LOW = failed). The microcontroller can fetch the data by applying a clock signal (maximum frequency = 5 MHz) to pin CDTCLK and reading the subsequent bitstream on pin CDTDATA.

The 128 data bits are streamed out LSB first. A complete CD text PACK consists of 4 header bytes, 12 data bytes, and 2 CRC bytes, although the latter 2 bytes are dropped internally once the CRC calculation is complete. Refer to the *"Red Book"* for further details relating to the format of a CD text PACK

The timing diagram for the CD text interface is illustrated in Fig.11.

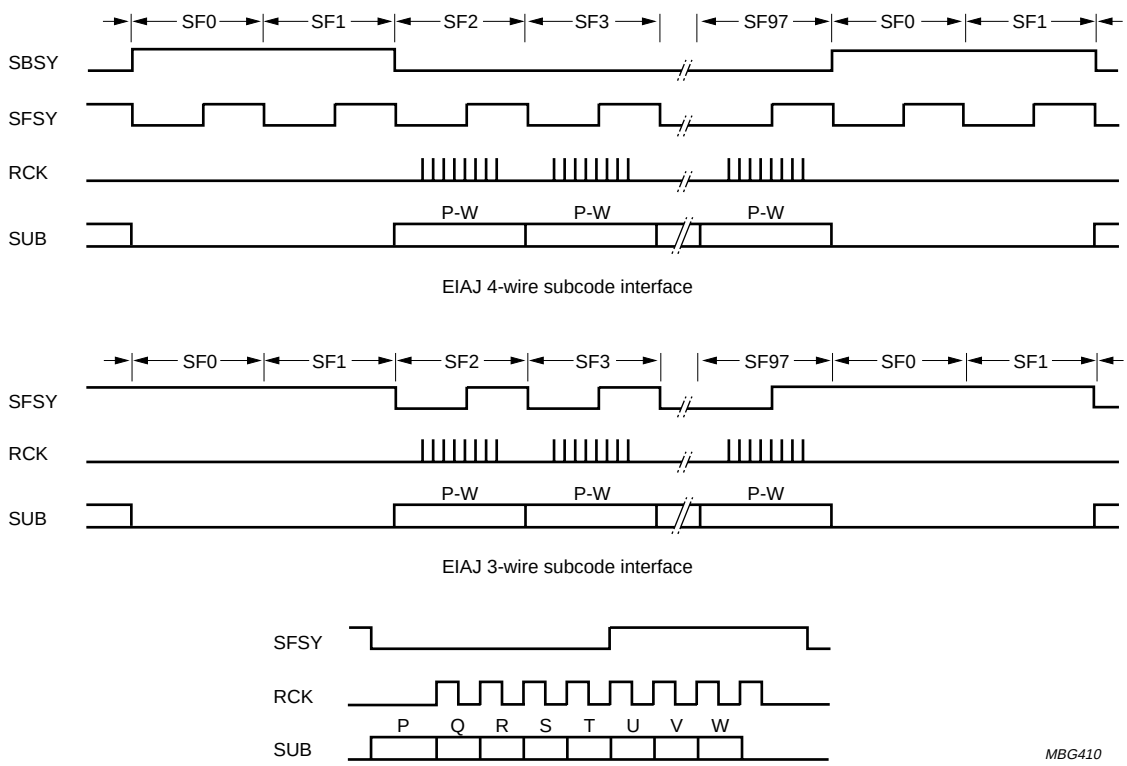
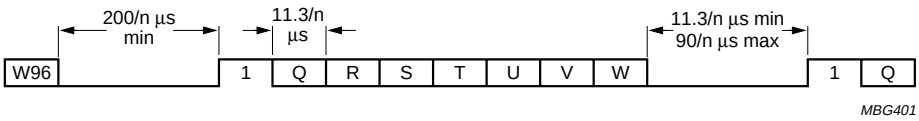
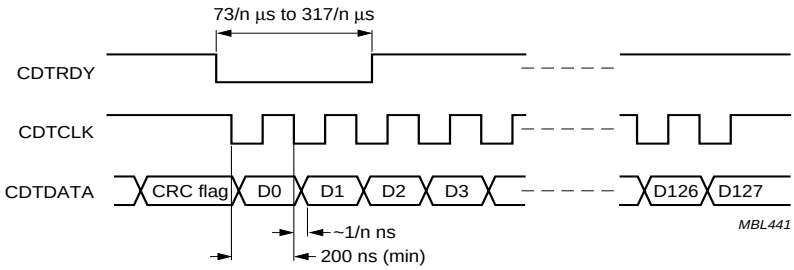


Fig.9 EIAJ subcode (CD graphics) interface format.



Where n = disc speed.

Fig.10 Subcode format and timing on pin V4.



Where n = disc speed.

Fig.11 CD text interface format and timing.

7.8 FIFO and error correction

The SAA7826 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.

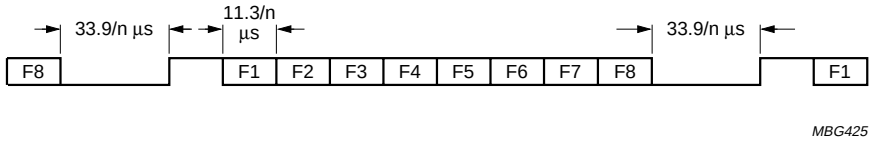
The error corrector also contains a flag processor. Flags are assigned to symbols when the error corrector cannot ascertain if the symbols are definitely good. C1 generates output flags which are read after de-interleaving by C2, to help in the generation of C2 output flags.

The C2 output flags are used by the interpolator for concealment of uncorrectable errors. They are also output via the EBU signal (DOBM). The EF output flags bytes in error in both audio and CD-ROM modes.

7.8.1 FLAGS OUTPUT (CFLG)

The flags output pin CFLG shows the status of the error corrector and interpolator and is updated every frame (7.35 × n kHz). In the SAA7826, 8 × 1-bit flags are present on the CFLG pin as illustrated in Fig.12. 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 decoder register A.



Where n = disc speed.

Fig.12 Flag output timing diagram.

Table 4 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

7.9 Audio functions

7.9.1 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 will control the phase of the digital oversampling filter to $\leq \pm 1°$ within the 0 to 16 kHz band. With de-emphasis the filter is not phase linear.

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

7.9.2 Digital oversampling filter

For optimization of performance with an external DAC, the SAA7826 contains a 2 to 4 times oversampling IIR filter. The filter specification of the 4 times oversampling filter is given in Table 5.

The attenuation does 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 5 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

7.9.3 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.13.

In CD-ROM modes (i.e. the external DAC interface is selected to be in a CD-ROM format) concealment is not executed.

7.9.4 Mute, full-scale, attenuation and fade

A digital level controller is present on the SAA7826 which performs the functions of soft mute, full-scale, attenuation and fade; these are selected via decoder register 0:

- Mute: signal reduced to 0 in a maximum of 128 steps; 3/n ms
- Attenuation: signal scaled by –12 dB
- Full-scale: ramp signal back to 0 dB level; from mute it takes 3/n ms
- Fade: activates a 128 stage counter which allows the signal to be scaled up or down in 0.07 dB steps
  - 128 = full-scale
  - 120 = –0.5 dB (i.e. full-scale if oversampling filter is used)
  - 32 = –12 dB
  - 0 = mute.

7.9.5 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 pin SDA.

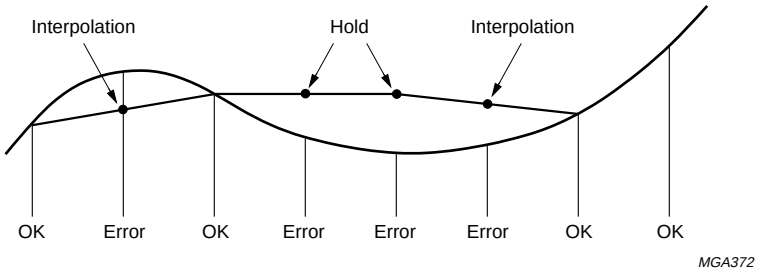


Fig.13 Concealment mechanism.

7.10 Audio DAC interface

7.10.1 Internal dynamic element matching digital-to-analog converter

The onboard audio DEM DAC operates at an oversampling rate of $96f_s$ and is designed for operation with an audio input at $1f_s$. The DAC is equipped with two pairs of stereo outputs for driving medium impedance line outputs and for directly driving low impedance headphones. A pair of analog inputs are provided to enable external audio sources to make use of the headphone output buffers.

Audio data from the decoder part of the SAA7826 can be routed as described in Sections 7.10.1.1 and 7.10.1.2.

Table 6 Shadow register

SHADEN BITS	SHADOW REGISTER	ADDRESS	DATA	FUNCTION	RESET
01 (bank 1)	7 control of onboard DAC	0111	0000	use external DAC or route audio data back into onboard DAC (loopback mode)	reset
			0010	route audio data directly into onboard DAC (non-loopback mode)	–

7.10.1.1 Use of internal DAC

Setting shadow register 7 to 0010 routes audio data from the decoder into the internal DAC. To enable the on-board DAC, the DAC interface format (set by register 3) must be set to 16-bit $1f_s$ mode, either I^2S-bus or EIAJ format. CD-ROM mode can also be used if interpolation is not required. The serial data output pins for interfacing with an external DAC (SCLK, WCLK, DATA and EF) are set to high-impedance.

7.10.1.2 Loopback external data into onboard DAC

The onboard DAC can also be set to accept serial data inputs from an external source, e.g. an Electronic Shock Absorption (ESA) IC. This is known as loopback mode and is enabled by setting shadow register 7 to 0000. This enables the serial data output pins (SCLK, WCLK, DATA and EF) so that data can be routed from the SAA7826 to an external ESA system (or external DAC).

The serial data from an external ESA IC can then also be input to the onboard DAC on the SAA7826 by utilising the serial data input interface (SCLI, SDI and WCLI).

In this mode, a wide range of data formats to the external ESA IC can be programmed as shown in Table 7.

However, the serial input on the SAA7826 always expects the input data from the ESA IC to be 16-bit 1fs and the same data format, either I2S-bus or EIAJ, as the serial output format (set by decoder register 3).

7.10.2 EXTERNAL DAC INTERFACE

Audio data from the SAA7826 can be sent to an external DAC, identical to the SAA732x series, in ‘loopback’ mode (i.e. shadow register 7 is set to 0000).

The SAA7826 is compatible with a wide range of external DACs. Eleven formats are supported which are given in Table 7. Figures 14 and 15 show the Philips I^2S-bus and the EIAJ data formats respectively. When the decoder is operated in lock-to-disc mode, the SCLK frequency depends on the disc speed factor ‘d’.

All formats are MSB first and $1f_s$ is 44.1 kHz. The polarity of the WCLK and the data can be inverted; selectable by decoder register 7. It should be noted that EF is only a defined output in CD-ROM and $1f_s$ modes.

When using an external DAC (or when using the onboard DAC in non-loopback mode), the serial data inputs to the onboard DAC (SCLI, SDI and WCLI) should be tied to ground.

Table 7 DAC interface formats

REGISTER 3	SAMPLE FREQUENCY	NUMBER OF BITS	SCLK (MHz)	FORMAT	INTERPOLATION
1010	f_s	16	$2.1168 \times n$	CD-ROM (I^2S-bus)	no
1011	f_s	16	$2.1168 \times n$	CD-ROM (EIAJ)	no
1110	f_s	16/18[1]	$2.1168 \times n$	Philips I^2S-bus 16/18 bits[1]	yes
0010	f_s	16	$2.1168 \times n$	EIAJ 16 bits	yes
0110	f_s	18	$2.1168 \times n$	EIAJ 18 bits	yes
0000	$4f_s$	16	$8.4672 \times n$	EIAJ 16 bits	yes
0100	$4f_s$	18	$8.4672 \times n$	EIAJ 18 bits	yes
1100	$4f_s$	18	$8.4672 \times n$	Philips I^2S-bus 18 bits	yes
0011	$2f_s$	16	$4.2336 \times n$	EIAJ 16 bits	yes
0111	$2f_s$	18	$4.2336 \times n$	EIAJ 18 bits	yes
1111	$2f_s$	18	$4.2336 \times n$	Philips I^2S-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.

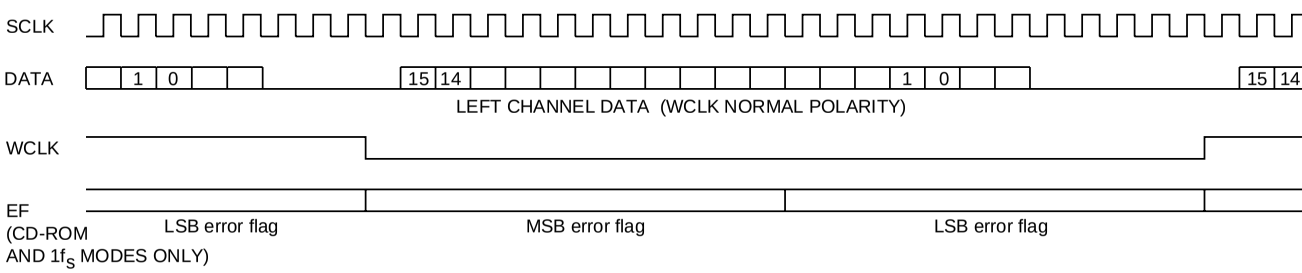


Fig.14 Philips I²S-bus data format (16-bit word length).

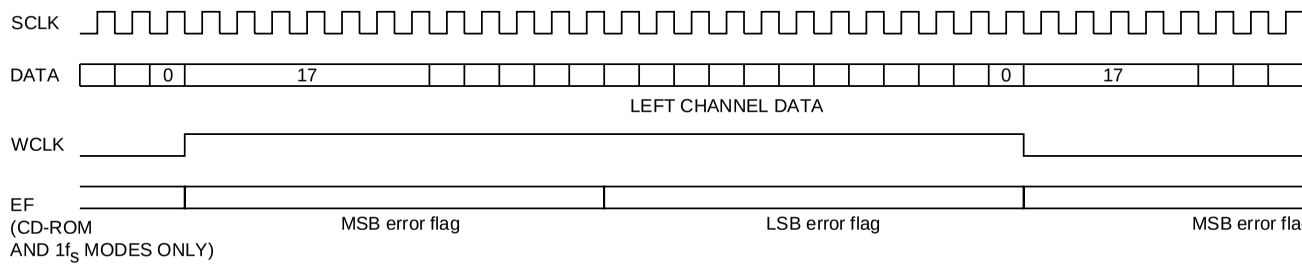


Fig.15 EIAJ data format (18-bit word length).

7.11 EBU interface

The bi-phase mark digital output signal at pin DOBM is in accordance with the format defined by the IEC 60958 specification. Three different modes can be selected via decoder register A:

- DOBM pin held LOW
- Data taken before concealment, mute and fade (must always be used for CD-ROM modes)
- Data taken after concealment, mute and fade.

An additional mute function is available via registers Shadow 7 (bank 1) and decoder register 0 and C. They provide the following:

- Hard mute: immediate mute of the audio sample in ROM mode at 1×, 2× or 4× speed
- Soft mute: 3 ms ramp up or ramp down of the audio samples in 1× audio mode
- Bypass: switches the EBU mute function out of the EBU signal path.

7.11.1 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. The EBU frame format is given in Table 8.

Table 8 EBU frame format; see also Table 9

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); twos complement; 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 9 Description of EBU frame function

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 10.

Table 10 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	6 to 27 and 30 to 191	always zero

7.12 KILL features

7.12.1 THE KILL CIRCUIT

The KILL circuit detects digital silence by testing for an all-zero or all-ones data word in the left and right channels. This occurs in two places; prior to the digital filter (internal KILL), and in the digital DAC (loopback/external KILL). Programming bit 3 of new shadow register A (bank 2) determines whether internal or external data is used. The output is switched to active HIGH when silence has been detected for at least 270 ms, or if mute is active, or in CD-ROM mode. Two KILL modes are available which can be selected by decoder register C:

- Mono KILL: LKILL and RKILL are both active HIGH when silence is detected on left and right channels simultaneously
- Stereo KILL: LKILL and RKILL are active HIGH independently of each other when silence is detected on either channel.

7.12.2 SILENCE INJECTION

The silence inject function monitors the left and right KILL signals and forces the analog DAC into silence when KILL is asserted. This improves the internal Signal-to-Noise Ratio (S/N) by preventing any spurious noise from reaching the DAC. The silence inject function can be enabled or disabled by programming bit 2 of the new shadow register A (bank 2).

7.13 Audio features off

The audio features can be turned off (selected by decoder register E) and will affect the following functions:

- Digital filter, fade, peak detector, internal KILL circuit (although RKILL and LKILL outputs are still active) are disabled
- V5 (if selected to be the de-emphasis flag output) and the EBU outputs become undefined.

The EBU output should be set LOW prior to switching the audio features off and after switching the audio features back on; a full-scale command should be given.

7.14 The versatile pins interface

The SAA7826 has five pins that can be reconfigured for different applications.

The functions of these versatile pins are identical to the SAA732x series and can be programmed by decoder registers C, D and shadow register 3 (bank 1) as shown in Table 11.

Table 11 Pin applications

PIN NAME	PIN NUMBER	TYPE	REGISTER ADDRESS	REGISTER DATA	FUNCTION
V1	71	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	72	input	–	–	input may be read via decoder status bit; selected via register 2
V3	73	output	1100	00XX	output = 0
			–	01XX	output = 1
V4	74	output	1101	0000	4-line motor drive (using V4 and V5)
			–	XX01	Q-to-W subcode output
			–	XX10	output = 0
			–	XX11	output = 1
V5	75	output	1101	01XX	de-emphasis output (active HIGH)
			–	10XX	output = 0
			–	11XX	output = 1

7.15 Spindle motor control

7.15.1 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 decoder register 6, are supported:

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

7.15.1.1 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 duty factors means 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 × n) MHz internal clock signal.

7.15.1.2 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 16. A typical application diagram is illustrated in Fig 17.

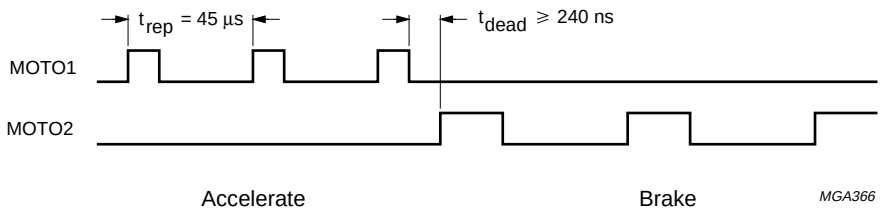


Fig.16 2-line PWM mode timing.

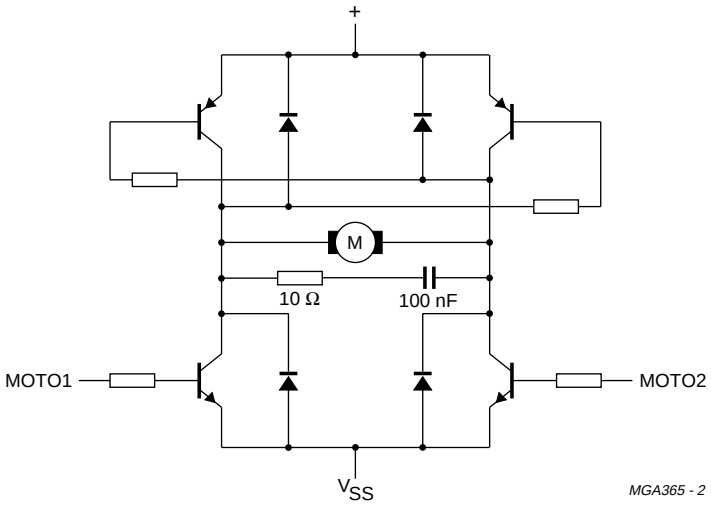


Fig.17 Motor 2-line PWM mode application diagram.

7.15.1.3 PWM output mode (4-line)

By using two extra outputs from the versatile pins interface, it is possible to use the SAA7826 with a 4-input motor bridge. The timing is illustrated in Fig 18. A typical application diagram is illustrated in Fig 19.

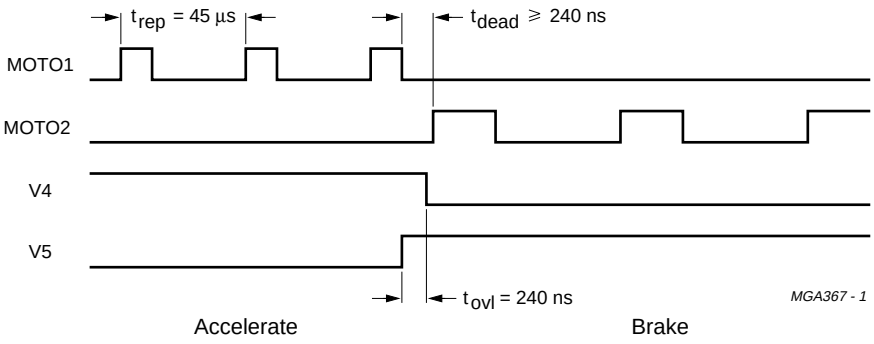


Fig.18 4-line PWM mode timing.

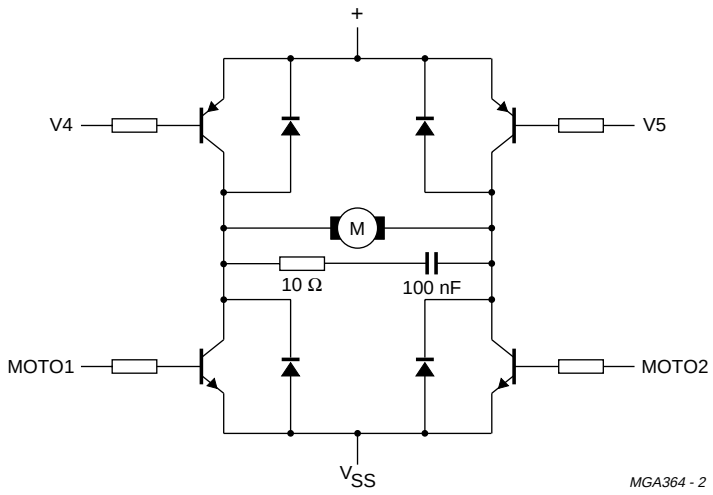


Fig.19 Motor 4-line PWM mode application diagram.

7.15.1.4 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 × d Hz; where 'd' is the disc speed factor]. The PLL frequency signal will be put in pulse-density modulated form (carrier frequency = 4.23 × n 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%.

In the lock-to-disc (CAV) mode the CDV motor mode is the only mode that can be used to control the motor.

7.15.2 SPINDLE MOTOR OPERATING MODES

The operating modes of the motor servo are controlled by decoder register 1; see Table 12.

In the SAA7826 decoder there is an anti-windup mode for the motor servo, selected via decoder register 1. When the anti-windup mode is activated the motor servo integrator will hold if the motor output saturates.

7.15.2.1 Motor OV flag

The SAA7826 contains a servo loop that is used to regulate the spindle speed. The motor OV flag is provided to indicate when the motor output has overloaded. During a large change in disc speed, i.e. by a long jump or X factor change, the motor OV flag will be asserted due to the full and longer duration required to attain the new desired sped.

The OC flag indicates when the internal processes of the modulator have overflowed and not necessarily when the output power has reached 100%. Similarly, the flag does not fall at a specific output power level but at a specific speed error level. The error level at which the flag falls is determined by the selected servo gain and will be internally equivalent to +3 × gain or –3 × gain.

7.15.2.2 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.

7.15.3 LOOP CHARACTERISTICS

The gain and crossover frequencies of the motor control loop can be programmed via decoder 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: $0.5 \times n$ Hz, $0.7 \times n$ Hz, $1.4 \times n$ Hz and $2.8 \times n$ Hz
- Crossover frequency f_3: $0.85 \times n$ Hz, $1.71 \times n$ Hz and $3.42 \times n$ Hz.

It should be noted that the crossover frequencies f_3 and f_4 are scaled with the overspeed factor ‘n’ whereas the gains are not.

7.15.4 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 will conceal as much as possible to minimize the effect of data loss.

Table 12 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. It should be noted that in the CD-ROM modes the data, on EBU and the I^2S-bus, is not muted.
Jump mode 1	Similar to jump mode but motor integrator is kept at zero. It is used for long jumps where there is a large change in disc speed.
Play mode	FIFO released after resetting to 50% and the audio mute is 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.

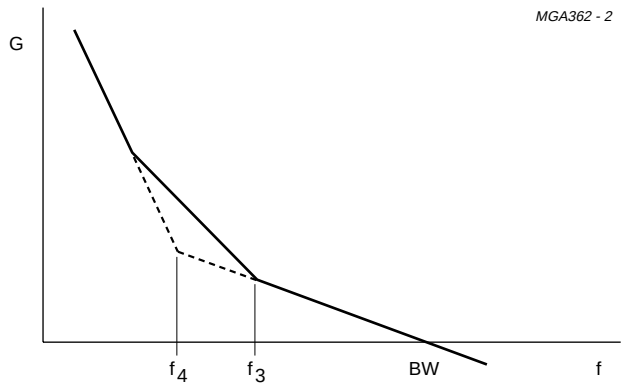


Fig.20 Motor servo mode diagram.

7.16 Servo part

7.16.1 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 signals are summed into an HF signal for the decoder function and are also differentiated (after analog-to-digital conversion) to produce the low frequency focus control signals.

The low frequency content of the six (five if single Foucault) photo diode inputs are converted to digital Pulse Density Modulated (PDM) bitstreams by six Sigma-delta ADCs. These support a range of OPUs by interfacing to Voltage mode mechanisms and by having 16 selectable gain ranges in two sets, one set for D1-to-D4 and the other for R1 and R2.

Table 13 Shadow register settings to control diode input current and voltage ranges

SHADEN BITS	SHADOW REGISTER	ADDRESS	DATA	VOLTAGE MODE (mV)	INITIAL
01 (bank 1)	A signal magnitude control for diodes D1 to D4 (LF only)	1010	0000	20	–
			0001	25	–
			0010	30	–
			0011	40	–
			0100	60	–
			0101	75	–
			0110	100	–
			0111	120	–
			1000	150	–
			1001	200	–
			1010	270	–
			1011	350	–
			1100	450	–
			1101	600	–
			1110	720	–
			1111	960	reset

SHADEN BITS	SHADOW REGISTER	ADDRESS	DATA	VOLTAGE MODE (mV)	INITIAL
01 (bank 1)	C signal magnitude control for diodes R1 and R2 (LF only)	1100	0000	20	–
			0001	25	–
			0010	30	–
			0011	40	–
			0100	60	–
			0101	75	–
			0110	100	–
			0111	120	–
			1000	150	–
			1001	200	–
			1010	270	–
			1011	350	–
			1100	450	–
			1101	600	–
			1110	720	–
			1111	960	reset

7.16.2 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 to be as shown in Fig 21.

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 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 dropout 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:

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

Where the weighting factor sum_gain is generated internally by the SAA7826 during initialization.

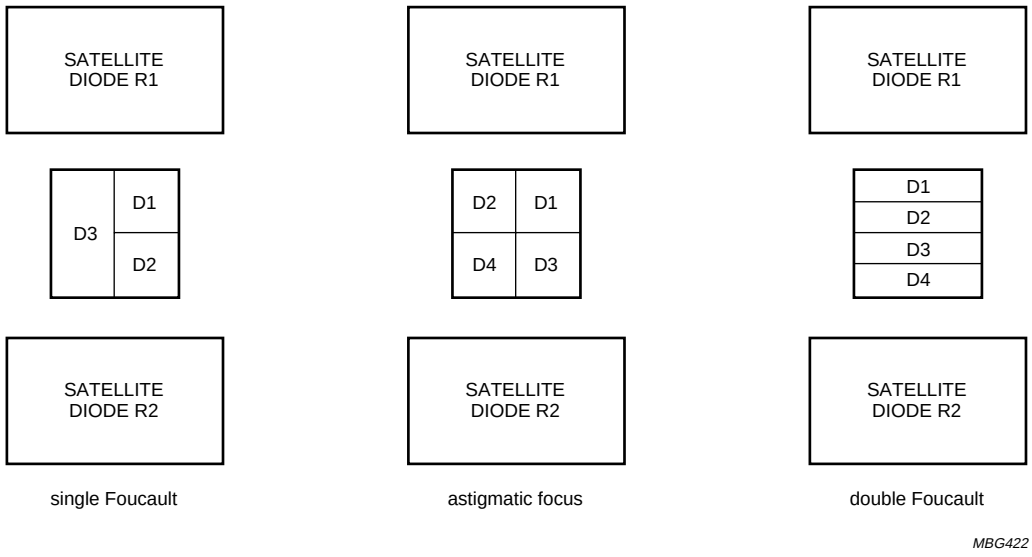


Fig.21 Detector arrangement.

7.16.3 Focus servo system

7.16.3.1 Focus start-up

Five initially loaded coefficients influence the start-up behaviour of the focus controller. The automatically generated triangular 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.

7.16.3.2 Focus position control loop

The focus control loop contains a digital PID controller which has 5 parameters that 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.

7.16.3.3 Dropout 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.

7.16.3.4 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.

7.16.3.5 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.

7.16.3.6 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).

7.16.4 RADIAL SERVO SYSTEM

7.16.4.1 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 ±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 < duty factor < 0.6 (default duty factor = TPI HIGH/TPI period).

7.16.4.2 Sledge control

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

7.16.4.3 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 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 disturbances in the audio output and providing improved shock resistance. 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.

7.16.4.4 Access

The access procedure is divided into two different modes (see Table 14), depending on the requested jump size.

Table 14 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. The microcontroller can be preset.

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 content of the actuator integrator leaks to zero just after the sledge jump mode is initiated). The actuator can be electronically damped during sledge jump. The gain of the damping loop is controlled via the hold_mult parameter.

The fast track jumping circuitry can be enabled or disabled via the xtra_preset parameter.

7.16.4.5 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.

7.16.5 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 ±0.25 of the track pitch. In combination with the Radial Polarity flag (RP) the relative spot position over the tracks can be determined.

These signals can have 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 0.5π 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.

7.16.6 Track counting modes

Fast counting mode is auto-selected for track-crossing speeds above 1200 tracks/s. In this case the off-track counting decrements occur only for effect of the RP signal. The direction of the jump is already known because the Slow counting mode occurs prior to entering the Fast counting mode.

When the Slow counting mode is selected the maximum track-crossing speed that can be reached is 12 kHz (providing that the maximum value for rad_pole_lead is used). In this case the direction of the jump is given by the phase shift between RP and TL(+90^o for outward jumps and -90^o for inward jumps). The number of pulses in the TL signal gives the number of tracks crossed.

When Fast counting mode is enabled, whenever the track-crossing speed falls below 12 kHz, the counting mode is automatically changed to Slow counting mode.

7.16.7 Defect detection

A defect detection circuit is incorporated into the SAA7826. 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.22) has programmable set points selectable by the parameter defect_parm.

7.16.8 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.

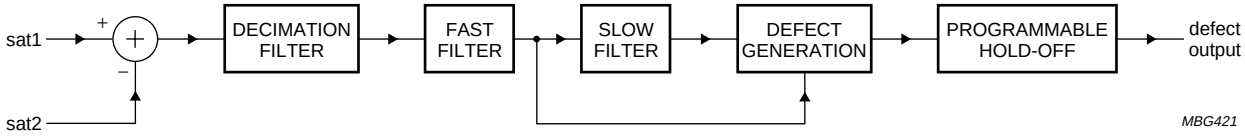


Fig.22 Block diagram of the defect detector.

7.16.9 HIGH-LEVEL FEATURES

7.16.9.1 Interrupt mechanism and STATUS pin

The STATUS pin is an output which can be configured by decoder register 7 and new shadow register C (bank 3) for one of three different modes of operation. These are:

- Output the interrupt signal generated by the servo part (it should be noted that the selection of this mode will override all other modes)
- Output the decoder status bit (active LOW) selected by decoder register 2 (only available in 4-wire bus mode)
- Output DC offset information (it should be noted that this mode is used in conjunction with the decoder status mode; see Section 7.5).

Eight 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:

- Focus lost: dropout of longer than 3 ms
- Subcode ready
- Subcode absolute seconds changed
- Subcode discontinuity detected: new subcode time before previous subcode time, or more than 10 frames later than previous subcode time
- Radial error: during radial on-track, no new subcode frame occurs within the time defined by the ‘playwatchtime’ parameter; during radial jump, less than 4 tracks have been crossed during the time defined by the ‘jumpwatchtime’ parameter
- Autosequencer state change
- Autosequencer error
- Subcode interface blocked: the internal decoder interface is being used.

It should be noted that if the STATUS pin is configured to output decoder status information [decoder register 7 = XX10 and new shadow register C (bank 3) = X00X] and either the microcontroller writes a different value to decoder register 2 or the decoder interface is enabled then the STATUS output will change.

7.16.9.2 Decoder interface

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

7.16.9.3 Automatic error handling

Three Watchdogs are present:

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

7.16.9.4 Automatic sequencers and timer interrupts

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

- Auto-start sequencer: controls the start-up of focus, radial and motor
- Auto-stop sequencer: brakes the disc and shuts down the servos.

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

7.16.9.5 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.

7.16.10 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 or 2.1168 MHz; controlled via the xtra_preset parameter. An analog representation of the output signals can be achieved by connecting a 1st-order low-pass filter to the outputs.

During reset (i.e. $\overline{\text{RESET}}$ pin is held LOW) the RA, FO and SL pins are high-impedance. At all other times, when the laser is switched off, the RA and FO pins output a 2 MHz 50% duty factor signal.

7.16.11 LASER INTERFACE

The laser diode pre-amplifier function is built into the SAA7826; see Fig.23. The current can be regulated, up to 120 mA [programmed via new shadow register A (bank 2) and register 3 (bank 3)], in four steps ranging from 58% up to full power. New shadow register A (bank 2) and register 3 (bank 3)] are used to select the step values.

The voltage derived from the monitor diode is maintained at a steady state by the laser drive circuitry, by regulating the current through the laser diode. The type of monitor diode being used (150 mV or 180 mV) must be selected by new shadow register 7 (bank 2) (reset state = 150 mV).

The laser can be switched on or off by the xtra_preset parameter; it is automatically driven if the focus control loop is active.

7.17 Microcontroller interface

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

- 4-wire bus mode: where;
  - SCL = serial clock
  - SDA = serial data
  - RAB = R/$\overline{W}$ control and data strobe (active HIGH) for writing to decoder registers 0 to F, reading status bit selected via decoder register 2 and reading Q-channel subcode
  - SILD = $\overline{R}$/W control and data strobe (active LOW) for servo commands
- 3-wire bus mode: where;
  - SCL = serial clock
  - SDA = serial data
  - RAB = not used, pulled LOW
  - SILD = $\overline{R}$/W control and data strobe (active LOW) for servo commands
- I^2C-bus mode: I^2C-bus protocol where the SAA7826 behaves as slave device, activated by setting RAB = HIGH and SILD = LOW where;
  - I^2C-bus slave address (write mode) = 30H
  - I^2C-bus slave address (read mode) = 31H
  - Maximum data transfer rate = 400 kbits/s.

It should be noted that when using the I^2C-bus mode, only servo commands can be used. Therefore, writing to decoder registers 0 to F, reading decoder status and reading Q-channel subcode data must be performed by servo commands.

The 3-wire mode is very similar to the 4-wire mode, except that all communication to the decoder is via the servo.

Communication to the servo uses the same hardware protocol and timing as the 4-wire mode.

Extra servo commands exist for write and read access to the decoder via the internal decoder interface. The internal interface must be enabled by using the xtra_preset command. RAB is not used and must be tied LOW; see Fig.23.

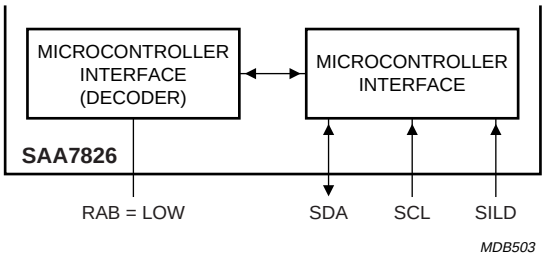


Fig.23 Microcontroller interface (3-wire mode).

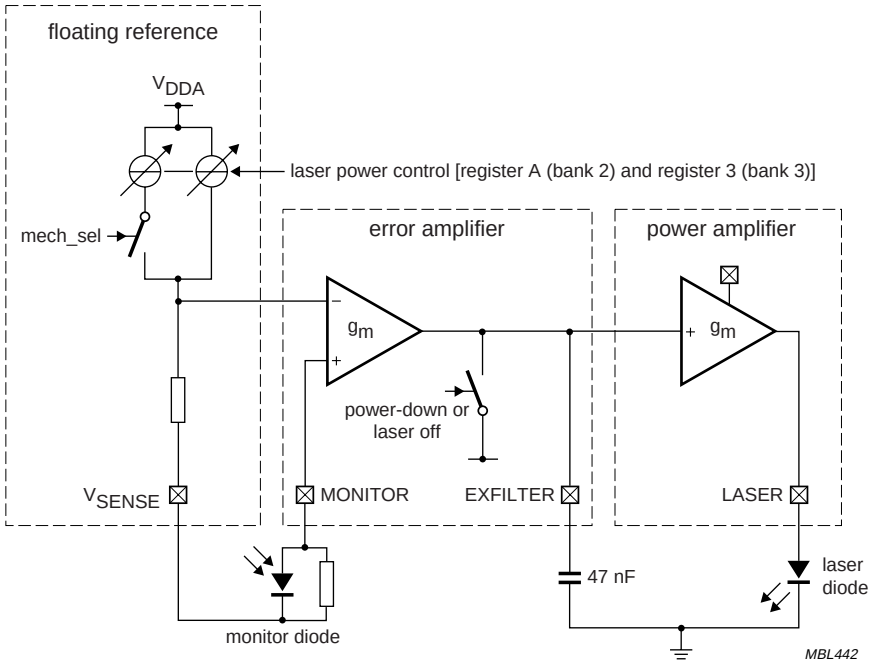


Fig.24 Simplified block diagram of the laser driver.

7.17.1 MICROCONTROLLER INTERFACE (4-WIRE BUS MODE)

7.17.1.1 Writing data to registers 0 to F

The sixteen 4-bit programmable configuration registers, 0 to F (see Table 15), can be written to via the microcontroller interface using the protocol shown in Fig.25. 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.

7.17.1.2 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.26. It should be noted that SCL must stay HIGH between RAB pulses.

7.17.1.3 Multiple writes to the new shadow registers

Some of the new shadow registers are a multiple of four bits in length and require a number of write operations to fill them up; see Section 7.17.5. They must be completely filled before writing to another register, otherwise unpredictable behaviour may result.

The protocol for writing to these registers is exactly the same as the decoder registers; see Fig.25. The write command must be executed multiple times with the same address content. The first four bits of data in a sequence of write commands represent the most significant nibble of the register, while the last four represent the least significant nibble. The data content can change from one write to the next without consequence.

7.17.1.4 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 pin V1
- V2: follows input on pin V2
- MOTOR-OV: HIGH if the motor servo output stage saturates.

The status read protocol is illustrated in Fig.27. It should be noted that SILD must be held HIGH.

7.17.1.5 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 the status signal. The subcode read protocol is illustrated in Fig.28.

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), the reading can be terminated 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.

7.17.1.6 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 illustrated in Fig.29. When the CRC is good and the subcode is being read, the timing in Fig.30 applies.

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

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

It should be noted that in the lock-to-disc mode ‘n’ is replaced by ‘d’, which is the disc speed factor.

7.17.1.7 Write servo commands

A write data command is used to transfer data (a number of bytes) from the microcontroller, using the protocol illustrated in Fig.31. 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 SAA7826 after the HIGH-to-LOW transition of SILD; there must be a minimum time of 70 µs between SILD pulses.

7.17.1.8 Writing repeated data in servo commands

The same data byte can be repeated by applying extra SILD pulses as illustrated in Fig.32. SCL must be HIGH between the SILD pulses.

7.17.1.9 Read servo commands

A read data command is used to transfer data (status information) to the microcontroller, using the protocol shown in Fig.33. 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 µs before data can be read (i.e. the next HIGH-to-LOW transition on SILD) and there must be a minimum time of 70 µs between SILD pulses.

7.17.2 MICROCONTROLLER INTERFACE (I^2C-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:

1. Send START condition.
2. Send address 30H (write).
3. Write command byte.
4. Write data byte 1.
5. Write data byte 2.
6. Write data byte 3.
7. 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:

1. Send START condition.
2. Send address 30H (write).
3. Write command byte.
4. Send STOP condition.
5. Send START condition.
6. Send address 31H (read).
7. Read data byte 1.
8. Read data byte 2.
9. Send STOP condition.

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

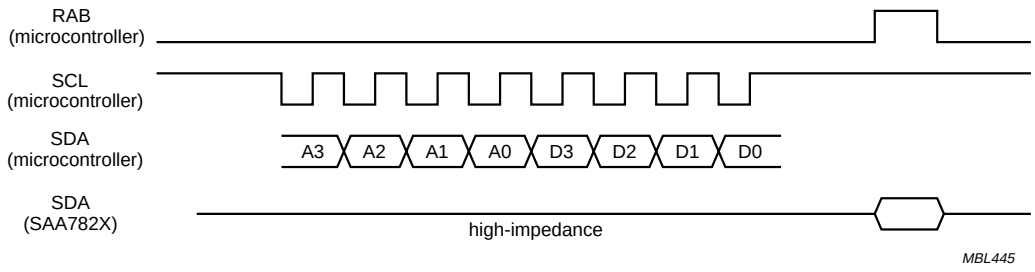


Fig.25 Microcontroller write protocol for registers 0 to F.

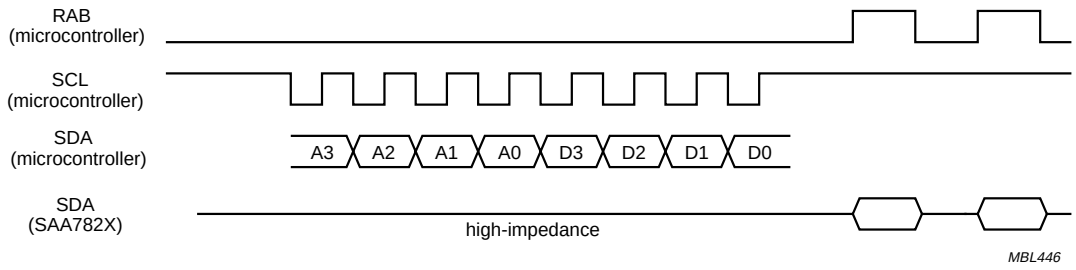


Fig.26 Microcontroller write protocol for registers 0 to F (repeat mode).

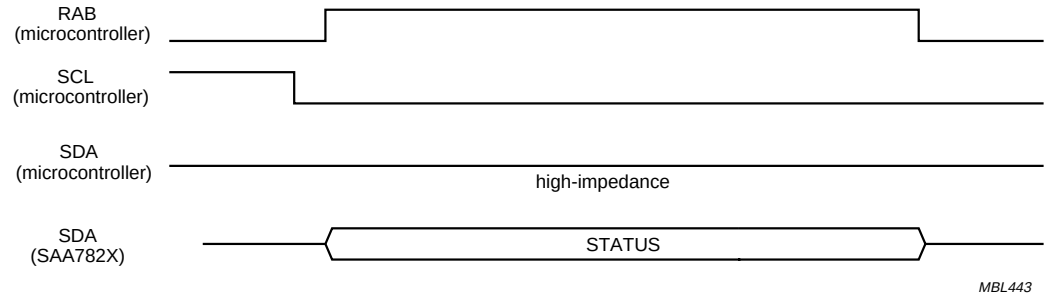


Fig.27 Microcontroller read protocol for decoder status on SDA.

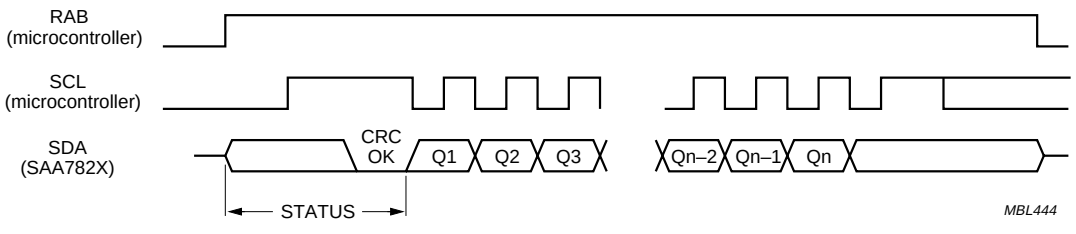


Fig.28 Microcontroller protocol for reading Q-channel subcode.

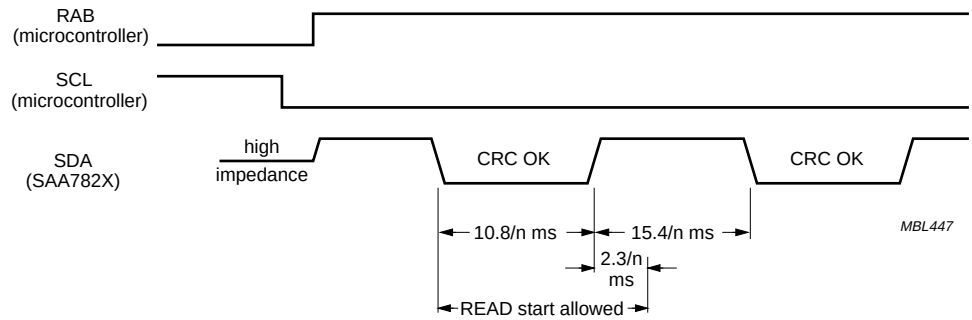


Fig.29 SUBQREADY-I status timing when no subcode is read.

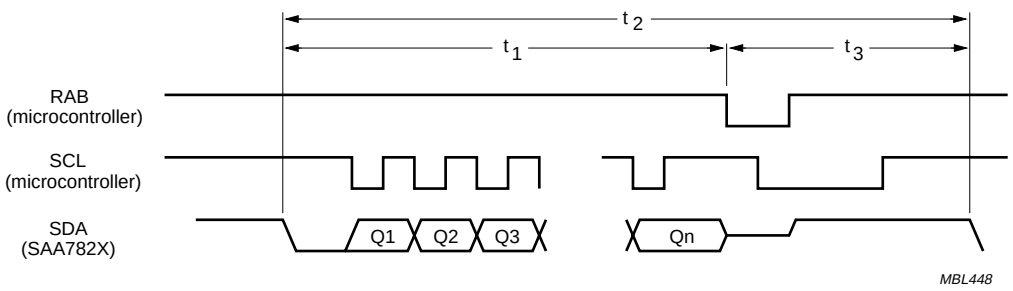


Fig.30 SUBQREADY-I status timing when subcode is read.

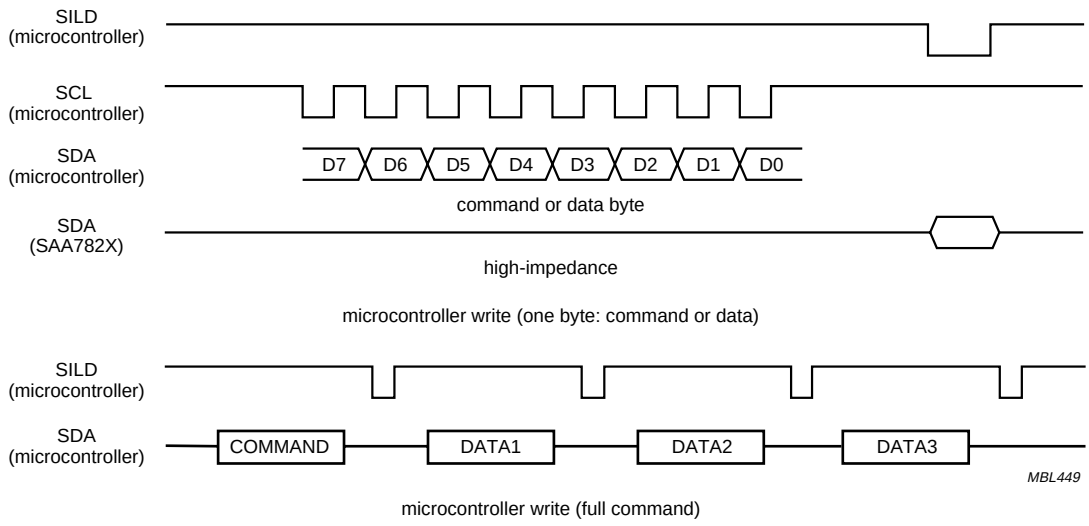


Fig.31 Microcontroller protocol for write servo commands.

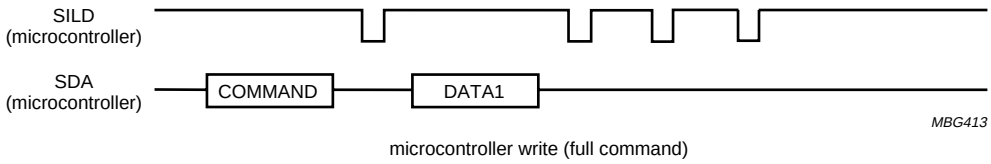


Fig.32 Microcontroller protocol for repeated data in write servo commands.

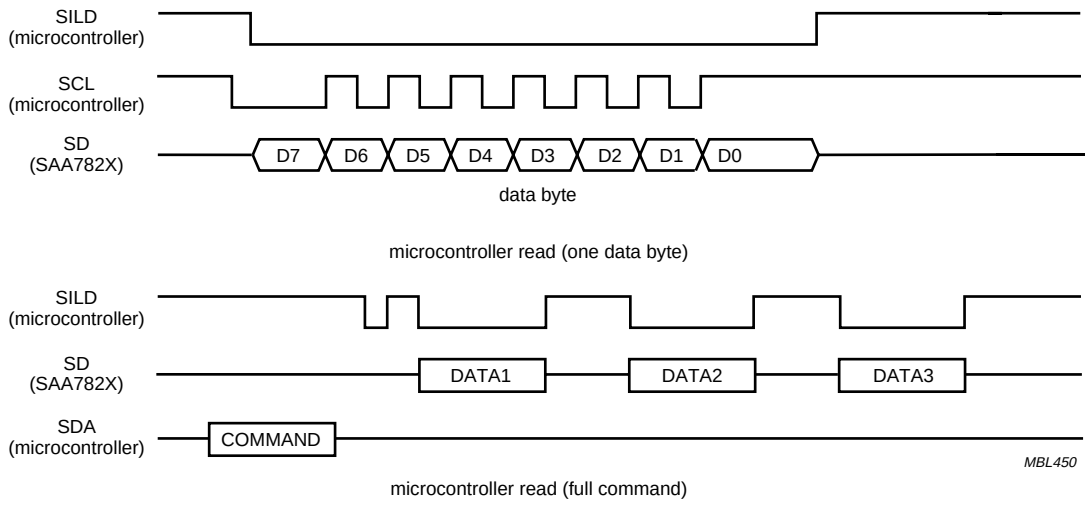


Fig.33 Microcontroller protocol for read servo commands.

7.17.3 Decoder and shadow registers

To maintain compatibility with the SAA732x series, decoder registers 0 to F and the shadow registers are largely unchanged. However, to control the extra functionality of SAA7826, the shadow registers have been extended to include new shadow registers.

All shadow registers are accessed by using the two LSBs (bits 0 and 1) of decoder register F. These bits are called SHADEN1 and SHADEN2 respectively. These bits are decoded according to Table 15.

This two bit encoding allows the use of three shadow register banks; bank 1 (SAA732X shadow registers), and banks 2 and 3 (new shadow registers). Only the four addresses 3, 7, A and C are implemented in any one bank. Any other addresses sent while accessing any of the shadow register banks are invalid and have no effect.

When SHADEN1 and SHADEN2 are both set to logic 0 (decoder register F set to XX00) all subsequent addresses are decoded by the main decoder registers again.

Access to decoder register F is always enabled so that SHADEN1 and SHADEN2 can be set or reset as required.

The SHADEN bits and subsequent shadow registers are programmed identically to the main decoder registers, i.e. they can be directly programmed when using the SAA7826 in 4-wire mode or programmed via the servo interface when using 3-wire or I^2C-bus modes. The main decoder registers are given in Table 16 and the shadow registers in Table 18. Details of the new shadow registers can be found in Tables 19 to 22.

Table 15 Shadow register accessibility

SHADEN2	SHADEN1	FUNCTION	INITIAL
0	0	access decoder registers 0 to F	reset
0	1	access SAA732X shadow registers (bank 1)	–
1	0	access new shadow registers (bank 2)	–
1	1	access new shadow registers (bank 3)	–

7.17.4 Summary of functions controlled by decoder registers 0 to F

Table 16 Registers 0 to F

REGISTER	ADDRESS	DATA	FUNCTION	INITIAL[1]
0 (Fade and attenuation)	0000	X000	mute	reset
		X010	attenuate	–
		X001	full-scale	–
		X100	step-down	–
		X101	step-up	–
1 (Motor mode)	0001	X000	motor off mode	reset
		X001	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	–
2 unavailable via the I^2C-bus or 3-wire mode		1000	status = FIFO overflow	–
		1001	status = shock detect	–
		1010	status = latched shock detect	–
		1011	status = latched shock detect reset	–

REGISTER	ADDRESS	DATA	FUNCTION	INITIAL[1]
3 (DAC output)	0011	1010	I^2S-bus; CD-ROM mode	–
		1011	EIAJ; CD-ROM mode	–
		1100	I^2S-bus; 18-bit; $4f_s$ mode	reset
		1111	I^2S-bus; 18-bit; $2f_s$ mode	–
		1110	I^2S-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	–
4 (Motor gain)	0100	0000	motor gain G = 3.2	reset
		0001	motor gain G = 4.0	–
		0010	motor gain G = 6.4	–
		0011	motor gain G = 8.0	–
		0100	motor gain G = 12.8	–
		0101	motor gain G = 16.0	–
		0110	motor gain G = 25.6	–
		0111	motor gain G = 32.0	–
5 (Motor bandwidth)	0101	XX00	motor $f_4 = 0.5 \times n$ Hz	reset
		XX01	motor $f_4 = 0.7 \times n$ Hz	–
		XX10	motor $f_4 = 1.4 \times n$ Hz	–
		XX11	motor $f_4 = 2.8 \times n$ Hz	–
		00XX	motor $f_3 = 0.85 \times n$ Hz	reset
		01XX	motor $f_3 = 1.71 \times n$ Hz	–
		10XX	motor $f_3 = 3.42 \times n$ 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	–

REGISTER	ADDRESS	DATA	FUNCTION	INITIAL(1)
7 (DAC output and STATUS pin control)	0111	XX00	interrupt signal from servo only at STATUS pin	reset
		XX10	status bit from decoder status register or DC offset information at STATUS pin [see also new shadow register C (bank 3)]	–
		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 16	–
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	–
A (EBU output)	1010	XX0X	EBU data before concealment	–
		XX1X	EBU data after concealment and fade	reset
		X0X0	Level II clock accuracy (<1000 ppm)	reset
		X0X1	Level I clock accuracy (<50 ppm)	–
		X1X0	Level III clock accuracy (>1000 ppm)	–
		X1X1	EBU off - output LOW	–
		0XXX	flags in EBU off	reset
		1XXX	flags in EBU on	–
B (speed control)	1011	X000	standby 1: ‘CD-STOP’ mode	reset
		X010	standby 2: ‘CD-PAUSE’ mode	–
		X011	operating mode	–
		00XX	single-speed mode	reset
		10XX	double-speed mode	–
C (versatile pins interface and KILL function)	1100	XXX1	external off-track signal input at V1	–
		XXX0	internal off-track signal used (V1 may be read via status)	reset
		XX0X	stereo KILL	–
		XX1X	mono KILL	reset
		00XX	V3 = 0	reset
		01XX	V3 = 1	–
C EBU mute mode select (for M1 version only		0XXX	mute type: soft mute audio (only available at 1× speed)	reset
		1XXX	mute type: ROM hard mute (available at 1×, 2× and 4× speed)	–

REGISTER	ADDRESS	DATA	FUNCTION	INITIAL(1)
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	XXX0	motor brakes to 12%	reset
		XXX1	motor brakes to 6%	–
		XX0X	lock-to-disc mode disabled	reset
		XX1X	lock-to-disc mode enabled	–
		X0XX	audio features disabled	–
		X1XX	audio features enabled	reset
		0XXX	quad-speed mode disabled	reset
		1XXX	quad-speed mode enabled	–
F (subcode interface and shadow register enable)	1111	X0XX	subcode interface off	reset
		X1XX	subcode interface on	–
		0XXX	4-wire subcode	reset
		1XXX	3-wire subcode	–
		XX00	SHADEN bits = 00; shadow registers not enabled; addresses will be decoded by main decoder registers	reset
		XX01	SHADEN bits = 01; SAA732X shadow registers (bank 1) enabled; all subsequent addresses will be decoded by shadow register (bank 1), not decoder registers	–
		XX10	SHADEN bits = 10; new shadow registers (bank 2) enabled; all subsequent addresses will be decoded by shadow register (bank 2)	–
		XX11	SHADEN bits = 11; new shadow registers (bank 3) enabled; all subsequent addresses will be decoded by shadow register (bank 3)	–

Note

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

Table 17 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 × n	525 × n	8400 × n	–
		0001	3279 × n	263 × n	16800 × n	–
		0010	6560 × n	131 × n	33600 × n	–
		0100	1640 × n	1050 × n	8400 × n	–
		0101	3279 × n	525 × n	16800 × n	–
		0110	6560 × n	263 × n	33600 × n	–
		1000	1640 × n	2101 × n	8400 × n	–
		1001	3279 × n	1050 × n	16800 × n	reset
		1010	6560 × n	525 × n	33600 × n	–
		1100	1640 × n	4200 × n	8400 × n	–
		1101	3279 × n	2101 × n	16800 × n	–
		1110	6560 × n	1050 × n	33600 × n	–

Note

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

7.17.5 Summary of functions controlled by shadow registers

Table 18 Bank 1 shadow register settings (single write)

SHADEN BITS	SHADOW REGISTER	ADDRESS	DATA	FUNCTION	INITIAL
01 (bank 1)	3 control of versatile and clock pins	0011	XX00	select CLK4 on CLK4/12 output	reset
			XX01	select CLK12 on CLK4/12 output	–
			X0XX	enable CLK16 output pin	reset
			X1XX	set CLK16 output pin to high-impedance	–
			0XXX	set V3 output pin to high-impedance	reset
			1XXX	enable V3 output pin	–
	7 control of onboard DAC	0111	0000	use external DAC or route audio data back into onboard DAC (loopback mode)	reset
			0010	route audio data directly into onboard DAC (non-loopback mode)	–
	7 EBU mute bypass control (for M1 version only)		XXX0	EBU mute function not bypassed	reset
			XXX1	EBU mute function bypassed	–

SHADEN BITS	SHADOW REGISTER	ADDRESS	DATA	FUNCTION	INITIAL
01 (bank 1)	A signal magnitude control for diodes D1 to D4 (LF only)	1010	0000	voltage mode: 20 mV	–
			0001	voltage mode: 25 mV	–
			0010	voltage mode: 30 mV	–
			0011	voltage mode: 40 mV	–
			0100	voltage mode: 60 mV	–
			0101	voltage mode: 75 mV	–
			0110	voltage mode: 100 mV	–
			0111	voltage mode: 120 mV	–
			1000	voltage mode: 150 mV	–
			1001	voltage mode: 200 mV	–
			1010	voltage mode: 270 mV	–
			1011	voltage mode: 350 mV	–
			1100	voltage mode: 450 mV	–
			1101	voltage mode: 600 mV	–
			1110	voltage mode: 720 mV	–
			1111	voltage mode: 960 mV	reset
01 (bank 1)	C signal magnitude control for diodes R1 and R2 (LF only)	1100	0000	voltage mode: 20 mV	–
			0001	voltage mode: 25 mV	–
			0010	voltage mode: 30 mV	–
			0011	voltage mode: 40 mV	–
			0100	voltage mode: 60 mV	–
			0101	voltage mode: 75 mV	–
			0110	voltage mode: 100 mV	–
			0111	voltage mode: 120 mV	–
			1000	voltage mode: 150 mV	–
			1001	voltage mode: 200 mV	–
			1010	voltage mode: 270 mV	–
			1011	voltage mode: 350 mV	–
			1100	voltage mode: 450 mV	–
			1101	voltage mode: 600 mV	–
			1110	voltage mode: 720 mV	–
			1111	voltage mode: 960 mV	reset

Table 19 Bank 2 new shadow register settings (single write)

SHADEN BITS	SHADOW REGISTER	ADDRESS	DATA	FUNCTION	INITIAL
10 (bank 2)	3 Power-down control	0011	XXX0	analog front-end active	reset
			XXX1	analog front-end powered down	–
			XX0X	buffer amplifier on	reset
			XX1X	buffer amplifier off (power saving)	–
			X0XX	DAC active	reset
			X1XX	DAC powered down	–
	3 DAC output mode		0XXX	normal mode	reset
			1XXX	current mode (bypass internal I-to-V converters)	–
	7 mechanism and voltage reference selection	0111	XX10	voltage mechanism: $\frac{1.65 \times V_{DDA}}{3.3\ V}$	reset
			XX11	voltage mechanism: $\frac{2.5 \times V_{DDA}}{3.3\ V}$	–
			X0XX	150 mV mechanism	reset
			X1XX	180 mV mechanism	–
	7 CD-text control		0XXX	flag all data (CRC pass and fail)	reset
			1XXX	flag only data that passes the CRC	–

SHADEN BITS	SHADOW REGISTER	ADDRESS	DATA	FUNCTION	INITIAL
10 (bank 2)	A laser power control 1	1010	XXX0	approximately 58% (laser power control 2 = 0)	reset
				approximately 72% (laser power control 2 = 1)	
				see shadow register 3 (bank 3)	
			XXX1	approximately 86% (laser power control 2 = 0)	–
				approximately 100% (laser power control 2 = 1)	
				see shadow register 3 (bank 3)	
	A clock source		XX0X	bypass PLL (external clock source)	–
			XX1X	select and enable PLL	reset
	A KILL control		X0XX	disable silence injection	reset
			X1XX	enable silence injection	–
			0XXX	internal KILL	reset
			1XXX	loop-back KILL	–
	C DC offset measurement times	1100	XX00	settling time = 354 μs	reset
			XX01	settling time = 1 ms	–
			XX10	settling time = 2 ms	–
			XX11	settling time = 10 ms	–
	C upsampler dither selection		00XX	no dither selected	–
			01XX	AC dither only	–
			10XX	DC dither only	–
			11XX	AC and DC dither selected	reset

Table 20 Bank 3 new shadow register settings (single write)

SHADEN BITS	SHADOW REGISTER	ADDRESS	DATA	FUNCTION	INITIAL
11 (bank 3)	3 diode selection for DC offset measurement	0011	X000	select D1	reset
			X001	select D1	–
			X010	select D2	–
			X011	select D3	–
			X100	select D4	–
			X101	select R1	–
			X110	select R2	–
			X111	select D1	–
	3 laser power control 2		0XXX	60% (laser power control 1 = 0)	reset
				87% (laser power control 1 = 1)	
				see shadow register A (bank 2)	
			1XXX	73% (laser power control 1 = 0)	–
				100% (laser power control 1 = 1)	
				see shadow register A (bank 2)	
	C enable equalizer	1100	XXX0	equalizer disabled and powered-down	reset
			XXX1	equalizer enabled	–
	C STATUS pin control		000X	STATUS pin outputs decoder status register information	reset
			001X	STATUS pin outputs DC offset ready flag	–
			010X	STATUS pin outputs DC offset value	–

Table 21 Bank 3 new shadow register settings (multiple write)

SHADEN BITS	SHADOW REGISTER	ADDRESS	SIZE (DATA NIBBLES)	REGISTER ELEMENTS[1]
11 (bank 3)	7 DC cancellation levels	0111	9	<r2_off> <r1_off> <d4_off> <d3_off> <d2_off> <d1_off>
	A analog FE control	1010	4	<hp_filter_sel> <eq_speed_sel> <slicer_slew> <hf_gain>

Note

1. Register elements are described in Tables 26 and 27.

Table 22 Multiple write register element description

SHADOW REGISTER	ELEMENT NAME	BIT NUMBERS	DESCRIPTION
7 (bank 3)	<d1_off>	<5:0>	DC offset level for D1 (reset value = 000000)
	<d2_off>	<11:6>	DC offset level for D2 (reset value = 000000)
	<d3_off>	<17:12>	DC offset level for D3 (reset value = 000000)
	<d4_off>	<23:18>	DC offset level for D4 (reset value = 000000)
	<r1_off>	<29:24>	DC offset level for R1 (reset value = 000000)
	<r2_off>	<35:30>	DC offset level for R2 (reset value = 000000)
A (bank 3)	<hf_gain>	<3:0>	see Table 23
	<slicer_slew>	<7:4>	see Table 24
	<eq_speed_sel>	<9:8>	equaliser operating speed: 00 = 1× (reset); 01 = 2×; 10 = 4×
	<hp_filter_sel>	<15:10>	see Table 25

Table 23 HF gain

DATA	DESCRIPTION
0000	voltage mode = 1.11 V
0001	voltage mode = 952 mV
0010	voltage mode = 588 mV
0011	voltage mode = 392 mV
0100	voltage mode = 1.11 V
0101	voltage mode = 952 mV
0110	voltage mode = 588 mV
0111	voltage mode = 392 mV
1000	voltage mode = 303 mV
1001	voltage mode = 200 mV
1010	voltage mode = 157 mV
1011	voltage mode = 107 mV
1100	voltage mode = 79 mV
1101	voltage mode = 54 mV
1110	voltage mode = 39 mV
1111	voltage mode = 27 mV

Table 24 Slicer threshold tracking slew rate (ISlice code to current conversion)

DATA	CURRENT (μA)
0000	10 (reset)
0001	10
0010	20
0011	30
0100	50
0101	60
0110	70
0111	80
1000	100
1001	110
1010	120
1011	130
1100	150
1101	160
1110	170
1111	180

Table 25 High-pass filter frequency cut-off level (lowest roll-off)

DATA	NOMINAL FREQUENCY (kHz)	PERCENTAGE DEVIATION	ACTUAL FREQUENCY (kHz)
000000	10	–37.5%	6.367 (reset)
010000		–28.2%	7.31
001000		–17.6%	8.395
011000		–9.2%	9.247
000100		0%	10.186
010100		+8.6%	11.066
001100		+18%	12.023
000010	20	–37.5%	12.706
010010		–28.2%	14.588
001010		–17.6%	16.520
011010		–9.2%	18.45
000110		0%	20.324
010110		+8.6%	22.080
001110		+18%	23.988
000001	30	–37.5%	18.967
010001		–28.2%	21.777
001001		–17.6%	24.660
011001		–9.2%	27.542
000101		0%	30.339
010101		+8.6%	32.961
001101		+18%	35.318
000011	40	–37.5%	25.003
010011		–28.2%	29.107
001011		–17.6%	32.961
011011		–9.2%	36.307
000111		0%	39.994
010111		+8.6%	43.451
001111		+18%	47.206

7.17.6 Summary of servo commands

A list of the servo commands is given in Table 26. These are fully compatible with the SAA732X.

Table 26 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> <FFH>
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 to 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 are only available when the 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.

7.17.7 Summary of servo command parameters

Table 27 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 normalizing
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 dropout 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	electronic damping
				sledge bandwidth during jump
brake_dist_max	21H	radial jump	–	maximum sledge distance allowed in fast actuator steered mode; the value of brake_dist_max must be negative and is irrespective of the direction of jump
sledge_long_brake	58H	radial jump	FFH	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

PARAMETER	RAM ADDRESS	AFFECTS	POR VALUE	DETERMINES
defect_parm	–	defect detector	–	defect detector setting
playwatchtime	54H	Watchdog	–	radial on-track Watchdog time
jumpwatchtime	57H	Watchdog	–	radial jump Watchdog time-out
radcontrol	59H	Watchdog	–	enable/disable automatic radial off feature
chip_init	–	set-up	–	enable/disable decoder interface
xtra_preset	4AH	set-up	38H	laser on/off
				RA, FO and SL PDM modulating frequency
				fast jumping circuit on/off
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

8 SUMMARY OF SERVO COMMAND PARAMETERS VALUES

Table 28 foc_parm1 parameter: focus end lead frequency, defect detector, offtrack detector

foc_parm1	**Focus end lead frequency f_3 kHz**
foc_pole_lead value (binary)	
xxx1 1100	1.97
xxx1 1000	2.29
xxx0 0000	2.61
xxx0 1000	2.94
xxx0 1100	3.26
xxx1 1101	3.90
xxx1 1001	4.55
xxx0 0001	5.19
xxx0 1001	5.82
xxx0 1101	6.46
xxx1 1110	7.72
xxx1 1010	8.98
xxx0 0010	10.22
xxx0 1010	11.46
xxx0 1110	12.69
xxx1 1111	15.13
xxx1 1011	17.54
xxx0 0011	19.93
xxx0 1011	22.28
defect_det_sw	**Defect detector**
x11x xxxx	defect detector does not influence focus and radial
x10x xxxx	focus hold on defect detector
x00x xxxx	focus and radial hold on defect detector
x01x xxxx	undefined, reserved
otd_select	**Offtrack detector**
0xxx xxxx	ON track active 1
1xxx xxxx	ON track active 0

Table 29 foc_parm2 parameter: focus low-pass start frequency, focusing system

foc_parm2	**Focus low-pass start frequency f_4 kHz**
foc_pole_noise value (binary)	
xxx1 1100	3.90
xxx1 1000	4.55
xxx0 0000	5.19
xxx0 1000	5.82
xxx0 1100	6.46
xxx1 1101	7.72
xxx1 1001	8.98
xxx0 0001	10.22
xxx0 1001	11.46
xxx0 1101	12.69
xxx1 1110	15.13
xxx1 1010	17.54
xxx0 0010	19.93
xxx0 1010	22.28
xxx0 1110	25.40
xxx1 1111	30.26
xxx1 1011	35.08
xxx0 0011	39.86
xxx0 1011	44.56
detector_arr	**Focusing system**
xx1x xxxx	single foucault
xx0x xxxx	double foucault

Table 30 foc_parm3 parameter: focus lead length, CA start level for focus acquisition

foc_parm3	**Focus lead length f_3/f_2**
foc_lead_length value (binary)	
0000 xxx1	64
1000 xxx1	32
0100 xxx1	21.3
1100 xxx1	16
0010 xxx1	12.8
1010 xxx1	10.7
0110 xxx1	9.1
1110 xxx1	8
0001 xxx1	7.1
1001 xxx1	6.4
0101 xxx1	5.8
1101 xxx1	5.3
0011 xxx1	4.9
1011 xxx1	4.6
0111 xxx1	4.3
1111 xxx1	4
CA_start value (binary)	**CA_{min}**
xxxx 000x	0.0225
xxxx 001x	0.03
xxxx 010x	0.045
xxxx 011x	0.06
xxxx 100x	0.09
xxxx 101x	0.125
xxxx 110x	0.18
xxxx 111x	1.0

Table 31 CA_drop parameter: CA level for dropout detection

CA_drop value (binary)	**CA_{min}**
xxx0 0000	0.0225
xxx0 0100	0.03
xxx0 1000	0.045
xxx0 1100	0.06
xxx1 0000	0.09
xxx1 0100	0.125
xxx1 1000	0.18
xxx1 1100	1.0

Table 32 FE_start parameter: minimum threshold for focus start

FE_start value (decimal)	**Minimum threshold for $(d_1 - d_2)/(d_1 + d_2)$**
0	always
1	1/127
2	2/127
i	i/127
64	64/127
65...127	65 to 127/127
127	continuous ramping
128...255	not allowed

Table 33 foc_int_strength parameter: focus integrator strength

foc_int_strength value (decimal)	**Focus integrator strength f_5 Hz**
0	integrator hold
1	1.2
2	2.4
i	$1.2 \times i$
21	25
22...255	undefined

Table 34 foc_gain parameter: focus gain

foc_gain value (decimal)	**G**
1	2048
2	1024
3	2048/3
i	2048/i
255	2048/255
0	undefined

Table 35 rad_pole_noise parameter: radial low-pass start frequency

rad_pole_noise value (binary)	Radial low-pass start frequency f_4 kHz
1101 1100	3.90
1011 1000	4.55
1010 0000	5.19
1010 1000	5.82
1000 1100	6.46
1001 1101	7.72
1001 1001	8.98
0100 0001	10.22
0100 1001	11.46
0100 1101	12.69
0101 1110	15.13
0101 1010	17.54
0100 0010	19.93
0100 1010	22.28
xxx0 1110	25.40
xxx1 1111	30.26
xxx1 1011	35.08
xxx0 0011	39.86
xxx0 1011	44.56

Table 36 rad_lead_length parameter: radial lead length

rad_lead_length value (binary)	rad_lead_length value (hex)	Radial lead length f_3/f_2
0000 xxxx	0x	128
1000 xxxx	8x	64
0100 xxxx	4x	42.7
1100 xxxx	Cx	32
0010 xxxx	2x	25.6
1010 xxxx	Ax	21.3
0110 xxxx	6x	18.3
1110 xxxx	Ex	16
0001 xxxx	1x	14.2
1001 xxxx	9x	12.8
0101 xxxx	5x	11.6
1101 xxxx	Dx	10.7
0011 xxxx	3x	9.8
1011 xxxx	Bx	9.1
0111 xxxx	7x	8.5
1111 xxxx	Fx	8

Table 37 rad_parm_play, rad_parm_jump parameters: radial end lead frequency

rad_parm_play rad_parm_jump value (binary)	rad_parm_play rad_parm_jump value (hex)	Radial end lead frequency f_3 kHz
1101 1100	DC	1.97
1101 1000	D8	2.29
1100 0000	C0	2.61
1100 1000	C8	2.94
1100 1100	CC	3.26
1101 1101	DD	3.90
1001 1001	99	4.55
1010 0001	A1	5.19
1010 1001	A9	5.82
1010 1101	AD	6.46
1001 1110	9E	7.72
0101 1010	5A	8.98
0100 0010	42	10.22
0100 1010	4A	11.46
1000 1110	8E	12.69
0101 1111	5F	15.13
0101 1011	5B	17.54
0100 0011	43	19.93
0100 1011	4B	22.28

Table 38 rad_gain parameter: radial PID gain

rad_gain value (decimal)	Radial PID gain G
1	256
2	256/2
3	256/3
i	256/i
255	256/255
0	undefined

Table 39 rad_int_strength parameter: radial integrator strength

rad_int_strength value (decimal)	Radial integrator strength f_5 Hz
0	integrator hold
1	0.3
2	0.6
i	$0.31 \times i$
255	79.05

Table 40 Sledge_parm1 parameter: sledge integrator bandwidth, shock filter (low-pass, high-pass selection); RAM address 36H

sledge_parm1 sledge_int	Sledge integrator f_1 Hz
x00x xxxx	integrator disabled
x10x xxxx	0.15
x01x xxxx	0.31
x11x xxxx	0.45

Table 41 sledge_parm2 parameter: sledge gain, low-pass frequencies, operation mode; RAM address 17H

sledge_parm2	**Sledge gain G_S**
sledge_gain	
0xxx x000	0.218
0xxx x001	0.281
0xxx x010	0.436
0xxx x011	0.562
0xxx x100	0.875
0xxx x101	1.125
0xxx x110	1.750
0xxx x111	2.250
1xxx x000	3.500
1xxx x001	4.500
1xxx x010	7.000
1xxx x011	9.000
1xxx x100	14.00
1xxx x101	18.00
1xxx x110	28.00
1xxx x111	36.00
sledge_low_pass	**Sledge low-pass frequency f_2 Hz**
x00x 0xxx	5.0
x10x 0xxx	10.1
x01x 0xxx	15.3
x11x 0xxx	20.5
x00x 1xxx	0.3
x10x 1xxx	0.6
x01x 1xxx	0.9
x11x 1xxx	1.2
sledge_op_mode	**Sledge operation mode**
xxx0 0xxx	PI mode operation
xxx0 1xxx	pulsed mode operation, microcontroller controlled
xxx1 1xxx	pulsed mode operation, automatic mode

Table 42 sledge_pulse1 parameter: sledge pulse high time, low time; RAM address 46H

sledge_pulse1	**Hex**	**Time low ms**
time_lo		
0000 xxxx	0x	0
0001 xxxx	1x	2
0010 xxxx	2x	4
0011 xxxx	3x	6
0100 xxxx	4x	8
0101 xxxx	5x	10
0110 xxxx	6x	12
0111 xxxx	7x	14
1000 xxxx	8x	16
1001 xxxx	9x	18
1010 xxxx	Ax	20
1011 xxxx	Bx	22
1100 xxxx	Cx	24
1101 xxxx	Dx	26
1110 xxxx	Ex	28
1111 xxxx	Fx	30
time_hi		**Time high ms**
xxxx 0000	x0	0
xxxx 0001	x1	2
xxxx 0010	x2	4
xxxx 0011	x3	6
xxxx 0100	x4	8
xxxx 0101	x5	10
xxxx 0110	x6	12
xxxx 0111	x7	14
xxxx 1000	x8	16
xxxx 1001	x9	18
xxxx 1010	xA	20
xxxx 1011	xB	22
xxxx 1100	xC	24
xxxx 1101	xD	26
xxxx 1110	xE	28
xxxx 1111	xF	30

Table 43 sledge_pulse2 parameter: sledge pulse height; RAM address 64H

sledge_pulse2	Hex	Pulse height
0111 1111	78	full-scale, positive
....	....	
0100 0000	40	half-scale, positive
a		level = a/7F, positive
0000 0000	00	zero
....	....	
1000 0000	80	full-scale, negative

Table 44 vel_parm1 parameter: gain constant for short jump, integrator cross-over frequency during jump; RAM address 1FH

vel_parm1 vel_prop	Hex	Gain constant for short jump K_v
0000 xxxx	0x	0.1875
1000 xxxx	8x	0.4375
0100 xxxx	4x	0.6875
1100 xxxx	Cx	0.9375
0010 xxxx	2x	1.1875
1010 xxxx	Ax	1.4375
0110 xxxx	6x	1.6875
1110 xxxx	Ex	1.9375
0001 xxxx	1x	2.1875
1001 xxxx	9x	2.4375
0101 xxxx	5x	2.6875
1101 xxxx	Dx	2.9375
0011 xxxx	3x	3.1875
1011 xxxx	Bx	3.4375
0111 xxxx	7x	3.6875
1111 xxxx	Fx	3.9375
vel_int		**Integrator cross-over frequency during jump f_0**
xxxx 0000	x0	integrator hold
xxxx 0001	x1	$10.0/K_v$
xxxx 0010	x2	$20.0/K_v$
xxxx 0011	x3	$30.0/K_v$
i		$i \times 10.0/K_v$
xxxx 1111	xF	$150.0/K_v$

Table 45 vel_parm2 parameter: time constant during sledge access/actuator access, minimum jump speed during short jump; RAM address 32H

vel_parm2 vel_setp (binary)	Hex	Deceleration time fast actuator steered ms	Deceleration time sledge steered ms
0000 xxxx	0x	7.5	7.5
1000 xxxx	8x	8.2	8.2
0100 xxxx	4x	9	9
1100 xxxx	Cx	9.7	9.7
0010 xxxx	2x	10.5	10.5
1010 xxxx	Ax	11.2	11.2
0110 xxxx	6x	12.5	12.5
1110 xxxx	Ex	14	14
0001 xxxx	1x	15.5	15.5
1001 xxxx	9x	16.5	16.5
0101 xxxx	5x	20.7	20.7
1101 xxxx	Dx	25	25
0011 xxxx	3x	31.2	31.2
1011 xxxx	Bx	41	41
0111 xxxx	7x	63	63
1111 xxxx	Fx	128	128
vel_min		**V_1 minimum jump speed kHz**	
xxxx 0000	x0	0.0	
xxxx 0001	x1	1.0	
xxxx 0010	x2	2.0	
xxxx 0011	x3	3.0	
xxxx 0100	x4	4.0	
xxxx 0101	x5	5.0	
xxxx 0110	x6	6.0	
xxxx 0111	x7	7.0	
xxxx 1xxx		undefined	

Table 46 brake_dist_max parameter: maximum sledge distance allowed in fast actuator steered mode; RAM address 21H

brake_dist_max value (decimal)	Maximum sledge distance allowed in fast actuator steered mode, number of tracks
0...127	not allowed
–1	1×16
–2	2×16
....	....
–i	$i \times 16$
....	....
–127	127×16
–128	128×16

Table 47 sledge_Umax parameter: voltage on sledge during long jump

sledge_Umax (decimal)	voltage on sledge
127	$255/256 \times V_{DD}$
i	$(i + 128)/256 \times V_{DD}$
0	$0.5 \times V_{DD}$
–1	$(128 - 1)/256 \times V_{DD}$
–i	$(–i + 128)/256 \times V_{DD}$
–128	0

Table 48 sledge_level parameter: voltage on sledge when steered

sledge_level (decimal)	voltage on sledge
127	$127/256 \times V_{DD}$
i	$i/256 \times V_{DD}$
0	0
–1	$–1/256 \times V_{DD}$
–i	$–i/256 \times V_{DD}$
–128	$–128/256 \times V_{DD}$

Table 49 jumpwatchtime parameter: radial jump watchdog readout time difference; RAM address 57H

jumpwatchtime	Radial jump watchdog readout time difference ms
80H to FFH	none
0H	0
1H	0.25
i	$i \times 0.25$
7FH	32

Table 50 playwatchtime parameter: radial play watchdog maximum time-out; RAM address 54H

playwatchtime	Radial play watchdog maximum time-out ms
80H	0
81H	0.5
82H	1
i	$(i – 80H) \times 0.5$
00H	64
j	$(j + 80H) \times 0.5$
7fH	128

Table 51 radcontrol parameter: automatic radial servo switch-off control; RAM address 59H

radcontrol	Hex	Automatic radial servo switch-off control
0000 0000	00	radial servo not influenced by watchdog
0100 0000	40	switch-off radial servo on jump error; no action on play error
0010 0000	20	switch-off radial servo on play error; no action on jump error
0110 0000	60	switch-off radial servo on play or jump error

Table 52 hold_mult parameter: velocity proportional part during long jump, sledge gain in steered sledge mode; RAM address 49H

hold_mult	**Hex**	**Velocity proportional part during long jump K_p**
vel_prop1 (binary)		
0000 xxxx	0x	0
1000 xxxx	8x	0.015625
0100 xxxx	4x	0.031250
1100 xxxx	Cx	0.046875
0010 xxxx	2x	0.062500
1010 xxxx	Ax	0.078125
0110 xxxx	6x	0.093750
1110 xxxx	Ex	0.109375
0001 xxxx	1x	0.125000
1001 xxxx	9x	0.140625
0101 xxxx	5x	0.156250
1101 xxxx	Dx	0.171875
0011 xxxx	3x	0.187500
1011 xxxx	Bx	0.203125
0111 xxxx	7x	0.218750
1111 xxxx	Fx	0.234375
vel_prop2		**Sledge gain in steered mode G_S**
xxxx x000	x0	2
xxxx x001	x1	3
xxxx x010	x2	4
xxxx x011	x3	6
xxxx x100	x4	8
xxxx x101	x5	12
xxxx x110	x6	16
xxxx x111	x7	24

Table 53 speed_threshold parameter: maximum sledge speed allowed in fast actuator steered mode; RAM address 48H

speed_threshold value (decimal)	**Maximum sledge speed allowed in fast actuator steered mode, number of tracks (x 1000 tracks/sec)**
0...127	not allowed
–1	1
–2	2
–3...–127	3...127
–128	128
–64	reset value

Table 54 sledge_long_brake parameter: maximum sledge distance allowed in sledge steered mode; RAM address 58H

sledge_long_brake (decimal)	**Maximum sledge distance allowed in sledge steered mode, number of tracks**
–1...–128	test always true
1	1×128
2	2×128
3...62	$3 \times 128...62 \times 128$
63	63×128
–1	reset value

Table 55 defect_parm parameter: defect detector control

defect_parm	Fast filter bandwidth	
xxxx xx00	3500 Hz	
xxxx xx01	7000 Hz	
xxxx xx10	14000 Hz	
xxxx xx11	reserved for future use	
defect_parm	**Slow filter time constant**	**Alpha value**
xxxx 10xx	16 ms	0.00006
xxxx 11xx	8 ms	0.00012
xxxx 00xx	4 ms	0.00024
xxxx 01xx	2 ms	0.00048
defect_parm	**Coefficient β value**	
xx00 xxxx	0.25	
xx01 xxxx	0.125	
xx10 xxxx	0.0625	
xx11 xxxx	reserved for future use	
defect_parm	**Defect detector maximum ON time**	
00xx xxxx	1.0 ms	
01xx xxxx	1.5 ms	
10xx xxxx	2.0 ms	
11xx xxxx	2.5 ms	

Table 56 interrupt_mask parameter: mask to enable interrupt in interrupt status register; RAM address 53H

interrupt_mask	Interrupt enabled
0000 0000	no interrupt
xxxx xxx1	focus lost
xxxx xx1x	subcode ready
xxxx x1xx	subcode absolute seconds changed
xxxx 1xxx	subcode discontinuity
xxx1 xxxx	radial error
xx1x xxxx	autosequencer state changes
x1xx xxxx	autosequencer error

Table 57 time_parameter: timer interrupt values

time_parameter value (decimal)(1)	Timer interrupt values wait time (ms)
129 ≤ i ≤ 143	4.26 × (i – 128)
144 ≤ i ≤ 159	68.2 + 4.57 × (i – 144)
160 ≤ i ≤ 175	141.4 + 4.92 × (i – 160)
176 ≤ i ≤ 191	224.1 + 5.33 × (i – 176
192 ≤ i ≤ 207	305.4 + 5.82 × (i – 192
208 ≤ i ≤ 223	398.5 + 6.40 × (i – 208)
224 ≤ i ≤ 239	500.8 + 7.11 × (i – 224
2402 ≤ i ≤ 55	614.6 + 8.00 × (i – 240)
0 ≤ i ≤ 15	742.6 + 9.11 × i
16 ≤ i ≤ 31	888.9 + 10.6 × (i – 16)
32 ≤ i ≤ 47	1059 + 12.8 × (i – 32)
48 ≤ i ≤ 63	1263 + 16.0 × (i – 48)
64 ≤ i ≤ 79	1519 + 21.2 × (i – 64)
80 ≤ i ≤ 95	1860 + 32.0 × (i – 80)
96 ≤ i ≤ 111	2372 + 64.0 × (i – 96)
111	3398.0
112...127	infinite

Note

1. The time_parameter values are also used for focus_start_time, motor_start_time1, motor_start_time2, radial_init_time and brake_time.

Table 58 phase_shift parameter: focus/radial AGC detection phase shift; RAM address 67H

phase_shift (decimal)	Focus/radial AGC detection phase shift	
	(μs)	(deg)
0	0	0
1 × a(1)	60.47	180 × (a/128)
2 × a	120.94	180 × (2 × a/128)
i × a	i × 60.47	180 × (i × a/128)
128		180
–1 × a	–60.47	–180 × (a/128)
–2 × a	–120.94	–180 × (2 × a/128)
–i × a	–i × 60.47	–180 × (i × a/128)
128		180

Note

1. The value a is the value programmed in Table 60 as the 6 LSBs of osc_inc.

Table 59 level1, level2 parameter: amplitude of signal injected into focus/radial AGC; RAM address level1 = 69H, level2 = 6AH

level1, level2 (decimal)	Amplitude of injected signal
0	0
1 to 126	higher
127	highest
128 to 255	not allowed

Table 60 osc_inc parameter: focus/radial AGC system control, oscillator frequency; RAM address 68H

osc_inc	Oscillator frequency Hz
xx00 0000	0
xx00 0001	64.6
xx00 0010	129.2
xx00 0011	193.8
a	a × 64.6
xx11 1111	4069.8
	AGC control
00xx xxxx	AGC system off
11xx xxxx	focus AGC active
01xx xxxx	radial AGC active

Table 61 re_offset parameter: initial value setting

re_offset	Value
127	128/256
i	i/256
0	0
–i	–i/256
–128	–128/256

Table 62 re_gain parameter: initial value setting

re_gain	Value
–128	not allowed
–127	1/256
–i	(–i + 128)/256
–1	127/256
0	128/256
1	129/256
i	(i + 128)/256
127	255/256

Table 63 sum_gain parameter: initial value setting

sum_gain	Value
–128	not allowed
–127	1/256
–i	(–i + 128)/256
–1	127/256
0	128/256
1	129/256
i	(i + 128)/256
127	255/256

9 LIMITING VALUES

In accordance with the Absolute Maximum Rating System (IEC 60134).

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
V_{DDD}	digital supply voltage	internal rail	–0.5	+2.5	V
		external rail	–0.5	+4.6	V
$V_{I(max)}$	maximum input voltage				
	any input	notes 1, 2 and 3	–0.5	V_{DDD} + 0.5	V
	5 V tolerant pins		–0.5	+6.0	V
V_O	any output voltage		–0.5	V_{DDD}	V
I_{DDD}	digital supply current per supply pin	note 4	–	20	mA
I_{SSD}	digital ground current per supply pin	note 4	–	20	mA
V_{es}	electrostatic handling voltage	note 5	–2000	+2000	V
		note 6	–200	+200	V
T_{amb}	ambient temperature		–40	+85	°C
T_{stg}	storage temperature		–55	+125	°C

Notes

1. Must not exceed 4.2 V.
2. Including voltage on outputs in 3-state mode.
3. Only valid when both supply voltages are present.
4. The peak current is limited to 25 times the corresponding maximum current.
5. Human body model.
6. Machine model.

10 CHARACTERISTICS

V_{DDD} = 1.65 to 1.95 V; V_{DDA} = 3.0 to 3.6 V; V_{SS} = 0 V; T_{amb} = –40 to +85 °C; unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
Supplies						
V_{DDD}	digital supply voltage		1.65	1.8	1.95	V
I_{DDD}	digital supply current	n = 1 mode	–	4.0	–	mA
		n = 2 mode	–	5.0	–	mA
		n = 4 mode	–	6.0	–	mA
V_{DDA}	analog supply voltage		3.0	3.3	3.6	V
I_{DDA}	analog supply current	n = 1 mode	–	34	–	mA
		n = 2 mode	–	34	–	mA
		n = 4 mode	–	34	–	mA
DEM DAC output (V_{pos} = 3.3 V, V_{SS} = 0 V, V_{neg} = 0 V and T_{amb} = 25 °C)						
DIFFERENTIAL OUTPUTS: PINS DACLN, DACLP, DACRN AND DACRP						
S/N_{DAC}	onboard signal-to-noise ratio	note 1	–	90	–	dB
(THD + N)/S	total harmonic distortion plus noise-to-signal ratio	note 2	–	–	–80	dB
Headphone buffer (V_{pos} = 3.3 V, V_{SS} = 0 V, V_{neg} = 0 V and T_{amb} = 25 °C)						
OUTPUTS: PINS BUFOUTR AND BUFOUTL						
S/N	signal-to-noise ratio		–	85	–	dB
(THD + N)/S	total harmonic distortion plus noise-to-signal ratio	note 3	–	–	–80	dB
INPUTS: PINS BUFINR AND BUFINL						
Z_i	input impedance		–	47	–	kΩ
Servo and decoder analog functions (V_{DDA} = 3.3 V, V_{SSA} = 0 V and T_{amb} = 25 °C)						
REFERENCE GENERATOR: PIN I_{REF}						
V_{IREF}	reference voltage level		1.16	1.26	1.36	V
I_{REF}	input reference current		–	50	–	µA
$R_{IREF(ext)}$	external resistance		–	24 ±2%	–	kΩ
DIODE VOLTAGE INPUT: PINS D1 TO D4, R1 AND R2						
$V_{i(D)(max)}$	maximum input voltage for central diode input signal		0	–	960	mV
$V_{i(R)(max)}$	maximum input voltage for satellite diode input signal		0	–	960	mV
$V_{ref(int)}$	internally generated reference voltage	V_{ref_sel} = 10	–	note 4	–	V
		V_{ref_sel} = 11	–	note 5	–	V
B_{HF}	high frequency bandwidth (D1 to D4)	at 0 dB	5	–	–	MHz
$G_{tol(HF)}$	high frequency gain tolerance		–20	–	+20	%

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
B_{LF}	low frequency bandwidth (D1 to D4, R1 and R2)	at 0 dB	20	–	–	kHz
(THD + N)/S_{LF}	low frequency total harmonic distortion plus noise-to-signal ratio	at 0 dB	–	–50	–40	dB
S/N_{LF}	low frequency signal-to-noise ratio		55	–	–	dB
$G_{tol(LF)}$	low frequency gain tolerance		–20	–	+20	%
$\Delta G_{v(LF)}$	low frequency variation of gain between channels		–3	–	+3	%
$\alpha_{cs(LF)}$	low frequency channel separation		–	60	–	dB
Laser drive circuit (V_{DDA} = 3.3 V; V_{SSA} = 0 V; T_{amb} = 25 °C; R_{IREF} = 30 kΩ)						
$I_{o(LASER)}$	output current	V_{LASER} = 1 V – (V_{DDA} – 0.6 V)	10	50	120	mA
SNR	signal-to-noise ratio	I_o = 50 mA; B = 20 MHz	–	40	–	dB
$I_{LFPOWER(max)}$	maximum laser supply current	I_o = 120 mA	–	–	140	mA
$V_{MONITOR1}$	monitor diode voltage 1	maximum power; sel180 = 0	140	150	160	mV
$V_{MONITOR2}$	monitor diode voltage 2	maximum power; sel180 = 1	170	180	190	mV
R_i	input resistance		10	–	–	MΩ
V_{sense}	sense voltage		–100	–	+100	mV
P_{step}	laser output power range		43	–	100	%
I_{pd}	power-down supply current		–	–	10	µA
$I_{LASER(off)}$	laser off current		–	–	30	µA
Digital inputs						
PIN $\overline{\text{RESET}}$ (5 V TOLERANT; TTL INPUTS WITH PULL-UP RESISTOR AND HYSTERESIS)						
V_{IH}	HIGH-level input voltage		2.0	–	–	V
V_{IL}	LOW-level input voltage		–	–	0.8	V
V_{hys}	hysteresis voltage		0.3	–	–	V
I_{PU}	pull-up current	V_i = 0 to V_{DDD}; notes 6 and 7	–31	–	–68	µA
$t_{W(L)}$	pulse width (active LOW)	$\overline{\text{RESET}}$ only	1	–	–	µs
PINS V1 AND V2 (CMOS INPUTS)						
V_{IH}	HIGH-level input voltage		2.0	–	–	V
V_{IL}	LOW-level input voltage		–	–	0.8	V

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
PINS TEST1 TO TEST4 (5 V TOLERANT; TTL INPUTS WITH PULL-DOWN RESISTORS)						
V_{IH}	HIGH-level input voltage		2.0	–	–	V
V_{IL}	LOW-level input voltage		–	–	0.8	V
I_{PD}	pull-down current	V_i = 0 to V_{DDD}; notes 6 and 7 (V_i = 5 V; note 8)	20	50	75	µA
PINS RCK, WCLI, SDI AND SCLI (5 V TOLERANT; TTL INPUTS)						
V_{IH}	HIGH-level input voltage		2.0	–	–	V
V_{IL}	LOW-level input voltage		–	–	0.8	V
I_{IL}	LOW-level input current	V_i = 0; no pull-up	–	–	1	µA
I_{IH}	HIGH-level input current	V_i = V_{DDD}; no pull-down	–	–	1	µA
PINS SCL, SILD, RAB AND CDTCLK (5 V TOLERANT TTL INPUTS WITH HYSTERESIS)						
V_{IH}	HIGH-level input voltage		2.0	–	–	V
V_{IL}	LOW-level input voltage		–	–	0.8	V
I_{IL}	LOW-level input current	V_i = 0; no pull-up	–	–	1	µA
I_{IH}	HIGH-level input current	V_i = V_{DDE}; no pull-down	–	–	1	µA
V_{hys}	hysteresis voltage		0.3	–	–	V
3-state outputs						
PINS SCLK, WCLK, DATA, CLK16, RA, FO, SL, SBSY, SFSY, CLK4/12, STATUS, MOTO1 AND MOTO2 (5 V TOLERANT CMOS OUTPUTS; 10 ns SLEW RATE LIMITED)						
V_{OL}	LOW-level output voltage	I_{OL} = 4 mA	–	–	0.4	V
V_{OH}	HIGH-level output voltage	I_{OH} = –4 mA	V_{DDD} – 0.4	–	–	V
I_{OL}	LOW-level output current	V_{OL} = 0.4 V; note 9	4	–	–	mA
I_{OH}	HIGH-level output current	V_{OL} = V_{DDD} – 0.4 V; note 9	–4	–	–	mA
$t_{tran(L-H)}$	LOW-to-HIGH transition time	C_L = 30 pF	10.2	–	14.5	ns
I_{OZ}	3-state leakage current	V_i = 0; no pull-up or pull-down	–	–	1	µA
PINS DOBM, V4 AND V5 (5 V TOLERANT CMOS OUTPUTS; 5 ns SLEW RATE LIMITED)						
V_{OL}	LOW-level output voltage	I_{OL} = 4 mA	–	–	0.4	V
V_{OH}	HIGH-level output voltage	I_{OH} = –4 mA	V_{DDD} – 0.4	–	–	V
I_{OL}	LOW-level output current	V_{OL} = 0.4 V; note 9	4	–	–	mA
I_{OH}	HIGH-level output current	V_{OL} = V_{DDD} – 0.4 V; note 9	–4	–	–	mA
$t_{tran(L-H)}$	LOW-to-HIGH transition time	C_L = 30 pF	–	10	13.8	ns
I_{OZ}	3-state leakage current	V_i = 0	–	–	1	µA

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
Digital inputs and outputs						
PIN V3 (5 V TOLERANT; TTL INPUT; 3-STATE OUTPUT)						
V_{IH}	HIGH-level input voltage		2.0	–	–	V
V_{IL}	LOW-level input voltage		–	–	0.8	V
I_{IL}	LOW-level input current	V_i = 0; no pull-up	–	–	1	µA
I_{IH}	HIGH-level input current	$V_i = V_{DDD}$; no pull-down	–	–	1	µA
V_{OL}	LOW-level output voltage	I_{OL} = 4 mA	–	–	0.4	V
V_{OH}	HIGH-level output voltage	I_{OH} = –4 mA	V_{DDD} – 0.4	–	–	V
I_{OL}	LOW-level output current	V_{OL} = 0.4 V; note 9	4	–	–	mA
I_{OH}	HIGH-level output current	$V_{OL} = V_{DDD}$ – 0.4 V; note 9	–4	–	–	mA
$t_{tran(L-H)}$	LOW-to-HIGH transition time	C_L = 30 pF	2.6	–	6.3	ns
I_{OZ}	3-state leakage current	V_i = 0	–	–	1	µA
PINS LKILL, RKILL AND CFLAG (5 V TOLERANT; TTL INPUT WITH PULL-UP; 3-STATE OPEN-DRAIN OUTPUT; 10 ns SLEW RATE LIMITED)						
V_{IH}	HIGH-level input voltage		2.0	–	–	V
V_{IL}	LOW-level input voltage		–	–	0.8	V
I_{PU}	pull-up current	V_i = 0 to V_{DDD}; notes 6 and 7	–13	–	–36	µA
V_{OL}	LOW-level output voltage	I_{OL} = 4 mA	–	–	0.4	V
V_{OH}	HIGH-level output voltage	I_{OH} = –4 mA	V_{DDD} – 0.4	–	–	V
I_{OL}	LOW-level output current	V_{OL} = 0.4 V; note 9	4	–	–	mA
I_{OH}	HIGH-level output current	$V_{OL} = V_{DDD}$ – 0.4 V; note 9	–4	–	–	mA
$t_{tran(L-H)}$	LOW-to-HIGH transition time	C_L = 30 pF	8.6	10	13.8	ns
I_{OZ}	3-state leakage current	V_i = 0	–	–	1	µA
PINS CDTRDY, CDTDATA, EF AND SUB (5 V TOLERANT; TTL INPUT; 3-STATE OUTPUT; 10 ns SLEW RATE LIMITED)						
V_{IH}	HIGH-level input voltage		2.0	–	–	V
V_{IL}	LOW-level input voltage		–	–	0.8	V
I_{IL}	LOW-level input current	V_i = 0	–	–	1	µA
I_{IH}	HIGH-level input current	$V_i = V_{DDD}$	–	–	1	µA
V_{OL}	LOW-level output voltage	I_{OL} = 4 mA	–	–	0.4	V
V_{OH}	HIGH-level output voltage	I_{OH} = –4 mA	V_{DDD} – 0.4	–	–	V
I_{OL}	LOW-level output current	V_{OL} = 0.4 V; note 9	4	–	–	mA
I_{OH}	HIGH-level output current	$V_{OL} = V_{DDD}$ – 0.4 V; note 9	–4	–	–	mA
$t_{tran(L-H)}$	LOW-to-HIGH transition time	C_L = 30 pF	8.6	10	13.8	ns
I_{OZ}	3-state leakage current	V_i = 0	–	–	1	µA

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
PIN SDA (5 V TOLERANT; 400 kHz I²C-BUS PAD)						
V_{IH}	HIGH-level input voltage		$0.7V_{TOL}$	–	–	V
V_{IL}	LOW-level input voltage	V_{TOL} = 5 V; note 10	–	–	$0.3V_{TOL}$	V
V_{hys}	hysteresis voltage		$0.05V_{TOL}$	–	–	V
V_{OL}	LOW-level output voltage	I_{OL} = 3 mA	–	–	0.4	V
t_f	output fall time from V_{IH} to V_{IL}	bus capacitance C_b = 10 pF to 400 pF	$20 + 0.1C_b$	–	250	ns
I_{ikg}	steady-state current input signal	$V_i = V_{DDD}$; note 11	–	2	4	µA
		V_i = 5 V; note 11	–	10	22	µA
Crystal oscillator						
INPUT: PIN OSCIN (EXTERNAL CLOCK)						
V_{IH}	HIGH-level input voltage		$0.8V_{DDD}$	–	–	V
V_{IL}	LOW-level input voltage		–	–	$0.2V_{DDD}$	V
OUTPUT: PIN OSCOUT; see Fig.4						
V_{OL}	LOW-level output voltage		–	–	0.4	V
V_{OH}	HIGH-level output voltage		$0.85V_{DDD}$	–	–	V
f_{xtal}	crystal frequency	±100 ppm	–	8.4672	–	MHz
g_m	mutual conductance	at start-up	19.1	–	23.0	mA/V

Notes

1. Assumes use of external components as shown in the application diagram; see Fig 38.
2. R_L = 10 kΩ.
3. R_L = 1 kΩ.
4. The typical value is: $\frac{1.65 \times 3.3}{V_{DDA}}$
5. The typical value is: $\frac{2.5 \times 3.3}{V_{DDA}}$
6. Pull up/down devices are protected by a pass-gate and do not behave as a normal resistor for external applications
7. Pull up/down resistors are connected to external power supply (V_{DDD}/GND).
8. Minimum condition for V_i = 4.5 V. Maximum condition for V_i = 5.5 V.
9. Accounts for 100 mV voltage drop in both supply lines.
10. Minimum condition for V_{TOL} = 4.5 V, Maximum condition for V_{TOL} = 5.5 V.
11. Leakage path from pad to ground.

11 OPERATING CHARACTERISTICS (SUBCODE INTERFACE TIMING)

V_{DDD} = 1.65 to 1.95 V; V_{SS} = 0 V; T_{amb} = –40 to +85 °C; unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
Subcode interface timing (single speed × n); see Fig.34; note 1						
INPUT: PIN RCK						
t_{CLKH}	input clock HIGH time		2/n	4/n	6/n	µs
t_{CLKL}	input clock LOW time		2/n	4/n	6/n	µs
t_r	input clock rise time		–	–	80/n	ns
t_f	input clock fall time		–	–	80/n	ns
$t_{d(SFSY-RCK)}$	delay time SFSY to RCK		10/n	–	20/n	µs
OUTPUTS: PINS SBSY, SFSY AND SUB (C_L = 20 pF)						
$T_{cy(block)}$	block cycle time		12.0/n	13.3/n	14.7/n	ms
$t_{W(SBSY)}$	SBSY pulse width		–	–	300/n	µs
$T_{cy(frame)}$	frame cycle time		122/n	136/n	150/n	µs
$t_{W(SFSY)}$	SFSY pulse width	3-wire mode	–	–	366/n	µs
t_{SFSYH}	SFSY HIGH time		–	–	66/n	µs
t_{SFSYL}	SFSY LOW time		–	–	84/n	µs
$t_{d(SFSY-SUB)}$	delay time SFSY to SUB (P data) valid		–	–	1/n	µs
$t_{d(RCK-SUB)}$	delay time RCK falling to SUB		–	–	0	µs
$t_{h(RCK-SUB)}$	hold time RCK to SUB		–	–	0.7/n	µs

Note

1. In the normal operating mode the subcode timing is directly related to the overspeed factor ‘n’. In the lock-to-disc mode ‘n’ is replaced by the disc speed factor ‘d’,

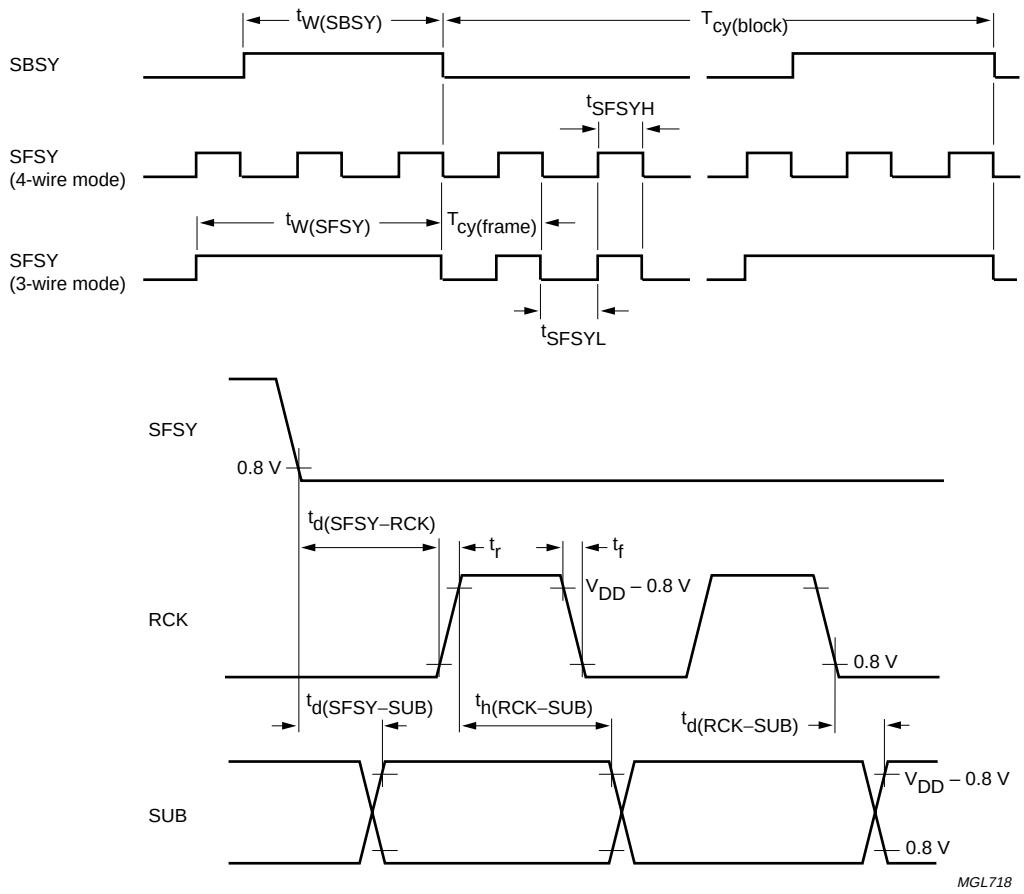


Fig.34 Subcode interface timing diagram.

12 OPERATING CHARACTERISTICS (I²S-BUS TIMING)

V_{DDD} = 1.65 to 1.95 V; V_{SS} = 0 V; T_{amb} = –40 to +85 °C; unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
I²S-bus timing (single speed × n); see Fig.35; note 1						
CLOCK OUTPUT: PIN SCLK (C_L = 20 pF)						
T_{cy}	output clock period	sample rate = f_s	–	472.4/n	–	ns
		sample rate = $2f_s$	–	236.2/n	–	ns
		sample rate = $4f_s$	–	118.1/n	–	ns
t_{CH}	clock HIGH time	sample rate = f_s	166/n	–	–	ns
		sample rate = $2f_s$	83/n	–	–	ns
		sample rate = $4f_s$	42/n	–	–	ns
t_{CL}	clock LOW time	sample rate = f_s	166/n	–	–	ns
		sample rate = $2f_s$	83/n	–	–	ns
		sample rate = $4f_s$	42/n	–	–	ns
OUTPUTS: PINS WCLK, DATA AND EF (C_L = 20 pF)						
t_{su}	set-up time	sample rate = f_s	95/n	–	–	ns
		sample rate = $2f_s$	48/n	–	–	ns
		sample rate = $4f_s$	24/n	–	–	ns
t_h	hold time	sample rate = f_s	95/n	–	–	ns
		sample rate = $2f_s$	48/n	–	–	ns
		sample rate = $4f_s$	24/n	–	–	ns

Note

1. In the normal operating mode the I²S-bus timing is directly related to the overspeed factor ‘n’. In the lock-to-disc mode ‘n’ is replaced by the disc speed factor ‘d’.

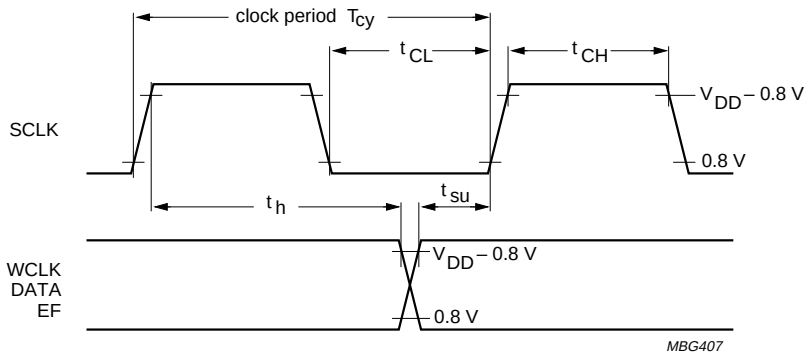


Fig.35 I²S-bus timing diagram.

13 OPERATING CHARACTERISTICS (MICROCONTROLLER INTERFACE TIMING)

V_{DD} = 1.65 to 1.95 V; V_{SS} = 0 V; T_{amb} = –40 to +85 °C; unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	NORMAL MODE		LOCK-TO-DISC MODE		UNIT
			MIN.	MAX.	MIN.	MAX.	
Microcontroller interface timing (4-wire bus mode; writing to decoder registers 0 to F; reading Q-channel subcode and decoder status); see Figs.36 and 37; note 1							
INPUTS SCL AND RAB							
t_{CL}	input clock LOW time		480/n + 20	–	2400/n + 20	–	ns
t_{CH}	input clock HIGH time		480/n + 20	–	2400/n + 20	–	ns
t_r	input rise time		–	480/n	–	480/n	ns
t_f	input fall time		–	480/n	–	480/n	ns
READ MODE (C_L = 20 pF)							
t_{dRD}	delay time RAB to SDA valid		–	50	–	50	ns
t_{PD}	propagation delay SCL to SDA		720/n – 20	960/n + 20	720/n + 20	4800/n + 20	
t_{dRZ}	delay time RAB to SDA high-impedance		–	50	–	50	ns
WRITE MODE (C_L = 20 pF)							
t_{suD}	set-up time SDA to SCL	note 2	20 – 720/n	–	20 – 720/n	–	ns
t_{hD}	hold time SCL to SDA		–	960/n + 20	–	4800/n + 20	ns
t_{suCR}	set-up time SCL to RAB		240/n + 20	–	1200/n + 20	–	ns
t_{dWZ}	delay time SDA to RAB high-impedance		0	–	0	–	ns
Microcontroller interface timing (4-wire bus mode; servo commands); see Figs.36 and 38; note 2							
INPUTS SCL AND SILD							
t_L	input LOW time		710	–	710	–	ns
t_H	input HIGH time		710	–	710	–	ns
t_r	input rise time		–	240	–	240	ns
t_f	input fall time		–	240	–	240	ns
READ MODE (C_L = 20 pF)							
t_{dLD}	delay time SILD to SDA valid		–	25	–	25	ns
t_{PD}	propagation delay SCL to SDA		–	950	–	950	ns
t_{dLZ}	delay time SILD to SDA high-impedance		–	50	–	50	ns
t_{suCLR}	set-up time SCL to SILD		480	–	480	–	ns

SYMBOL	PARAMETER	CONDITIONS	NORMAL MODE		LOCK-TO-DISC MODE		UNIT
			MIN.	MAX.	MIN.	MAX.	
t_{hCLR}	hold time SILD to SCL		830	–	830	–	ns
WRITE MODE (C_L = 20 pF)							
t_{sD}	set-up time SDA to SCL		0	–	0	–	ns
t_{hD}	hold time SCL to SDA		950	–	950	–	ns
t_{sCL}	set-up time SCL to SILD		480	–	480	–	ns
t_{hCL}	hold time SILD to SCL		120	–	120	–	ns
t_{dPLP}	delay between two SILD pulses		70	–	70	–	ns
t_{dWZ}	delay time SDA to SILD high-impedance		0	–	0	–	ns

Notes

1. The 4-wire bus mode microcontroller interface timing for writing to decoder registers 0 to F, and reading Q-channel subcode and decoder status, is a function of the overspeed factor ‘n’. In the lock-to-disc mode the maximum data rate is lower.
2. Negative set-up time means that the data may change after clock transition.

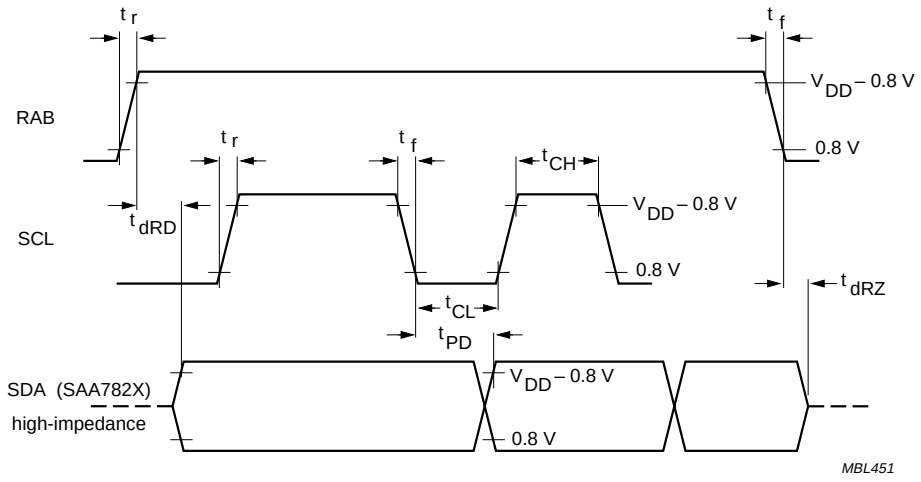


Fig.36 4-wire microcontroller timing; read mode (Q-channel subcode and decoder status information).

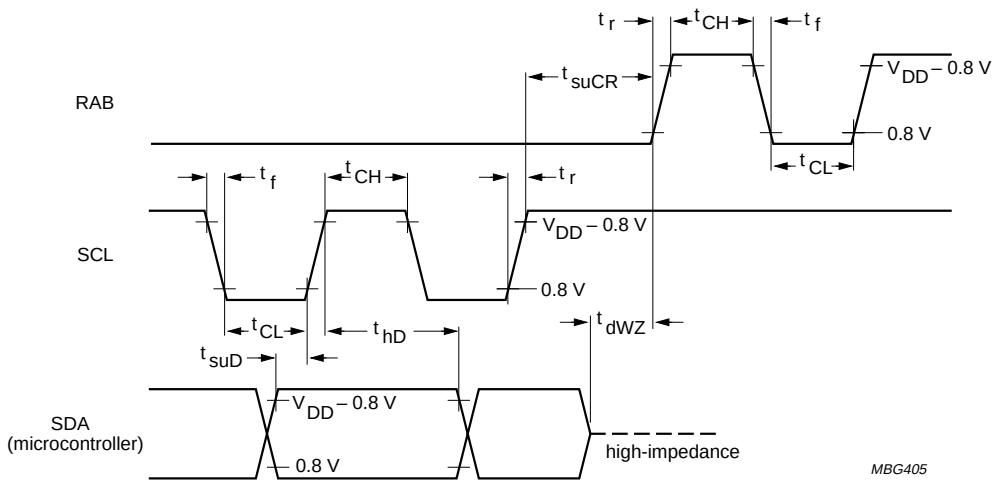


Fig.37 4-wire bus microcontroller timing; write mode (decoder registers 0 to F).

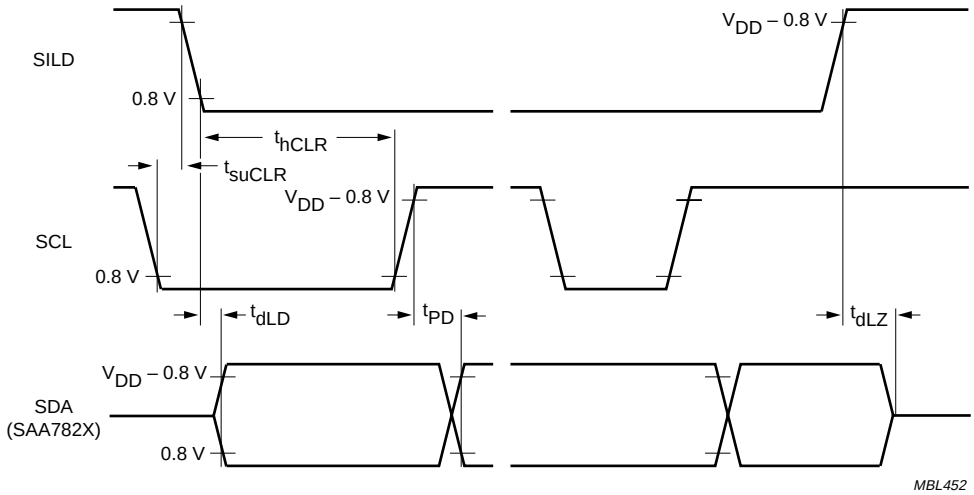


Fig.38 4-wire bus microcontroller timing; read mode (servo commands).

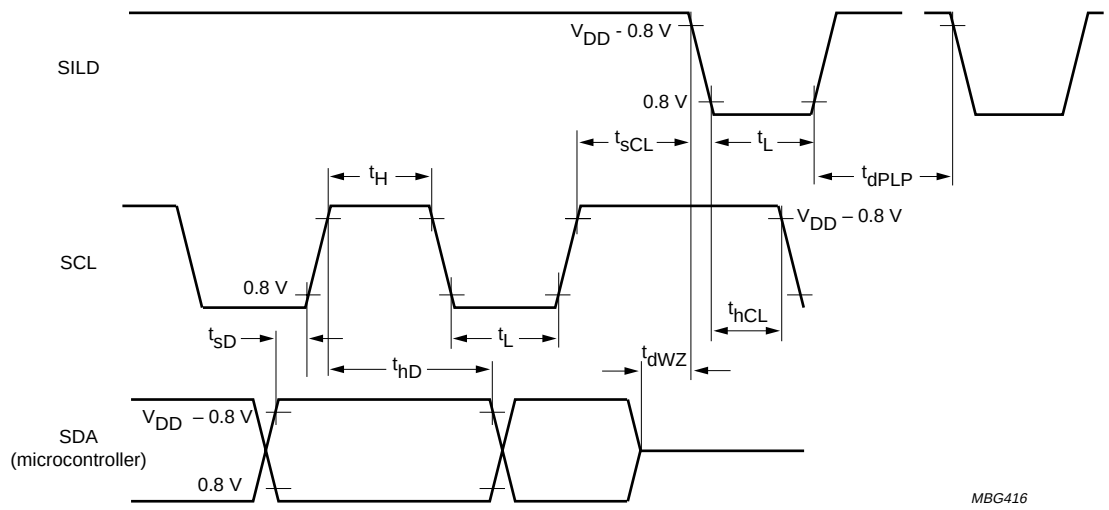


Fig.39 4-wire bus microcontroller timing; write mode (servo commands).

14 APPLICATION INFORMATION

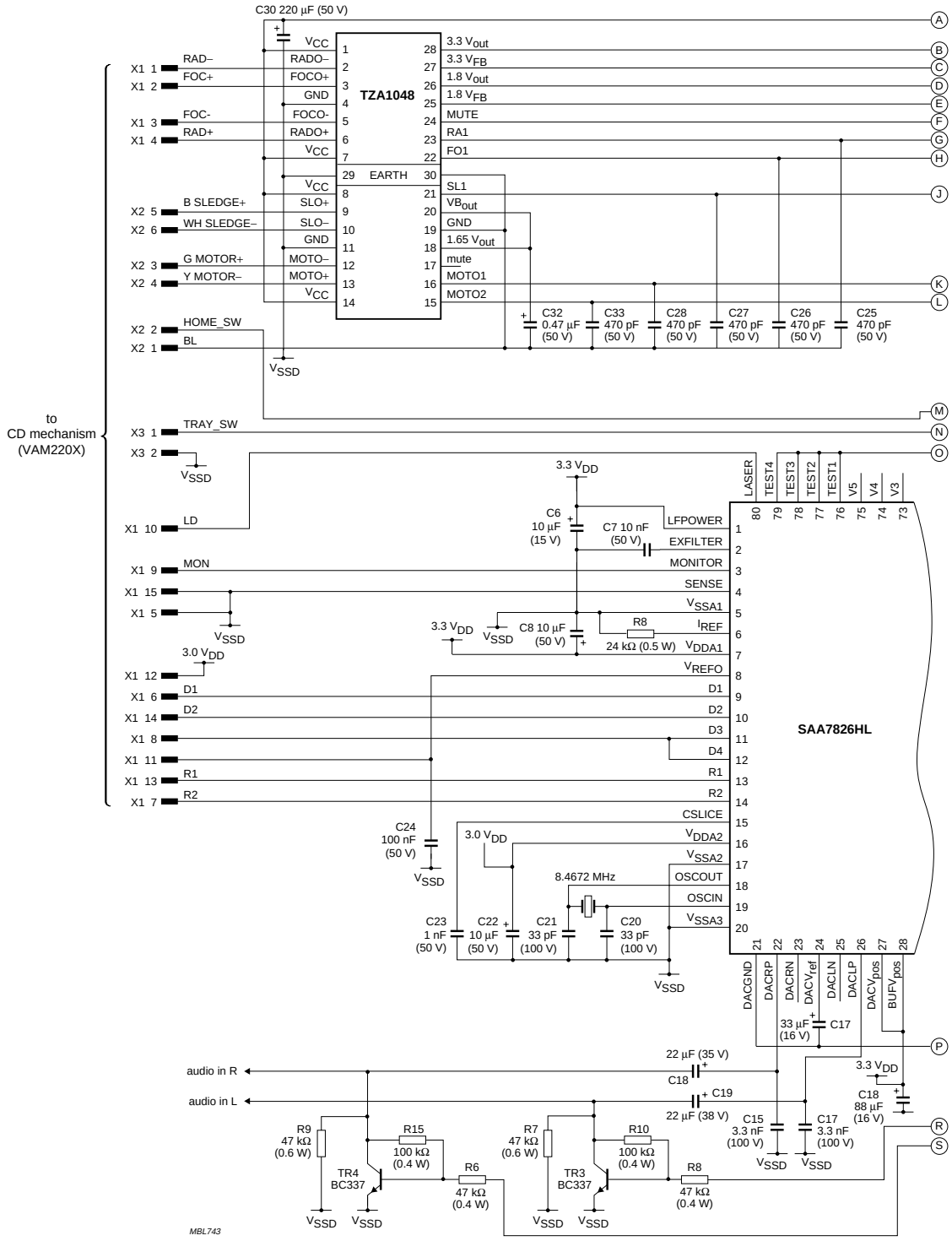


Fig.40 Typical application diagram incorporating a voltage mechanism (continued in Fig.41).

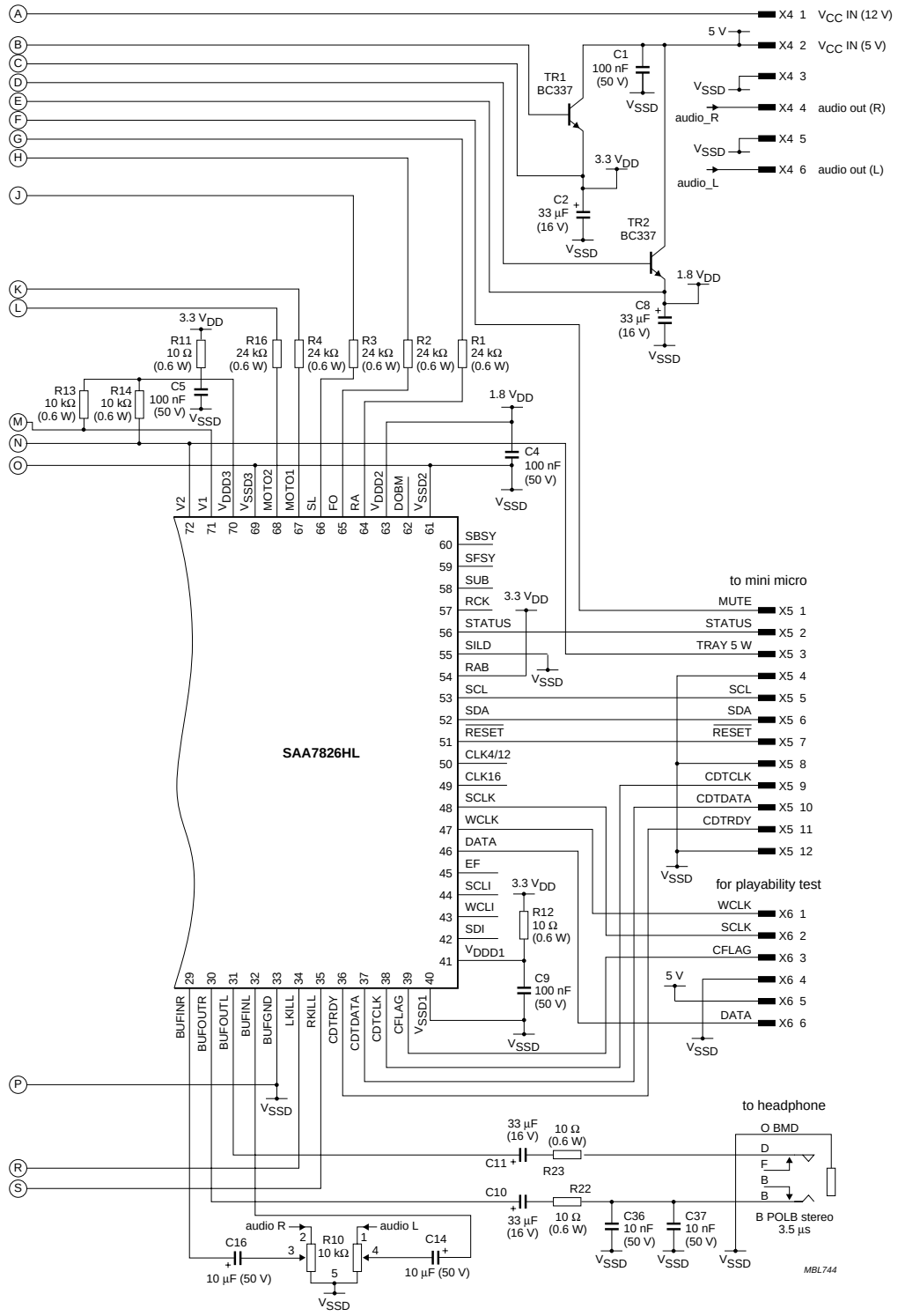
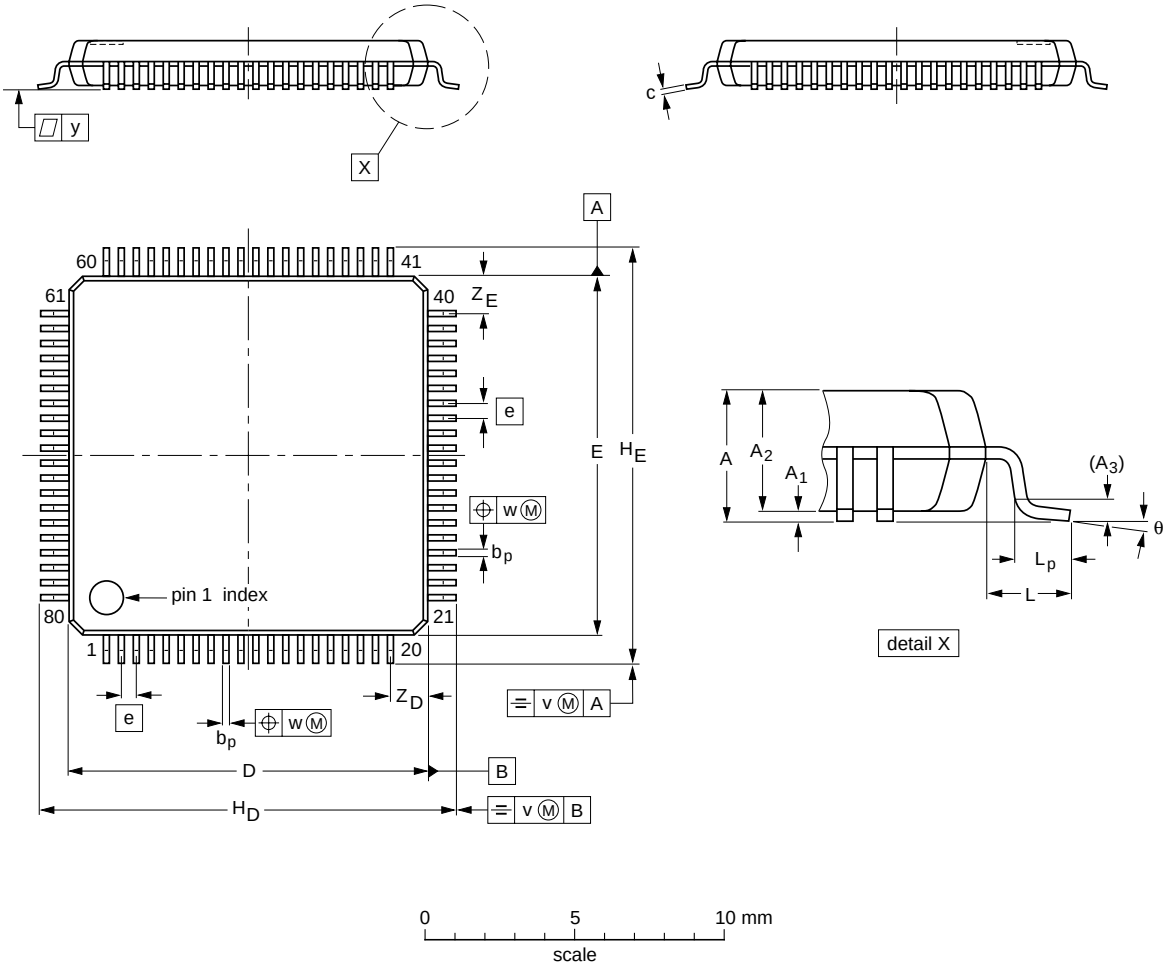


Fig.41 Typical application diagram incorporating a voltage mechanism (continued from Fig.40).

15 PACKAGE OUTLINE

LQFP80: plastic low profile quad flat package; 80 leads; body 12 x 12 x 1.4 mm **SOT315-1**



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	1.6	0.16 0.04	1.5 1.3	0.25	0.27 0.13	0.18 0.12	12.1 11.9	12.1 11.9	0.5	14.15 13.85	14.15 13.85	1	0.75 0.30	0.2	0.15	0.1	1.45 1.05	1.45 1.05	7^o 0^o

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	JEITA			
SOT315-1	136E15	MS-026				~~00-01-19~~ 03-02-25

16 SOLDERING

16.1 Introduction to soldering surface mount packages

This text gives a very brief insight to a complex technology. A more in-depth account of soldering ICs can be found in our *"Data Handbook IC26; Integrated Circuit Packages"* (document order number 9398 652 90011).

There is no soldering method that is ideal for all surface mount IC packages. Wave soldering can still be used for certain surface mount ICs, but it is not suitable for fine pitch SMDs. In these situations reflow soldering is recommended.

16.2 Reflow soldering

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. Driven by legislation and environmental forces the worldwide use of lead-free solder pastes is increasing.

Several methods exist for reflowing; for example, convection or convection/infrared heating in a conveyor type oven. Throughput times (preheating, soldering and cooling) vary between 100 and 200 seconds depending on heating method.

Typical reflow peak temperatures range from 215 to 270 °C depending on solder paste material. The top-surface temperature of the packages should preferably be kept:

- below 220 °C (SnPb process) or below 245 °C (Pb-free process)
  - for all BGA and SSOP-T packages
  - for packages with a thickness ≥ 2.5 mm
  - for packages with a thickness < 2.5 mm and a volume ≥ 350 mm^3 so called thick/large packages.
- below 235 °C (SnPb process) or below 260 °C (Pb-free process) for packages with a thickness < 2.5 mm and a volume < 350 mm^3 so called small/thin packages.

Moisture sensitivity precautions, as indicated on packing, must be respected at all times.

16.3 Wave soldering

Conventional single wave soldering is not recommended for surface mount devices (SMDs) or printed-circuit boards with a high component density, as solder bridging and non-wetting can present major problems.

To overcome these problems the double-wave soldering method was specifically developed.

If wave soldering is used the following conditions must be observed for optimal results:

- Use a double-wave soldering method comprising a turbulent wave with high upward pressure followed by a smooth laminar wave.
- For packages with leads on two sides and a pitch (e):
  - larger than or equal to 1.27 mm, the footprint longitudinal axis is **preferred** to be parallel to the transport direction of the printed-circuit board;
  - smaller than 1.27 mm, the footprint longitudinal axis **must** be parallel to the transport direction of the printed-circuit board.

  The footprint must incorporate solder thieves at the downstream end.
- For packages with leads on four sides, the footprint must be placed at a 45° angle to the transport direction of the printed-circuit board. The footprint 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.

Typical dwell time of the leads in the wave ranges from 3 to 4 seconds at 250 °C or 265 °C, depending on solder material applied, SnPb or Pb-free respectively.

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

16.4 Manual soldering

Fix the component by first soldering two diagonally-opposite end leads. Use a low voltage (24 V or less) soldering iron 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.

16.5 Suitability of surface mount IC packages for wave and reflow soldering methods

PACKAGE[1]	SOLDERING METHOD	
	WAVE	REFLOW[2]
BGA, LBGA, LFBGA, SQFP, SSOP-T[3], TFBGA, VFBGA	not suitable	suitable
DHVQFN, HBCC, HBGA, HLQFP, HSQFP, HSOP, HTQFP, HTSSOP, HVQFN, HVSON, SMS	not suitable[4]	suitable
PLCC[5], SO, SOJ	suitable	suitable
LQFP, QFP, TQFP	not recommended[5][6]	suitable
SSOP, TSSOP, VSO, VSSOP	not recommended[7]	suitable

Notes

1. For more detailed information on the BGA packages refer to the *"(LF)BGA Application Note*" (AN01026); order a copy from your Philips Semiconductors sales office.
2. All surface mount (SMD) packages are moisture sensitive. Depending upon the moisture content, the maximum temperature (with respect to time) and body size of the package, there is a risk that internal or external package cracks may occur due to vaporization of the moisture in them (the so called popcorn effect). For details, refer to the Drypack information in the *"Data Handbook IC26; Integrated Circuit Packages; Section: Packing Methods"*.
3. These transparent plastic packages are extremely sensitive to reflow soldering conditions and must on no account be processed through more than one soldering cycle or subjected to infrared reflow soldering with peak temperature exceeding 217 °C ± 10 °C measured in the atmosphere of the reflow oven. The package body peak temperature must be kept as low as possible.
4. These packages are not suitable for wave soldering. On versions with the heatsink on the bottom side, the solder cannot penetrate between the printed-circuit board and the heatsink. On versions with the heatsink on the top side, the solder might be deposited on the heatsink surface.
5. If wave soldering is considered, then the package must be placed at a 45° angle to the solder wave direction. The package footprint must incorporate solder thieves downstream and at the side corners.
6. Wave soldering is suitable for LQFP, TQFP and QFP packages with a pitch (e) larger than 0.8 mm; it is definitely not suitable for packages with a pitch (e) equal to or smaller than 0.65 mm.
7. Wave soldering is suitable for SSOP, TSSOP, VSO and VSSOP packages with a pitch (e) equal to or larger than 0.65 mm; it is definitely not suitable for packages with a pitch (e) equal to or smaller than 0.5 mm.

17 DATA SHEET STATUS

LEVEL	DATA SHEET STATUS(1)	PRODUCT STATUS(2)(3)	DEFINITION
I	Objective data	Development	This data sheet contains data from the objective specification for product development. Philips Semiconductors reserves the right to change the specification in any manner without notice.
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III	Product data	Production	This data sheet contains data from the product specification. Philips Semiconductors reserves the right to make changes at any time in order to improve the design, manufacturing and supply. Relevant changes will be communicated via a Customer Product/Process Change Notification (CPCN).

Notes

1. Please consult the most recently issued data sheet before initiating or completing a design.
2. The product status of the device(s) described in this data sheet may have changed since this data sheet was published. The latest information is available on the Internet at URL http://www.semiconductors.philips.com.
3. For data sheets describing multiple type numbers, the highest-level product status determines the data sheet status.

18 DEFINITIONS

Short-form specification — The data in a short-form 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 definition — Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 60134). 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.

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