



TDA19988

150 MHz pixel rate HDMI 1.4 transmitter with 3 × 8-bit video inputs, HDCP and CEC support

Rev. 1 — 23 July 2010

Objective data sheet



1. General description

TDA19988 is a very low power and very small size High-Definition Multimedia Interface (HDMI) v. 1.4 transmitter. It is backward compatible DVI 1.0 and can be connected to any DVI 1.0 and HDMI sink.

This device is primarily intended for mobile applications like Digital Video Camera (DVC), Digital Still Camera (DSC), Portable Multimedia Player (PMP), Mobile Phone and Ultra-Mobile Personal Computer (UM PC) where size and very low power are mandatory for battery autonomy.

It allows mixing 3 × 8-bit RGB or YCbCr video stream with a pixel rate up to 150 MHz together with one S/PDIF or two I²S-bus audio streams with an audio sampling rate up to 192 kHz.

In order to be compatible with most applications, TDA19988 integrates a full programmable input formatter and color space conversion block. The video input formats accepted are YCbCr 4 : 4 : 4 (up to 3 × 8-bit), YCbCr 4 : 2 : 2 semi-planar (up to 2 × 12-bit) and YCbCr 4 : 2 : 2 compliant with ITU656 (up to 1 × 12-bit). In case of ITU656-like format, the input pixel clock can be made active on one (SDR mode) or both edges (DDR mode).

TDA19988 includes a HDCP 1.3 compliant cipher block. The HDCP keys are stored internally in a non-volatile OTP memory for maximum security.

This device provides additional embedded feature like CEC (Consumer Electronic Control). CEC is a single bidirectional wire that transmits CEC commands (like Standby from remote control) over the home appliance network connected through this wire. This eliminates the need of any additional device to handle this feature thus improving BOM (Bill Of Materials) of the whole system and enabling the connected devices (CEC enabled) to be controlled by only one remote control.

TDA19988 supports xvYCC HDMI 1.4 feature.

It can be switched to very low power Standby or Sleep modes to save power when HDMI is not used.

TDA19988 includes I²C-bus master interface for DDC-bus communication for EDID reading and HDCP purpose.

This device can be controlled or configured via I²C-bus interface.

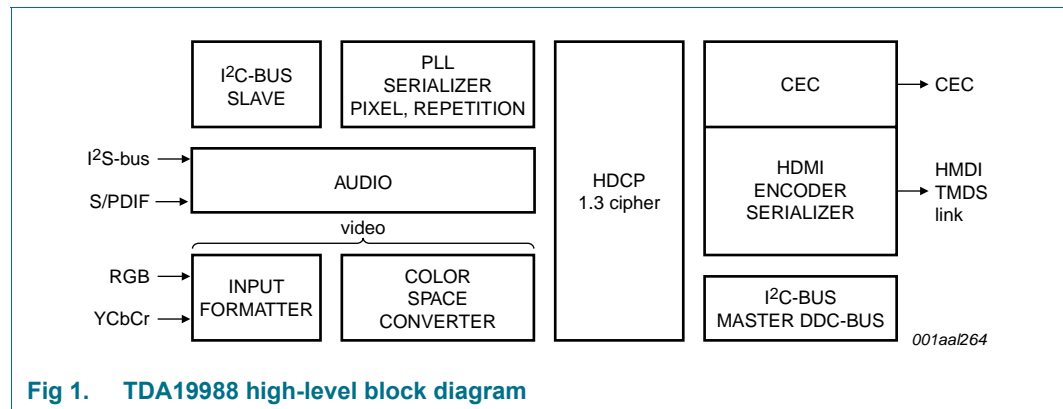


Fig 1. TDA19988 high-level block diagram

2. Features and benefits

- Compliance:
 - ◆ DVI 1.0
 - ◆ HDMI 1.4
 - ◆ EIA/CEA-861B
 - ◆ CEC (HDMI 1.4)
 - ◆ SimplayHD
 - ◆ HDCP 1.3
- Video:
 - ◆ xvYCC HDMI 1.4 feature
 - ◆ Video formats with a pixel rate up to 150 MHz:
 - RGB 4 : 4 : 4
 - YCbCr 4 : 4 : 4
 - YCbCr 4 : 2 : 2 semi-planar
 - YCbCr 4 : 2 : 2 ITU656
 - ◆ 3D:
 - Frame Packing : 720p at 50/60 Hz, 720p at 24/30 Hz
 - Side-by-Side (Half) : 720p at 50/60 Hz, 1080i at 50/60 Hz, 1080p at 24 Hz
 - Top-and-Bottom : 720p at 50/60 Hz, 1080p at 24/30 Hz, 1080p at 50/60 Hz
 - ◆ Maximum resolution:
 - 1080p for TV
 - 1600 × 1200 at 60 Hz for PC (UXGA60)
 - 720p/1080i in ITU656
 - ◆ Programmable color space converter:
 - RGB to YCbCr
 - YCbCr to RGB
 - ◆ Programmable input formatter and upsampler/interpolator allows input of any of the 4 : 4 : 4, 4 : 2 : 2 semi-planar, 4 : 2 : 2 ITU656-like formats
 - ◆ Horizontal synchronization, vertical synchronization and Data Enable (DE) inputs or VREF, HREF and FREF could be used for input data synchronization
 - ◆ Pixel clock input can be made active on one or both edges (selectable by I2C-bus)
 - ◆ Repetition of video samples as required by HDMI specification

- Audio:
 - ◆ $2 \times \text{I}^2\text{S}$ -bus 2 channels or one S/PDIF; audio data rate up to 192 kHz
- Deals with multiple levels of HDCP receivers and repeaters
- Internal SHA-1 calculation
- System operation:
 - ◆ Master DDC-bus interface for EDID read
 - ◆ Controllable via I^2C -bus
 - ◆ Downstream availability through the use of hot plug detect (HPD) and receiver detection (RxSense)
- Package:
 - ◆ TFBGA64
 - ◆ Size $4.5 \times 4.5 \times 0.95$ mm
- Power management:
 - ◆ External voltage supplies 1.8 V
 - ◆ Low power
 - ◆ Flexible power modes
- Miscellaneous:
 - ◆ POR (Power-On Reset)
 - ◆ Audio and video inputs LV-CMOS 1.8 V compatible and LV-CMOS 3.3 V tolerant
 - ◆ 250 MHz to 1.5 GHz TMDS transmitter operation

3. Applications

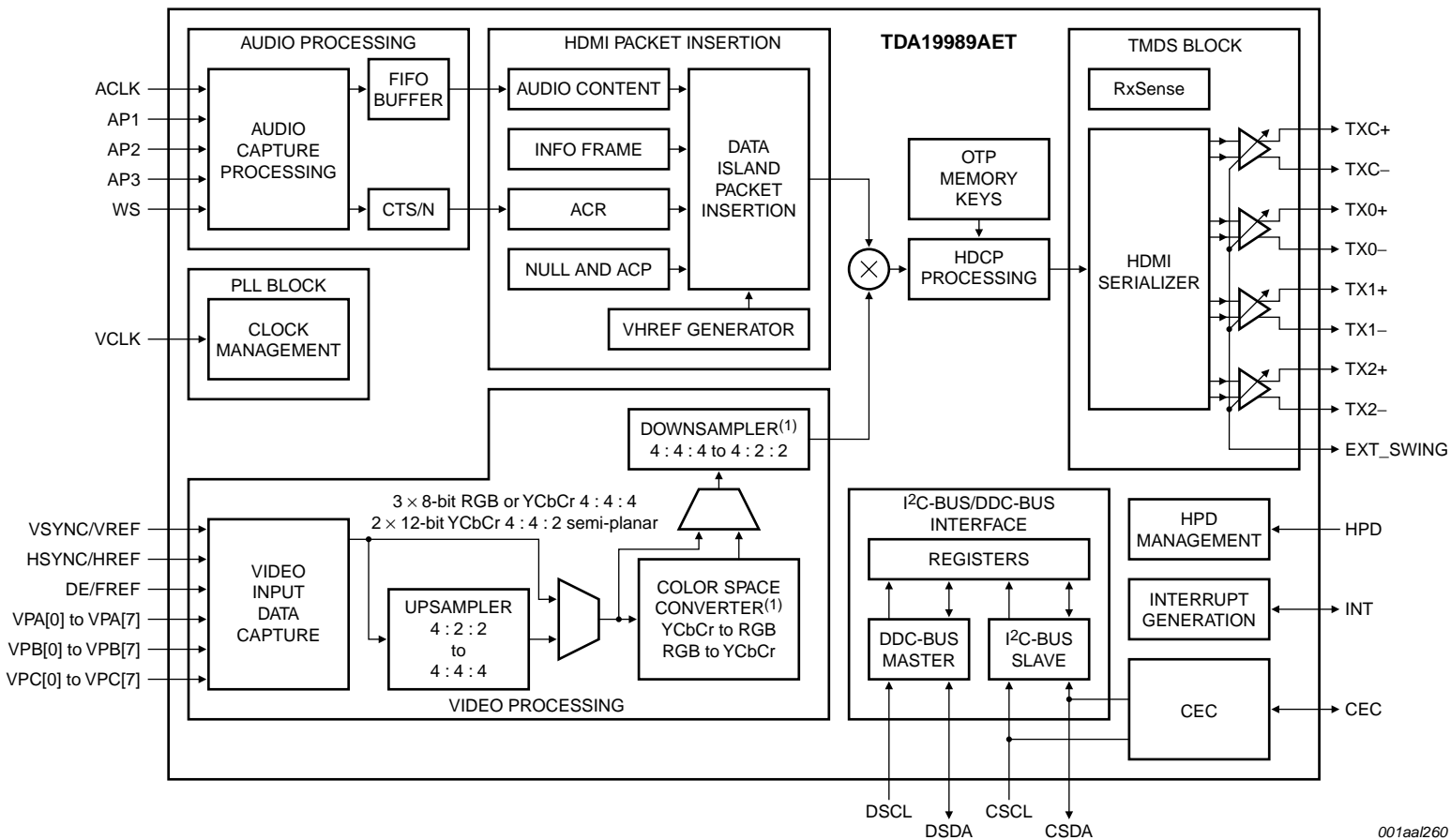
- Digital Video Camera (DVC)
- Digital Still Camera (DSC)
- Portable Multimedia Player (PMP)
- Ultra-Mobile Personal Computer (UM PC)
- YCbCr or RGB high-speed video digitizer
- DVD recorder
- AVR and HDMI splitter
- HDTV
- High-End TV
- Mobile Phone
- Home theater amplifier
- Projector, plasma and LCD TV
- Rear projection TV

4. Ordering information

Table 1. Ordering information

Type number	Package		
	Name	Description	Version
TDA19988AET	TFBGA64	plastic thin fine-pitch ball grid array package; 64 balls	SOT962-3
TDA19988BET	TFBGA64	plastic thin fine-pitch ball grid array package; 64 balls; without HDCP	SOT962-3
TDA19988AHN	HVQFN64	plastic thermal enhanced very thin quad flat package; no leads; 64 terminals; body $9 \times 9 \times 0.85$ mm	SOT804-4
TDA19988BHN	HVQFN64	plastic thermal enhanced very thin quad flat package; no leads; 64 terminals; body $9 \times 9 \times 0.85$ mm; without HDCP	SOT804-4

5. Block diagram

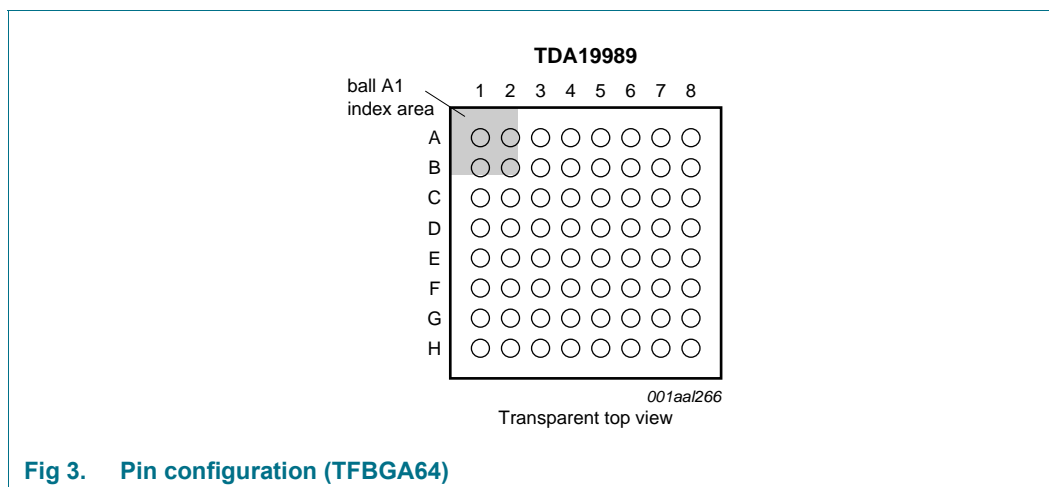


(1) The color space converter can be bypassed.
The device can handle HDCP based on 1.3 features.

Fig 2. TDA19988 Block diagram

6. Pinning information

6.1 Pinning



6.2 Pin description

Table 2. Pin description

Symbol	Pin	Type ^[1]	Description
ACLK	H5	I	audio clock input
AP0	G5	I	audio port 0 input
AP1	F5	I	audio port 1 input
AP2	G6	I	audio port 2 input
OSC_IN/AP3	H6	I	input connected to the external oscillator circuit or external clock source/audio port 3 input
HPD	E6	I	hot plug detect; 5 V tolerant
EXT_SWING	E7	O	TMDS output swing adjustment; place resistor ($R_{EXT_SWING} = 10\text{ k}\Omega \pm 1\%$) between this pin and analog ground.
DSDA	F6	I/O	DDC-bus data input/output; 5 V tolerant
DSCL	F7	I	DDC-bus clock input; 5 V tolerant
VCLK	D4	I	input video pixel clock
HSYNC/HREF	F4	I	input horizontal synchronization or reference input
VSYNC/VREF	G4	I	input vertical synchronization or reference input
DE/FREF	H4	I	data enable or field reference input
CSCL	B5	I	I ² C-bus clock input; 1.8 V to 3.3 V tolerant
CSDA	A5	I/O	I ² C-bus data input/output; 1.8 V to 3.3 V tolerant
INT	B6	I/O	interrupt HDMI output (open-drain); this pin is used as Dual function pin selectable through I ² C-bus. In calibration mode only this pin is used as input for $10\text{ ms} \pm 1\%$ calibration pulse. In operation mode this pin is used to warn the external microprocessor that a special event has occurred for HDMI or CEC

Table 2. Pin description ...continued

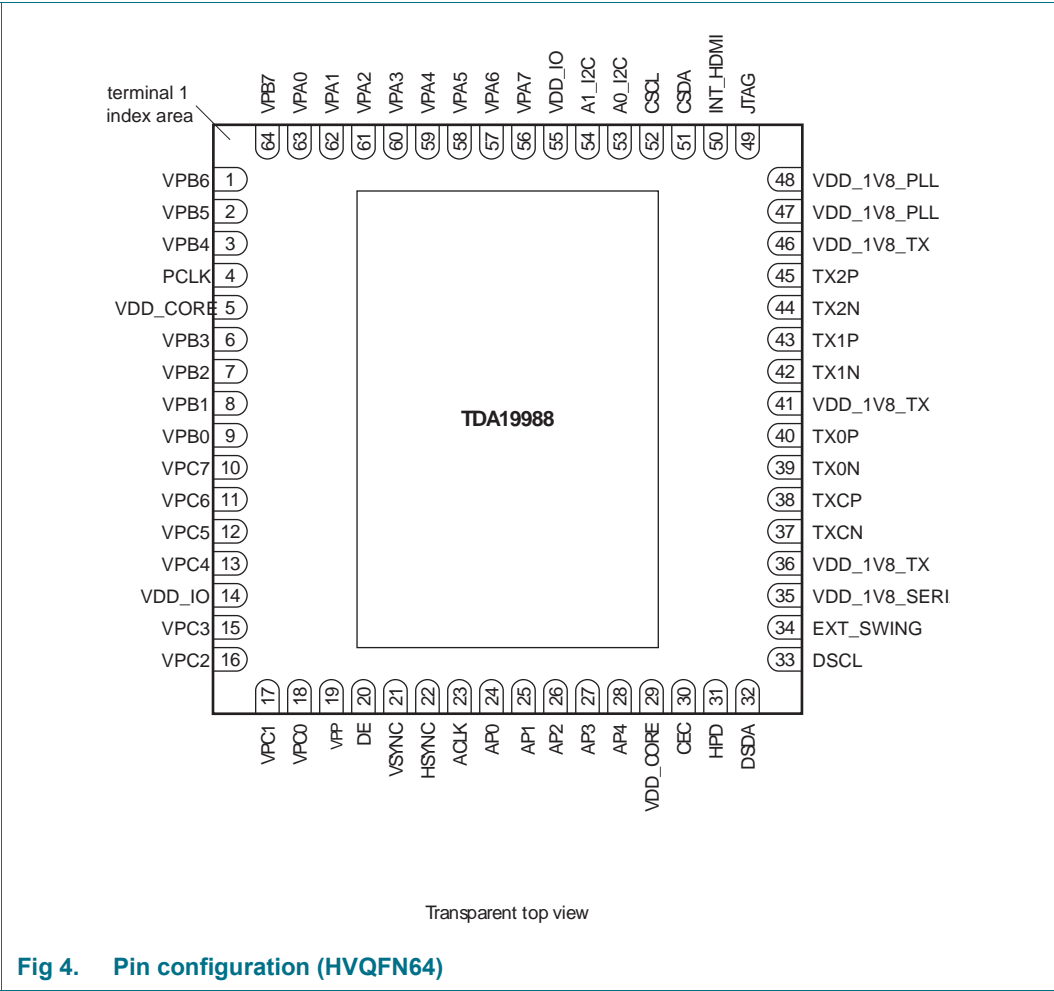
Symbol	Pin	Type ^[1]	Description
TX0–	E8	O	negative data channel 0 for TMDS output
TX0+	D8	O	positive data channel 0 for TMDS output
TX1–	C8	O	negative data channel 1 for TMDS output
TX1+	B8	O	positive data channel 1 for TMDS output
TX2–	A7	O	negative data channel 2 for TMDS output
TX2+	A6	O	positive data channel 2 for TMDS output
TXC–	G8	O	negative clock channel for TMDS output
TXC+	F8	O	positive clock channel for TMDS output
CEC	H7	I/O	CEC connection (open-drain) to HDMI connector
VPA[0]	C1	I	video port A input bit 0 (LSB)
VPA[1]	B1	I	video port A input bit 1
VPA[2]	B2	I	video port A input bit 2
VPA[3]	A2	I	video port A input bit 3
VPA[4]	B3	I	video port A input bit 4
VPA[5]	A3	I	video port A input bit 5
VPA[6]	B4	I	video port A input bit 6
VPA[7]	A4	I	video port A input bit 7 (MSB)
VPB[0]	E3	I	video port B input bit 0 (LSB)
VPB[1]	E2	I	video port B input bit 1
VPB[2]	E1	I	video port B input bit 2
VPB[3]	D1	I	video port B input bit 3
VPB[4]	D2	I	video port B input bit 4
VPB[5]	D3	I	video port B input bit 5
VPB[6]	C2	I	video port B input bit 6
VPB[7]	C3	I	video port B input bit 7 (MSB)
VPC[0]	H3	I	video port C input bit 0 (LSB)
VPC[1]	H2	I	video port C input bit 1
VPC[2]	G3	I	video port C input bit 2
VPC[3]	G2	I	video port C input bit 3
VPC[4]	G1	I	video port C input bit 4
VPC[5]	F1	I	video port C input bit 5
VPC[6]	F2	I	video port C input bit 6
VPC[7]	F3	I	video port C input bit 7 (MSB)
V _{DDA(TMDS)} (1V8)	A8, C7	P	TMDS analog supply voltage (1.8 V)
V _{DDD(IO)} (1V8)	E4	P	I/O digital supply voltage (1.8 V)
V _{DDA(PLL)} (1V8)	C6	P	PLL analog supply voltage (1.8 V), this PLL provides the clock for the serializer
V _{DDA} (1V8)	G7, H8	P	analog supply voltage (1.8 V), is used for parallel-to-serial shift register and miscellaneous blocks
V _{DDDC}	E5	P	core digital supply voltage (1.8 V)
V _{DDDC}	D5	P	core digital supply voltage (1.8 V)

Table 2. Pin description ...continued

Symbol	Pin	Type ^[1]	Description
V _{SSD}	B7, C4, C5, H1	G	digital ground supply voltage, is used for digital core; I/O
V _{SSA}	D6, D7	G	analog ground supply voltage, is used for PLL; serializer, transmitter, and parallel-to-serial shift register
n.c.	A1		not connected

[1] P = power supply, G = ground, I = input, O = output.

6.3 Pinning



6.4 Pin description

Table 3. Pin description

Symbol	Pin	Type ^[1]	Description
VPB[6]	1	I	video port B input bit 6
VPB[5]	2	I	video port B input bit 5
VPB[4]	3	I	video port B input bit 4

Table 3. Pin description ...continued

Symbol	Pin	Type ^[1]	Description
VCLK	4	I	input video pixel clock
V _{DDDC}	5	P	core digital supply voltage (1.8 V)
VPB[3]	6	I	video port B input bit 3
VPB[2]	7	I	video port B input bit 2
VPB[1]	8	I	video port B input bit 1
VPB[0]	9	I	video port B input bit 0 (LSB)
VPC[7]	10	I	video port C input bit 7 (MSB)
VPC[6]	11	I	video port C input bit 6
VPC[5]	12	I	video port C input bit 5
VPC[4]	13	I	video port C input bit 4
V _{DD(I/O)} (1V8)	14	P	I/O digital supply voltage (1.8 V)
VPC[3]	15	I	video port C input bit 3
VPC[2]	16	I	video port C input bit 2
VPC[1]	17	I	video port C input bit 1
VPC[0]	18	I	video port C input bit 0 LSB)
VPP	19		to be connected to GND
DE/FREF	20	I	data enable or field reference input
VSYNC/VREF	21	I	input vertical synchronization or reference input
HSYNC/HREF	22	I	input horizontal synchronization or reference input
ACLK	23	I	audio clock input
AP0	24	I	audio port 0 input
AP1	25	I	audio port 1 input
AP2	26	I	audio port 2 input
OSC_IN/AP3	27	I	input connected to the external oscillator circuit or external clock source/audio port 3 input
AP4	28	I	audio port 4 input
V _{DDDC}	29	P	core digital supply voltage (1.8 V)
CEC	30	I/O	CEC connection (open-drain) to HDMI connector
HPD	31	I	hot plug detect; 5 V tolerant
DSDA	32	I/O	DDC-bus data input/output; 5 V tolerant
DSCL	33	I	DDC-bus clock input; 5 V tolerant
EXT_SWING	34	O	TMDS output swing adjustment; place resistor ($R_{EXT_SWING} = 10\text{ k}\Omega \pm 1\%$) between this pin and analog ground.
V _{DDA} (1V8)	35	P	analog supply voltage (1.8 V), is used for parallel-to-serial shift register and miscellaneous blocks
V _{DDA} (Tx)(1V8)	36	P	Tx analog supply voltage (1.8 V)
TXC-	37	O	negative clock channel for TMDS output
TXC+	38	O	positive clock channel for TMDS output
TX0-	39	O	negative data channel 0 for TMDS output
TX0+	40	O	positive data channel 0 for TMDS output
V _{DDA} (Tx)(1V8)	41	P	Tx analog supply voltage (1.8 V)

Table 3. Pin description ...continued

Symbol	Pin	Type ^[1]	Description
TX1–	42	O	negative data channel 1 for TMDS output
TX1+	43	O	positive data channel 1 for TMDS output
TX2–	44	O	negative data channel 2 for TMDS output
TX2+	45	O	positive data channel 2 for TMDS output
V _{DDA(Tx)} (1V8)	46	P	Tx analog supply voltage (1.8 V)
V _{DDA(PLL)} (1V8)	47	P	PLL analog supply voltage (1.8 V), this PLL provides the clock for the serializer
V _{DDA(PLL)} (1V8)	48	P	PLL analog supply voltage (1.8 V), this PLL provides the clock for the serializer
TEST	49		to be connected to GND
INT	50	I/O	interrupt HDMI output (open-drain); this pin is used as Dual function pin selectable through I ² C-bus. In calibration mode only this pin is used as input for 10 ms ± 1 % calibration pulse. In operation mode this pin is used to warn the external microprocessor that a special event has occurred for HDMI or CEC
CSDA	51	I/O	I ² C-bus data input/output; 1.8 V to 3.3 V tolerant
CSCL	52	I	I ² C-bus clock input; 1.8 V to 3.3 V tolerant
A0_I2C	53		
A1_I2C	54		
V _{DDD(IO)} (1V8)	55	P	I/O digital supply voltage (1.8 V)
VPA[7]	56	I	video port A input bit 7 (MSB)
VPA[6]	57	I	video port A input bit 6
VPA[5]	58	I	video port A input bit 5
VPA[4]	59	I	video port A input bit 4)
VPA[3]	60	I	video port A input bit 3
VPA[2]	61	I	video port A input bit 2
VPA[1]	62	I	video port A input bit 1
VPA[0]	63	I	video port A input bit 0 (LSB)
VPB[7]	64	I	video port B input bit 7 (MSB)

[1] P = power supply, G = ground, I = input, O = output.

7. Functional description

TDA19988 is designed to convert digital data (video and audio) provided by Set-Top Boxes (STB), Digital Video Camera (DVC), Digital Still Camera (DSC), Portable Multimedia Player (PMP) or DVD into an HDMI output, which can be used by a TV with either an HDMI or DVI input.

The video data input formats are:

- RGB 4 : 4 : 4
- YCbCr 4 : 4 : 4
- YCbCr 4 : 2 : 2 semi-planar

- YCbCr 4 : 2 : 2 ITU656-like

TDA19988 is able to output HDMI with the formats:

- RGB 4 : 4 : 4
- YCbCr 4 : 4 : 4
- YCbCr 4 : 2 : 2

It can also handle audio formats:

- two I²S-bus channels
- one S/PDIF channel

TDA19988 is also designed to support CEC protocol. For more details about CEC, refer to *HDMI 1.4 specification*.

7.1 System clock

The system clock section has a PLL serializer.

It is a system clock generator which enables the stream produced by the encoder to be transmitted on the HDMI data channel at ten times, or above, the sampling rate.

7.2 Video input formatter

7.2.1 Description

TDA19988 has three video input ports VPA[0] to VPA[7], VPB[0] to VPB[7] and VPC[0] to VPC[7].

TDA19988 can accept any of the following video input modes (see [Table 7](#)):

- RGB, with 8-bit for each component
- YCbCr 4 : 4 : 4, with 8-bit for each component
- YCbCr 4 : 2 : 2 semi-planar, with up to 12-bit for each component (YCbCr)
- YCbCr 4 : 2 : 2 ITU656, with up to 12-bit data depth

TDA19988 can be set to latch data at either rising or falling edge, or both.

7.2.2 Internal assignment

The aim of the video input processor is to internally map the incoming data to the corresponding mode, which can be handled by the video processing. The internal signal named VP[23:0] is assigned depending on the input mode as defined below.

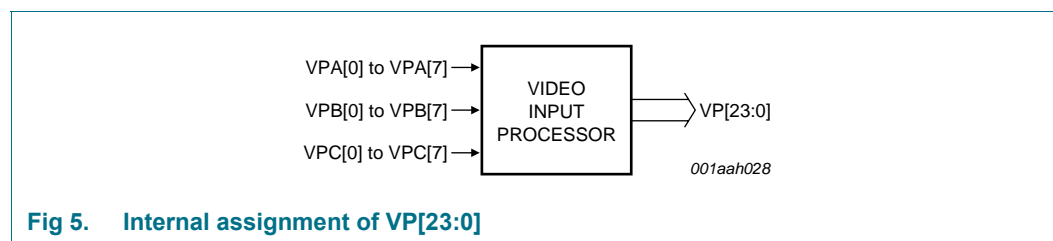


Table 4. Internal assignment

Internal assignment				
Internal port	RGB	YCbCr 4 : 4 : 4	YCbCr 4 : 2 : 2 semi-planar	YCbCr 4 : 2 : 2 ITU656
VP[23]	G[7]	Y[7]	Y[11]	YCbCr[11]
VP[22]	G[6]	Y[6]	Y[10]	YCbCr[10]
VP[21]	G[5]	Y[5]	Y[9]	YCbCr[9]
VP[20]	G[4]	Y[4]	Y[8]	YCbCr[8]
VP[19]	G[3]	Y[3]	Y[7]	YCbCr[7]
VP[18]	G[2]	Y[2]	Y[6]	YCbCr[6]
VP[17]	G[1]	Y[1]	Y[5]	YCbCr[5]
VP[16]	G[0]	Y[0]	Y[4]	YCbCr[4]
VP[15]	B[7]	Cb[7]	Y[3]	YCbCr[3]
VP[14]	B[6]	Cb[6]	Y[2]	YCbCr[2]
VP[13]	B[5]	Cb[5]	Y[1]	YCbCr[1]
VP[12]	B[4]	Cb[4]	Y[0]	YCbCr[0]

Table 4. Internal assignment ...continued

Internal assignment				
Internal port	RGB	YCbCr 4 : 4 : 4	YCbCr 4 : 2 : 2 semi-planar	YCbCr 4 : 2 : 2 ITU656
VP[11]	B[3]	Cb[3]	CbCr[11]	
VP[10]	B[2]	Cb[2]	CbCr[10]	
VP[9]	B[1]	Cb[1]	CbCr[9]	
VP[8]	B[0]	Cb[0]	CbCr[8]	
VP[7]	R[7]	Cr[7]	CbCr[7]	
VP[6]	R[6]	Cr[6]	CbCr[6]	
VP[5]	R[5]	Cr[5]	CbCr[5]	
VP[4]	R[4]	Cr[4]	CbCr[4]	
VP[3]	R[3]	Cr[3]	CbCr[3]	
VP[2]	R[2]	Cr[2]	CbCr[2]	
VP[1]	R[1]	Cr[1]	CbCr[1]	
VP[0]	R[0]	Cr[0]	CbCr[0]	

The device can swap and invert, in the event of a little endian stream, the incoming video data using I²C-bus registers VIP_CNTRL_0, VIP_CNTRL_1 and VIP_CNTRL_2 (page 00h) to match the expectation of the video processing block. [Table 5](#) shows the behavior of SWAP_A[2:0] of VIP_CNTRL_0 register, whose function is to map the 4 MSBs VP[23:20] to the incoming video port.

Table 5. Video input swap to VP[23:20]

External assignment		SWAP_A[2:0] selector value	Internal assignment							
Pin number	Pin name		Internal port	RGB	YCbCr 4 : 4 : 4	YCbCr 4 : 2 : 2 semi-planar		YCbCr 4 : 2 : 2 ITU656		
F3	VPC[7]	000b	VP[23]	G[7]	Y[7]	Y ₀ [11]	Y ₁ [11]	Cb[11]	Y ₀ [11]	Cr[11] Y ₁ [11]
F2	VPC[6]		VP[22]	G[6]	Y[6]	Y ₀ [10]	Y ₁ [10]	Cb[10]	Y ₀ [10]	Cr[10] Y ₁ [10]
F1	VPC[5]		VP[21]	G[5]	Y[5]	Y ₀ [9]	Y ₁ [9]	Cb[9]	Y ₀ [9]	Cr[9] Y ₁ [9]
G1	VPC[4]		VP[20]	G[4]	Y[4]	Y ₀ [8]	Y ₁ [8]	Cb[8]	Y ₀ [8]	Cr[8] Y ₁ [8]
G2	VPC[3]	001b	VP[23]	G[7]	Y[7]	Y ₀ [11]	Y ₁ [11]	Cb[11]	Y ₀ [11]	Cr[11] Y ₁ [11]
G3	VPC[2]		VP[22]	G[6]	Y[6]	Y ₀ [10]	Y ₁ [10]	Cb[10]	Y ₀ [10]	Cr[10] Y ₁ [10]
H2	VPC[1]		VP[21]	G[5]	Y[5]	Y ₀ [9]	Y ₁ [9]	Cb[9]	Y ₀ [9]	Cr[9] Y ₁ [9]
H3	VPC[0]		VP[20]	G[4]	Y[4]	Y ₀ [8]	Y ₁ [8]	Cb[8]	Y ₀ [8]	Cr[8] Y ₁ [8]
C3	VPB[7]	010b	VP[23]	G[7]	Y[7]	Y ₀ [11]	Y ₁ [11]	Cb[11]	Y ₀ [11]	Cr[11] Y ₁ [11]
C2	VPB[6]		VP[22]	G[6]	Y[6]	Y ₀ [10]	Y ₁ [10]	Cb[10]	Y ₀ [10]	Cr[10] Y ₁ [10]
D3	VPB[5]		VP[21]	G[5]	Y[5]	Y ₀ [9]	Y ₁ [9]	Cb[9]	Y ₀ [9]	Cr[9] Y ₁ [9]
D2	VPB[4]		VP[20]	G[4]	Y[4]	Y ₀ [8]	Y ₁ [8]	Cb[8]	Y ₀ [8]	Cr[8] Y ₁ [8]
D1	VPB[3]	011b	VP[23]	G[7]	Y[7]	Y ₀ [11]	Y ₁ [11]	Cb[11]	Y ₀ [11]	Cr[11] Y ₁ [11]
E1	VPB[2]		VP[22]	G[6]	Y[6]	Y ₀ [10]	Y ₁ [10]	Cb[10]	Y ₀ [10]	Cr[10] Y ₁ [10]
E2	VPB[1]		VP[21]	G[5]	Y[5]	Y ₀ [9]	Y ₁ [9]	Cb[9]	Y ₀ [9]	Cr[9] Y ₁ [9]
E3	VPB[0]		VP[20]	G[4]	Y[4]	Y ₀ [8]	Y ₁ [8]	Cb[8]	Y ₀ [8]	Cr[8] Y ₁ [8]
A4	VPA[7]	100b	VP[23]	G[7]	Y[7]	Y ₀ [11]	Y ₁ [11]	Cb[11]	Y ₀ [11]	Cr[11] Y ₁ [11]
B4	VPA[6]		VP[22]	G[6]	Y[6]	Y ₀ [10]	Y ₁ [10]	Cb[10]	Y ₀ [10]	Cr[10] Y ₁ [10]
A3	VPA[5]		VP[21]	G[5]	Y[5]	Y ₀ [9]	Y ₁ [9]	Cb[9]	Y ₀ [9]	Cr[9] Y ₁ [9]
B3	VPA[4]		VP[20]	G[4]	Y[4]	Y ₀ [8]	Y ₁ [8]	Cb[8]	Y ₀ [8]	Cr[8] Y ₁ [8]
A2	VPA[3]	101b	VP[23]	G[7]	Y[7]	Y ₀ [11]	Y ₁ [11]	Cb[11]	Y ₀ [11]	Cr[11] Y ₁ [11]
B2	VPA[2]		VP[22]	G[6]	Y[6]	Y ₀ [10]	Y ₁ [10]	Cb[10]	Y ₀ [10]	Cr[10] Y ₁ [10]
B1	VPA[1]		VP[21]	G[5]	Y[5]	Y ₀ [9]	Y ₁ [9]	Cb[9]	Y ₀ [9]	Cr[9] Y ₁ [9]
C1	VPA[0]		VP[20]	G[4]	Y[4]	Y ₀ [8]	Y ₁ [8]	Cb[8]	Y ₀ [8]	Cr[8] Y ₁ [8]

In the same way:

- SWAP_B[2:0] is used to map incoming video port to the internal port VP[19:16].
- SWAP_C[2:0] is used to map incoming video port to the internal port VP[15:12].
- SWAP_D[2:0] is used to map incoming video port to the internal port VP[11:8].
- SWAP_E[2:0] is used to map incoming video port to the internal port VP[7:4].
- SWAP_F[2:0] is used to map incoming video port to the internal port VP[3:0].

The device expects to receive big endian incoming data. However, in cases where the input digital stream to the chip is little endian, the use of the mirror bit of the same register can help to re-order the input bits as described in [Table 6](#).

Table 6. TDA19988 input/output capability

Bit setting	Internal port	To be mapped to
MIRR_A = 1 SWAP_A[2:0] = 1	VP[23]	VPC[0]
	VP[22]	VPC[1]
	VP[21]	VPC[2]
	VP[20]	VPC[3]
MIRR_B = 1 SWAP_B[2:0] = 0	VP[19]	VPC[4]
	VP[18]	VPC[5]
	VP[17]	VPC[6]
	VP[16]	VPC[7]
MIRR_C = 1 SWAP_C[2:0] = 3	VP[15]	VPB[0]
	VP[14]	VPB[1]
	VP[13]	VPB[2]
	VP[12]	VPB[3]
MIRR_D = 1 SWAP_D[2:0] = 2	VP[11]	VPB[4]
	VP[10]	VPB[5]
	VP[9]	VPB[6]
	VP[8]	VPB[7]
MIRR_E = 1 SWAP_E[2:0] = 5	VP[7]	VPA[4]
	VP[6]	VPA[5]
	VP[5]	VPA[6]
	VP[4]	VPA[7]
MIRR_F = 1 SWAP_F[2:0] = 4	VP[3]	VPA[0]
	VP[2]	VPA[1]
	VP[1]	VPA[2]
	VP[0]	VPA[3]

When input ports are not used, it is possible to deactivate them via the I²C-bus with the appropriate set of registers ENA_VP_0, ENA_VP_1 and ENA_VP_2 on page 00h.

7.2.3 Input format mappings

[Table 7](#) gives more information concerning input format supported.

Table 7. Inputs of video input formatter

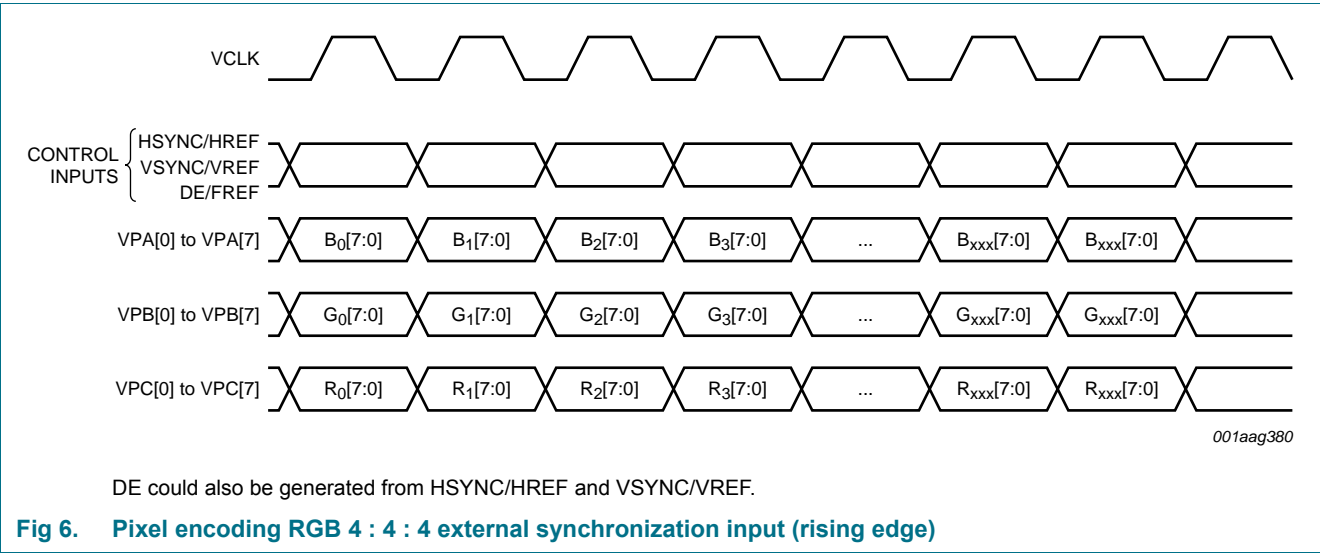
Color space	Format	Channels	Sync type	Rising edge	Falling edge	Double edge	Transmission input format	Max. pixel clock (MHz)	Max. input format	Comments
RGB	4 : 4 : 4	3 × 8-bit	external	X			-	150	-	
					X		-	150	-	
			embedded	X			-	150	-	
					X		-	150	-	
YCbCr	4 : 4 : 4	3 × 8-bit	external	X			-	150	-	
					X		-	150	-	
			embedded	X			-	150	-	
					X		-	150	-	
YCbCr	4 : 2 : 2	up to 1 × 12-bit ITU656-like	external	X			ITU656-like	54.054	480p/576p	
					X		ITU656-like	148.5	720p/1080i	
					X		ITU656-like	54.054	480p/576p	
					X		ITU656-like	148.5	720p/1080i	
			embedded			X	ITU656-like	74.25	720p/1080i	double edge
				X			ITU656-like	54.054	480p/576p	
					X		ITU656-like	148.5	720p/1080i	
					X		ITU656-like	54.054	480p/576p	
			up to 2 × 8-bit semi-planar			X	ITU656-like	148.5	720p/1080i	
						X	ITU656-like	74.25	720p/1080i	double edge
				X			SMPTE293M	148.5	1080p	
					X		SMPTE293M	148.5	1080p	
			embedded	X			SMPTE293M	148.5	1080p	
					X		SMPTE293M	148.5	1080p	

7.2.3.1 RGB 4 : 4 : 4 external synchronization (rising edge)

Table 8. RGB (3 × 8-bit) external synchronization input (rising edge) mapping

Register `VIP_CNTRL_0` = 23h; `VIP_CNTRL_1` = 45h; `VIP_CNTRL_2` = 01h.

Video port A		Video port B		Video port C		Control	
Pin	RGB 4 : 4 : 4	Pin	RGB 4 : 4 : 4	Pin	RGB 4 : 4 : 4	Pin	RGB 4 : 4 : 4
VPA[0]	B[0]	VPB[0]	G[0]	VPC[0]	R[0]	HSYNC/HREF	used
VPA[1]	B[1]	VPB[1]	G[1]	VPC[1]	R[1]	VSYSN/VREF	used
VPA[2]	B[2]	VPB[2]	G[2]	VPC[2]	R[2]	DE/FREF	used
VPA[3]	B[3]	VPB[3]	G[3]	VPC[3]	R[3]		
VPA[4]	B[4]	VPB[4]	G[4]	VPC[4]	R[4]		
VPA[5]	B[5]	VPB[5]	G[5]	VPC[5]	R[5]		
VPA[6]	B[6]	VPB[6]	G[6]	VPC[6]	R[6]		
VPA[7]	B[7]	VPB[7]	G[7]	VPC[7]	R[7]		

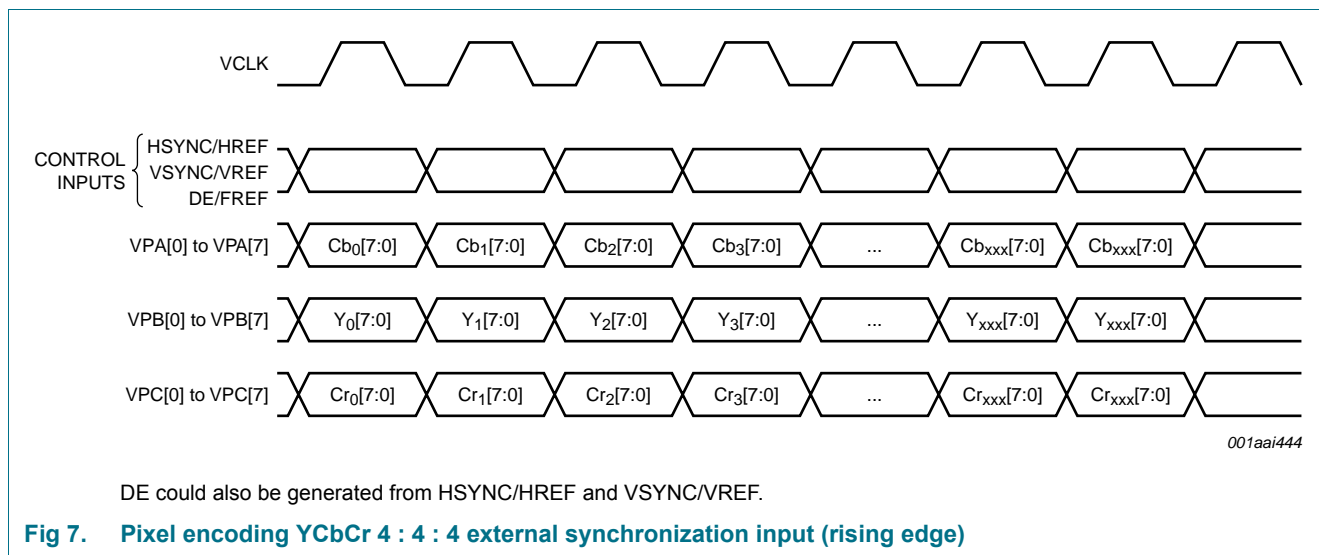


7.2.3.2 YCbCr 4 : 4 : 4 external synchronization (rising edge)

Table 9. YCbCr 4 : 4 : 4 (3 × 8-bit) external synchronization input (rising edge) mapping

Register *VIP_CNTRL_0* = 23h; *VIP_CNTRL_1* = 45h; *VIP_CNTRL_2* = 01h.

Video port A		Video port B		Video port C		Control	
Pin	YCbCr 4 : 4 : 4	Pin	YCbCr 4 : 4 : 4	Pin	YCbCr 4 : 4 : 4	Pin	YCbCr 4 : 4 : 4
VPA[0]	Cb[0]	VPB[0]	Y[0]	VPC[0]	Cr[0]	HSYNC/HREF	used
VPA[1]	Cb[1]	VPB[1]	Y[1]	VPC[1]	Cr[1]	VSYNC/VREF	used
VPA[2]	Cb[2]	VPB[2]	Y[2]	VPC[2]	Cr[2]	DE/FREF	used
VPA[3]	Cb[3]	VPB[3]	Y[3]	VPC[3]	Cr[3]		
VPA[4]	Cb[4]	VPB[4]	Y[4]	VPC[4]	Cr[4]		
VPA[5]	Cb[5]	VPB[5]	Y[5]	VPC[5]	Cr[5]		
VPA[6]	Cb[6]	VPB[6]	Y[6]	VPC[6]	Cr[6]		
VPA[7]	Cb[7]	VPB[7]	Y[7]	VPC[7]	Cr[7]		



7.2.3.3 YCbCr 4 : 2 : 2 ITU656-like external synchronization (rising edge)

Table 10. YCbCr 4 : 2 : 2 ITU656-like external synchronization input (rising edge) mapping

Register *VIP_CNTRL_0* = 23h; *VIP_CNTRL_1* = 50h; *VIP_CNTRL_2* = 00h.

Video port A					Video port B					Control	
Pin	YCbCr 4 : 2 : 2 (ITU656-like)				Pin	YCbCr 4 : 2 : 2 (ITU656-like)				Pin	YCbCr 4 : 2 : 2
VPA[0]	Cb[0]	Y ₀ [0]	Cr[0]	Y ₁ [0]	VPB[0]	Cb[4]	Y ₀ [4]	Cr[4]	Y ₁ [4]	HSYNC/HREF	used
VPA[1]	Cb[1]	Y ₀ [1]	Cr[1]	Y ₁ [1]	VPB[1]	Cb[5]	Y ₀ [5]	Cr[5]	Y ₁ [5]	VSYNC/VREF	used
VPA[2]	Cb[2]	Y ₀ [2]	Cr[2]	Y ₁ [2]	VPB[2]	Cb[6]	Y ₀ [6]	Cr[6]	Y ₁ [6]	DE/FREF	used
VPA[3]	Cb[3]	Y ₀ [3]	Cr[3]	Y ₁ [3]	VPB[3]	Cb[7]	Y ₀ [7]	Cr[7]	Y ₁ [7]		
VPA[4]	-	-	-	-	VPB[4]	Cb[8]	Y ₀ [8]	Cr[8]	Y ₁ [8]		
VPA[5]	-	-	-	-	VPB[5]	Cb[9]	Y ₀ [9]	Cr[9]	Y ₁ [9]		
VPA[6]	-	-	-	-	VPB[6]	Cb[10]	Y ₀ [10]	Cr[10]	Y ₁ [10]		
VPA[7]	-	-	-	-	VPB[7]	Cb[11]	Y ₀ [11]	Cr[11]	Y ₁ [11]		

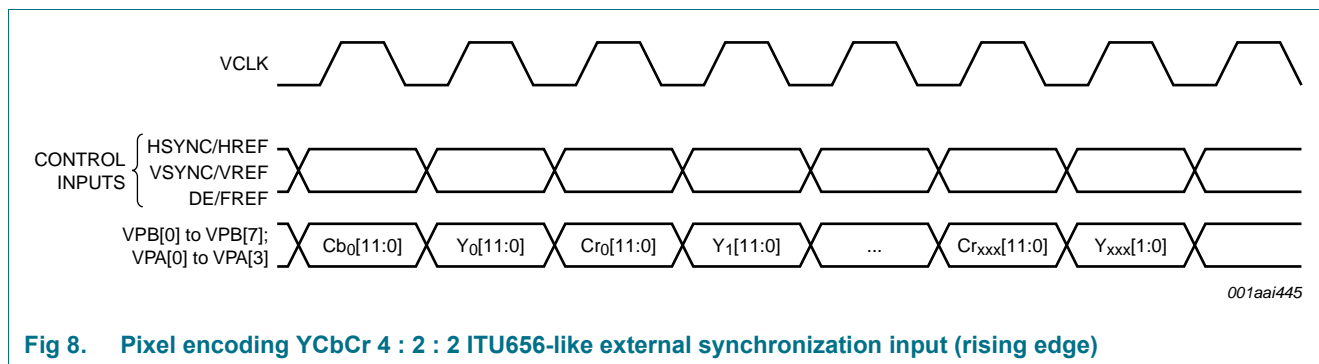


Fig 8. Pixel encoding YCbCr 4 : 2 : 2 ITU656-like external synchronization input (rising edge)

7.2.3.4 YCbCr 4 : 2 : 2 ITU656-like external synchronization (double edge)

Table 11. YCbCr 4 : 2 : 2 ITU656-like external synchronization input (double edge) mapping

Register VIP_CNTRL_0 = 23h; VIP_CNTRL_1 = 50h; VIP_CNTRL_2 = 00h.

Video port A					Video port B					Control	
Pin	YCbCr 4 : 2 : 2 (ITU656-like)				Pin	YCbCr 4 : 2 : 2 (ITU656-like)				Pin	YCbCr 4 : 2 : 2
VPA[0]	Cb[0]	Y ₀ [0]	Cr[0]	Y ₁ [0]	VPB[0]	Cb[4]	Y ₀ [4]	Cr[4]	Y ₁ [4]	HSYNC/HREF	used
VPA[1]	Cb[1]	Y ₀ [1]	Cr[1]	Y ₁ [1]	VPB[1]	Cb[5]	Y ₀ [5]	Cr[5]	Y ₁ [5]	VSYNC/VREF	used
VPA[2]	Cb[2]	Y ₀ [2]	Cr[2]	Y ₁ [2]	VPB[2]	Cb[6]	Y ₀ [6]	Cr[6]	Y ₁ [6]	DE/FREF	used
VPA[3]	Cb[3]	Y ₀ [3]	Cr[3]	Y ₁ [3]	VPB[3]	Cb[7]	Y ₀ [7]	Cr[7]	Y ₁ [7]		
VPA[4]	-	-	-	-	VPB[4]	Cb[8]	Y ₀ [8]	Cr[8]	Y ₁ [8]		
VPA[5]	-	-	-	-	VPB[5]	Cb[9]	Y ₀ [9]	Cr[9]	Y ₁ [9]		
VPA[6]	-	-	-	-	VPB[6]	Cb[10]	Y ₀ [10]	Cr[10]	Y ₁ [10]		
VPA[7]	-	-	-	-	VPB[7]	Cb[11]	Y ₀ [11]	Cr[11]	Y ₁ [11]		

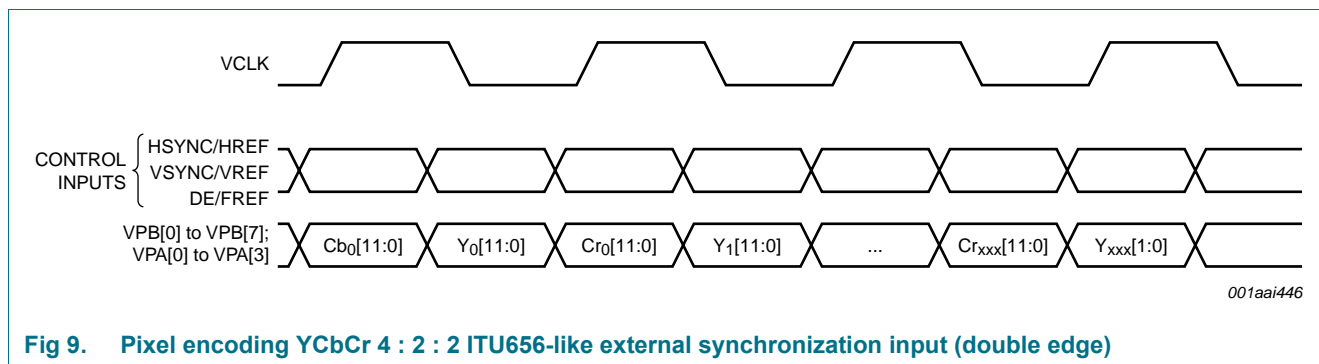


Fig 9. Pixel encoding YCbCr 4 : 2 : 2 ITU656-like external synchronization input (double edge)

7.2.3.5 YCbCr 4 : 2 : 2 ITU656-like embedded synchronization (rising edge)

Table 12. YCbCr 4 : 2 : 2 ITU656-like embedded synchronization input (rising edge) mappings

Register VIP_CNTRL_0 = 23h; VIP_CNTRL_1 = 50h; VIP_CNTRL_2 = 00h.

Video port A					Video port B					Control	
Pin	YCbCr 4 : 2 : 2 (ITU656-like)				Pin	YCbCr 4 : 2 : 2 (ITU656-like)				Pin	YCbCr 4 : 2 : 2
VPA[0]	Cb[0]	Y ₀ [0]	Cr[0]	Y ₁ [0]	VPB[0]	Cb[4]	Y ₀ [4]	Cr[4]	Y ₁ [4]	HSYNC/HREF	not used
VPA[1]	Cb[1]	Y ₀ [1]	Cr[1]	Y ₁ [1]	VPB[1]	Cb[5]	Y ₀ [5]	Cr[5]	Y ₁ [5]	VSYNC/VREF	not used
VPA[2]	Cb[2]	Y ₀ [2]	Cr[2]	Y ₁ [2]	VPB[2]	Cb[6]	Y ₀ [6]	Cr[6]	Y ₁ [6]	DE/FREF	not used
VPA[3]	Cb[3]	Y ₀ [3]	Cr[3]	Y ₁ [3]	VPB[3]	Cb[7]	Y ₀ [7]	Cr[7]	Y ₁ [7]		
VPA[4]	-	-	-	-	VPB[4]	Cb[8]	Y ₀ [8]	Cr[8]	Y ₁ [8]		
VPA[5]	-	-	-	-	VPB[5]	Cb[9]	Y ₀ [9]	Cr[9]	Y ₁ [9]		
VPA[6]	-	-	-	-	VPB[6]	Cb[10]	Y ₀ [10]	Cr[10]	Y ₁ [10]		
VPA[7]	-	-	-	-	VPB[7]	Cb[11]	Y ₀ [11]	Cr[11]	Y ₁ [11]		

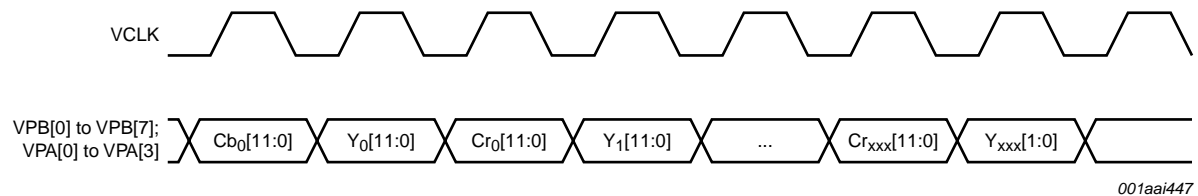


Fig 10. Pixel encoding YCbCr 4 : 2 : 2 ITU656-like embedded synchronization input (rising edge)

7.2.3.6 YCbCr 4 : 2 : 2 ITU656-like embedded synchronization (double edge)

Table 13. YCbCr 4 : 2 : 2 ITU656-like embedded synchronization input (double edge) mapping

Register *VIP_CNTRL_0* = 23h; *VIP_CNTRL_1* = 50h; *VIP_CNTRL_2* = 00h.

Video port A					Video port B					Control	
Pin	YCbCr 4 : 2 : 2 (ITU656-like)				Pin	YCbCr 4 : 2 : 2 (ITU656-like)				Pin	YCbCr 4 : 2 : 2
VPA[0]	Cb[0]	Y ₀ [0]	Cr[0]	Y ₁ [0]	VPB[0]	Cb[4]	Y ₀ [4]	Cr[4]	Y ₁ [4]	HSYNC/HREF	not used
VPA[1]	Cb[1]	Y ₀ [1]	Cr[1]	Y ₁ [1]	VPB[1]	Cb[5]	Y ₀ [5]	Cr[5]	Y ₁ [5]	VSYNC/VREF	not used
VPA[2]	Cb[2]	Y ₀ [2]	Cr[2]	Y ₁ [2]	VPB[2]	Cb[6]	Y ₀ [6]	Cr[6]	Y ₁ [6]	DE/FREF	not used
VPA[3]	Cb[3]	Y ₀ [3]	Cr[3]	Y ₁ [3]	VPB[3]	Cb[7]	Y ₀ [7]	Cr[7]	Y ₁ [7]		
VPA[4]	-	-	-	-	VPB[4]	Cb[8]	Y ₀ [8]	Cr[8]	Y ₁ [8]		
VPA[5]	-	-	-	-	VPB[5]	Cb[9]	Y ₀ [9]	Cr[9]	Y ₁ [9]		
VPA[6]	-	-	-	-	VPB[6]	Cb[10]	Y ₀ [10]	Cr[10]	Y ₁ [10]		
VPA[7]	-	-	-	-	VPB[7]	Cb[11]	Y ₀ [11]	Cr[11]	Y ₁ [11]		

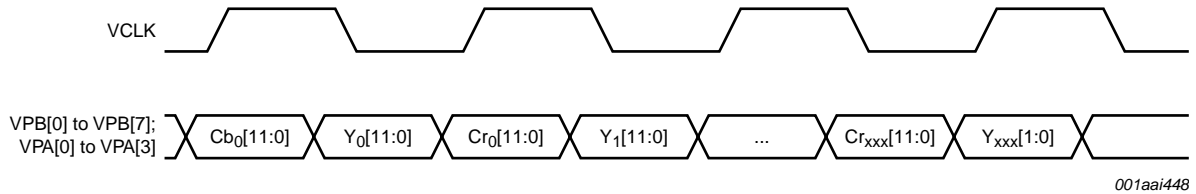


Fig 11. Pixel encoding YCbCr 4 : 2 : 2 ITU656-like embedded synchronization input (double edge)

7.2.3.7 YCbCr 4 : 2 : 2 semi-planar external synchronization (rising edge)

Table 14. YCbCr 4 : 2 : 2 semi-planar external synchronization input (rising edge) mapping

Register VIP_CNTRL_0 = 23h; VIP_CNTRL_1 = 50h; VIP_CNTRL_2 = 14h.

Video port A			Video port B			Video port C			Control	
Pin	YCbCr 4 : 2 : 2 semi-planar		Pin	YCbCr 4 : 2 : 2 semi-planar		Pin	YCbCr 4 : 2 : 2 semi-planar		Pin	YCbCr 4 : 2 : 2
VPA[0]	Y ₀ [0]	Y ₁ [0]	VPB[0]	Y ₀ [4]	Y ₁ [4]	VPC[0]	Cb[4]	Cr[4]	HSYNC/HREF	used
VPA[1]	Y ₀ [1]	Y ₁ [1]	VPB[1]	Y ₀ [5]	Y ₁ [5]	VPC[1]	Cb[5]	Cr[5]	VSYNC/VREF	used
VPA[2]	Y ₀ [2]	Y ₁ [2]	VPB[2]	Y ₀ [6]	Y ₁ [6]	VPC[2]	Cb[6]	Cr[6]	DE/FREF	used
VPA[3]	Y ₀ [3]	Y ₁ [3]	VPB[3]	Y ₀ [7]	Y ₁ [7]	VPC[3]	Cb[7]	Cr[7]		
VPA[4]	Cb[0]	Cr[0]	VPB[4]	Y ₀ [8]	Y ₁ [8]	VPC[4]	Cb[8]	Cr[8]		
VPA[5]	Cb[1]	Cr[1]	VPB[5]	Y ₀ [9]	Y ₁ [9]	VPC[5]	Cb[9]	Cr[9]		
VPA[6]	Cb[2]	Cr[2]	VPB[6]	Y ₀ [10]	Y ₁ [10]	VPC[6]	Cb[10]	Cr[10]		
VPA[7]	Cb[3]	Cr[3]	VPB[7]	Y ₀ [11]	Y ₁ [11]	VPC[7]	Cb[11]	Cr[11]		

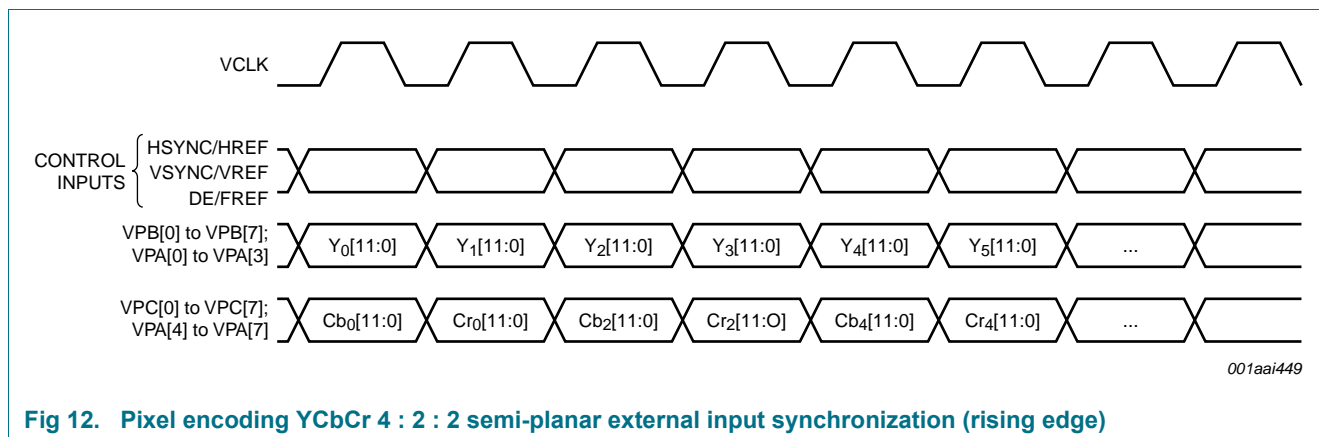


Fig 12. Pixel encoding YCbCr 4 : 2 : 2 semi-planar external input synchronization (rising edge)

7.2.3.8 YCbCr 4 : 2 : 2 semi-planar embedded synchronization (rising edge)

Table 15. YCbCr 4 : 2 : 2 semi-planar embedded synchronization input (rising edge) mapping

Register *VIP_CNTRL_0* = 23h; *VIP_CNTRL_1* = 50h; *VIP_CNTRL_2* = 14h.

Video port A			Video port B			Video port C			Control	
Pin	YCbCr 4 : 2 : 2 semi-planar		Pin	YCbCr 4 : 2 : 2 semi-planar		Pin	YCbCr 4 : 2 : 2 semi-planar		Pin	YCbCr 4 : 2 : 2
VPA[0]	Y ₀ [0]	Y ₁ [0]	VPB[0]	Y ₀ [4]	Y ₁ [4]	VPC[0]	Cb[4]	Cr[4]	HSYNC/HREF	not used
VPA[1]	Y ₀ [1]	Y ₁ [1]	VPB[1]	Y ₀ [5]	Y ₁ [5]	VPC[1]	Cb[5]	Cr[5]	VSYNC/VREF	not used
VPA[2]	Y ₀ [2]	Y ₁ [2]	VPB[2]	Y ₀ [6]	Y ₁ [6]	VPC[2]	Cb[6]	Cr[6]	DE/FREF	not used
VPA[3]	Y ₀ [3]	Y ₁ [3]	VPB[3]	Y ₀ [7]	Y ₁ [7]	VPC[3]	Cb[7]	Cr[7]		
VPA[4]	Cb[0]	Cr[0]	VPB[4]	Y ₀ [8]	Y ₁ [8]	VPC[4]	Cb[8]	Cr[8]		
VPA[5]	Cb[1]	Cr[1]	VPB[5]	Y ₀ [9]	Y ₁ [9]	VPC[5]	Cb[9]	Cr[9]		
VPA[6]	Cb[2]	Cr[2]	VPB[6]	Y ₀ [10]	Y ₁ [10]	VPC[6]	Cb[10]	Cr[10]		
VPA[7]	Cb[3]	Cr[3]	VPB[7]	Y ₀ [11]	Y ₁ [11]	VPC[7]	Cb[11]	Cr[11]		

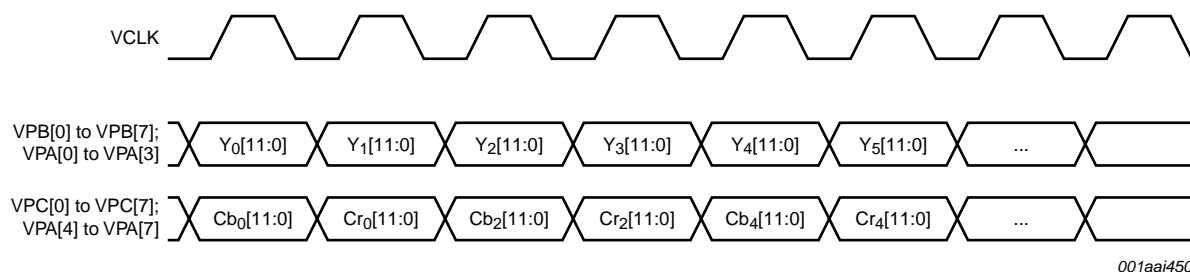


Fig 13. Pixel encoding YCbCr 4 : 2 : 2 semi-planar embedded synchronization input (rising edge)

7.2.4 Synchronization

TDA19988 can be synchronized with extraction of the sync information from embedded sync (SAV/EAV) codes inside the video stream or with external HSYNC/VSYNC inputs.

7.2.4.1 Timing extraction generator

Synchronization signals can be extracted from Start Active Video (SAV) and End Active Video (EAV) in case of embedded synchronization in the data stream.

Synchronization signals can be embedded in YCbCr 4 : 2 : 2 ITU656 (up to 1 × 12-bit) and YCbCr 4 : 2 : 2 semi-planar (up to 2 × 12-bit).

7.2.4.2 Data enable generator

TDA19988 contains a Data Enable (DE) generator; this can generate an internal DE signal for a system which does not provide one.

7.3 Input and output video format

Due to the flexible video input formatter, TDA19988 can accept a large range of input formats. This flexibility allows TDA19988 to be compatible with the maximum possible number of MPEG decoders. Moreover, these input formats may be changed in many ways (color space converter, upsampler, downsampler) before it is transmitted across the HDMI link. [Table 16](#) gives the possible inputs and outputs.

Table 16. Use of color space converter, upsampler and downsampler

Input			Output		
Color space	Format	Channels	Color space	Format	Channels
RGB	4 : 4 : 4	3 × 8-bit	RGB	4 : 4 : 4	3 × 8-bit
			YCbCr	4 : 4 : 4	3 × 8-bit
			YCbCr	4 : 2 : 2	2 × 12-bit
YCbCr	4 : 4 : 4	3 × 8-bit	RGB	4 : 4 : 4	3 × 8-bit
			YCbCr	4 : 4 : 4	3 × 8-bit
			YCbCr	4 : 2 : 2	2 × 12-bit
YCbCr	4 : 2 : 2	up to 1 × 12-bit semi-planar	RGB	4 : 4 : 4	3 × 8-bit
			YCbCr	4 : 4 : 4	3 × 8-bit
			YCbCr	4 : 2 : 2	2 × 12-bit
YCbCr	4 : 2 : 2	up to 2 × 12-bit semi-planar	RGB	4 : 4 : 4	3 × 8-bit
			YCbCr	4 : 4 : 4	3 × 8-bit
			YCbCr	4 : 2 : 2	2 × 12-bit

7.4 Upsampler

The incoming YCbCr 4 : 2 : 2 (2 × 12-bit) data stream format may be upsampled into YCbCr 4 : 4 : 4 (3 × 8-bit) data stream by repeating or linearly interpolating the chrominance pixels.

7.5 Color space converter

The color space converter is used to convert input video data from one type to another color space (e.g. RGB to YCbCr and YCbCr to RGB). This block can be bypassed and each coefficient is programmable via the I²C-bus register.

$$\begin{bmatrix} Y \\ Cr \\ Cb \end{bmatrix} = \begin{bmatrix} C_{11} & C_{12} & C_{13} \\ C_{21} & C_{22} & C_{23} \\ C_{31} & C_{32} & C_{33} \end{bmatrix} \times \left(\begin{bmatrix} Y \\ R/Cr \\ B/Cb \end{bmatrix} + \begin{bmatrix} Oin_{G/Y} \\ Oin_{R/Cr} \\ Oin_{B/Cb} \end{bmatrix} \right) + \begin{bmatrix} Oout_{Y/G} \\ Oout_{Cr/R} \\ Oout_{Cb/B} \end{bmatrix} \quad (1)$$

7.6 Gamut-related metadata

Gamut-related metadata is an enhanced colorimetry beyond the default standard with higher definition colorimetries. Profile P0 is supported, which means that only one packet per video field is sent. Color gamut boundary data are defined the standards:

- xvYCC601 (IEC 61966-2-4 – SD) (using YCbCr)
- xvYCC709 (IEC 61966-2-4 – HD) (using YCbCr)
- AdobeYCC601 (IEC 61966-2-5) (using YCbCr)
- AdobeRGB (IEC 61966-2-5) (using RGB)

Remark: Gamut-related metadata is an HDMI 1.4 feature.

7.7 Downsampler

This block works only with YCbCr input format; the filters downsample the Cb and Cr signals by a factor of 2. A delay is added on the Y channel, which corresponds to the pipeline delay of the filters, to put the Y channel in phase with the Cb-Cr channel.

7.8 Audio input format

TDA19988 is compatible with the following audio features described in the HDMI 1.4 specification:

- S/PDIF
- I²S-bus up to four channels

TDA19988 can carry audio in I²S-bus format (one stereo to two stereo channels) or in S/PDIF format through one audio pin named AP1 or AP2. S/PDIF or I²S-bus format can be selected via the I²C-bus. Only one audio format can be used at a time: either S/PDIF or I²S-bus. [Table 17](#) shows the audio port allocation and [Section 7.8.3](#) gives more details.

Table 17. Audio port configuration

Audio port	Input configuration	
	S/PDIF	I ² S-bus
AP0	-	WS (word select)
AP1	S/PDIF input	I ² S-bus channel 0
AP2	S/PDIF input	I ² S-bus channel 1
AP3	MCLK	
ACLK	-	SCK (I ² S-bus clock)

All audio ports are LV-CMOS 1.8 V compatible and LV-CMOS 3.3 V tolerant. It is possible to deactivate unused ports via I²C-bus with ENA_AP register on page 00h for both audio and clock inputs.

7.8.1 S/PDIF

In this format TDA19988 supports 2-channel uncompressed PCM data (IEC 60958) layout 0, or compressed bit stream (Dolby Digital, DTS, AC3 etc.) layout 1.

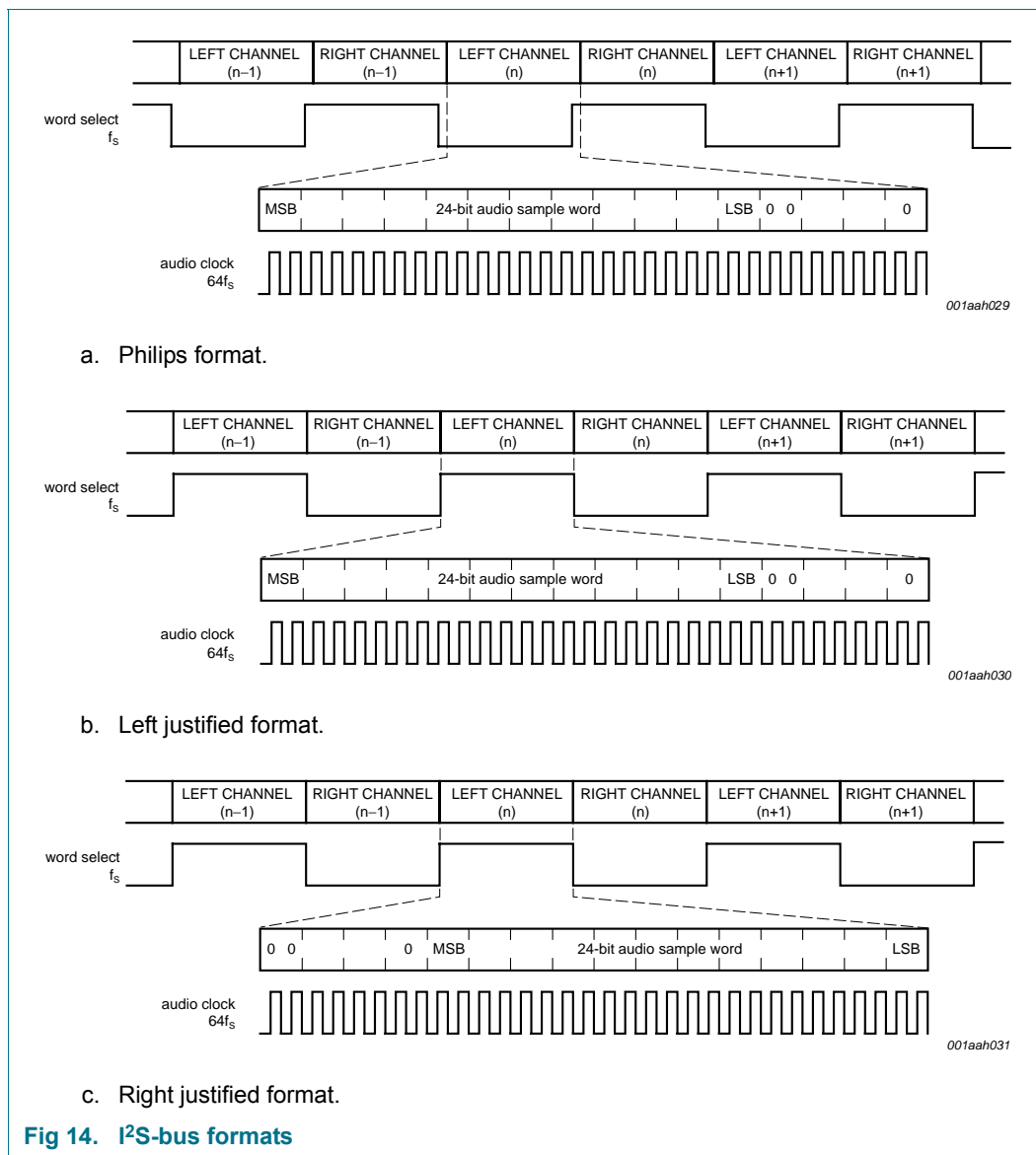
Only one S/PDIF input can be used at the same time. The selection is done by register.

TDA19988 is able to recover the original clock from the S/PDIF signal (no need of external clock). In addition, it can also use an external clock to decode the S/PDIF signal.

7.8.2 I²S-bus

There are 2 × I²S-bus stereo input, which enables 4 PCM channels to be carried. The I²S-bus input interface receives an I²S-bus signal including serial data, word select and serial clock.

Typical waveforms for the I²S-bus signals at 64f_s are given by [Figure 14](#).



The I²S-bus input interface can receive up to 24-bit wide audio samples via the serial data input with a clock frequency of at least 32 times the input sample frequency f_s .

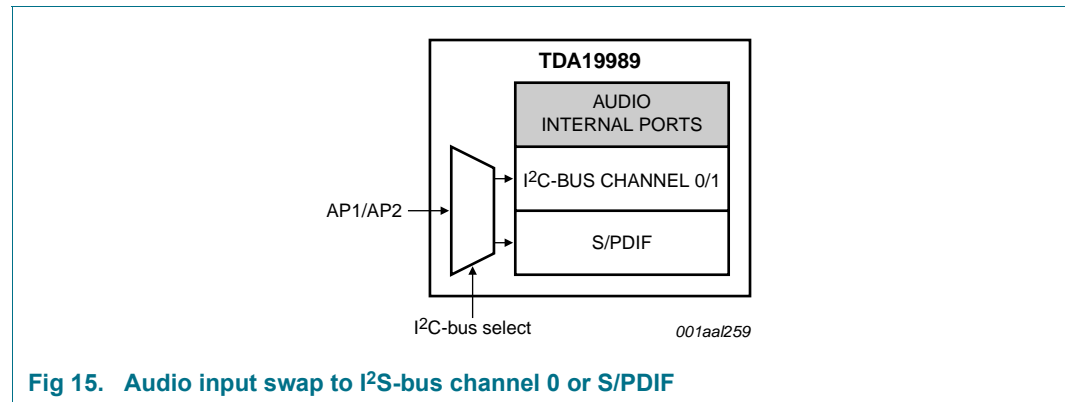
Audio samples with a precision better than 24-bit are truncated to 24-bit. If the input clock has a frequency of $32f_s$, only 16-bit audio-samples can be received. In this case, the 8 LSBs will be set to 0. If the input clock has a frequency of $64f_s$ and is left justified or Philips, the audio word is truncated to 24-bit format and other bits padded with zeros. If the input clock has a frequency of $64f_s$ and is right justified, audio sample size has to be specified via software drivers.

The serial data signal carries the serial baseband audio data, sample by sample left/right interleaved.

The word select signal indicates whether left or right channel information is transferred over the serial data line.

7.8.3 Audio port internal assignment

The aim of the internal audio input assignment is to internally map any of the incoming data from the audio port AP1 or AP2 to I²S-bus channel 0 or S/PDIF internal ports by setting the appropriate I²C-bus register.



7.9 Power management

TDA19988 HDMI and CEC cores can be independently powered down by the I²C-bus register. In Standby mode all activities are reduced by switching off all PLLs, HDMI and CEC cores and disconnecting the biasing structure of the output stage. TDA19988 has a very low power consumption, which is suitable for portable applications.

[Table 18](#) gives the typical power consumption of the device in different configurations.

Table 18. TDA19988 typical power consumption in different configurations

Typical power	Configuration	Comment
30 μ W	Standby mode: <ul style="list-style-type: none"> I²C-bus ON 	default configuration: after power-up; PLLs HDMI and CEC cores are OFF; can be switched ON via I ² C-bus register
1.5 mW	Sleep mode without CEC: <ul style="list-style-type: none"> HDMI interruption (HPD, RxSense only) 	no sink connected; CEC is OFF
1.8 mW	Sleep mode with CEC: <ul style="list-style-type: none"> HDMI interruption (HPD, RxSense only) CEC interruption 	no sink connected; CEC is ON
65 mW	Low power 1080i mode: <ul style="list-style-type: none"> Video format 1080i Video input RGB 4 : 4 : 4 No CEC 	sink connected; CEC is OFF; 30 % activity on video input ports
140 mW	Full speed mode: <ul style="list-style-type: none"> Video format 1080p 	all blocks enabled and running; 30 % activity on video input ports

7.10 Interrupt controller

Pin INT is used to alert the system microcontroller that a critical event concerning the HDMI or CEC has occurred. The software provided with the device read a status register (I²C-bus) to determine which block between HDMI and CEC has caused the interruption before processing it. Some of these interrupts are maskable. The interrupt types are described in [Table 19](#).

Table 19. Interruptions

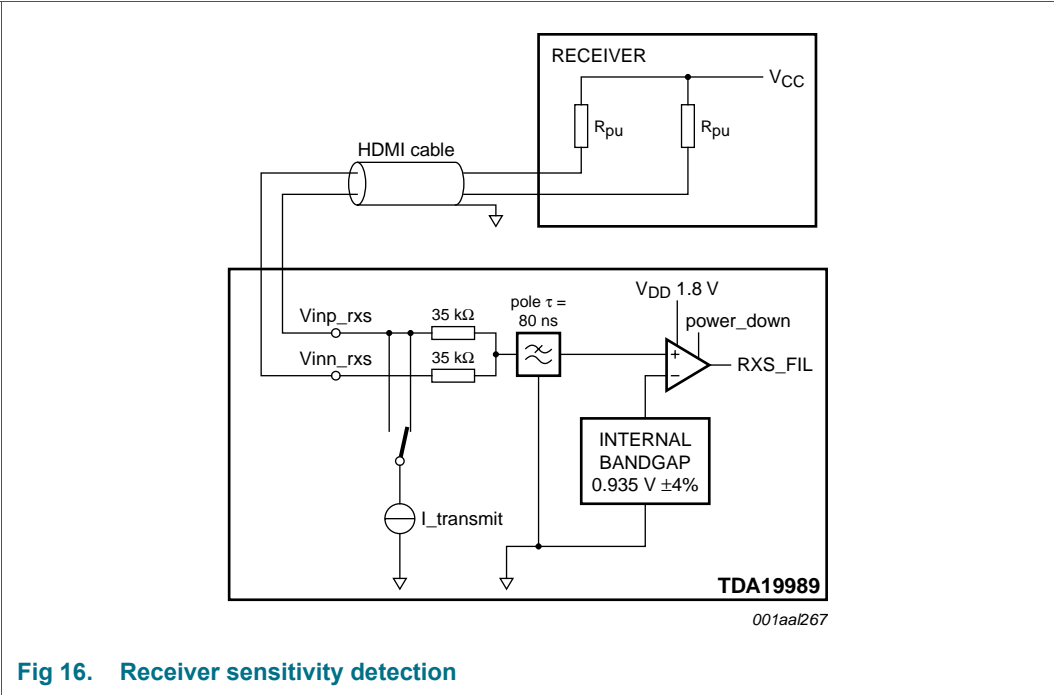
Interrupt domain	Interrupt name	Definition	Maskable feature
HDCP	r0	r0 = R'0 check done	maskable
	pj	pj = P'j check fails	
	sha-1	V = V' check success	
	bstatus	bstatus available	
	bcaps	bcaps available	
	t0	HDCP goes to initial state	
	security	HDCP encryption is off or blue screen removed	not maskable
HPD	hpd	transition on HPD input	maskable
RxSense	rx_sense	transition on RxSense	maskable
Interrupt	sw_intsoftware	test purpose (output an interrupt signal)	maskable
EDID	edid_block_rd	EDID block read finished	maskable
CEC	cec_int	CEC message received	not maskable

7.10.1 Hot plug/unplug detect

The hot plug detect (HPD) pin is 5 V input tolerant. The HPD signal, when asserted, tells the transmitter that the receiver is connected. When changing from LOW-to-HIGH, TDA19988 has to read the EDID of the receiver in order to select the video format that the receiver can handle.

7.10.2 Receiver sensitivity

TDA19988 has the capability to sense the receiver connectivity and working behavior. This feature (RxSense) detects the presence of the 50 Ω pull-up resistor R_T on the TMDS clock channel of the downstream side.



As long as the receiver is connected to the transmitter and powered-up, bit Rxs_FIL is set to logic 1.

As soon as the cable is unplugged or receiver side powered off (assuming in this case that V_{CC} is switched off), the RxSense generates an interrupt inside TDA19988, changing the value of bit Rxs_FIL to logic 0 (See [Table 20](#)). This allows the application to stop sending unnecessary video content.

This feature is very useful when the receiver recovers from an off-state and does not generate a HPD transition HIGH-to-LOW-to-HIGH. In this particular case, RxSense will generate an interrupt so that the chip restarts sending video.

Table 20. Receiver detection according to averaged terminal voltage

Average voltage (Vinp_rxs + Vinn_rxs) / 2	bit Rxs_FIL: receiver powered on	bit Rxs_FIL: receiver powered off
$V \geq 1.2\text{ V}$	1	0
$0.7\text{ V} < V < 1.2\text{ V}$	undefined	0
$V \leq 0.7\text{ V}$	0	0

Remark: According to the HDMI specification, only the HPD interrupt allows the application to read the EDID. The RxSense interrupt is not mandatory to initialize the EDID reading procedure.

7.11 HDCP processing

7.11.1 High-bandwidth digital content protection

TDA19988 contains an HDCP function, which encrypts the transmitted stream content (both video and audio). This function can be enabled and disabled via the I²C-bus.

The keys are stored internally in OTP non-volatile memory for maximum security.

7.11.1.1 Repeater function

TDA19988 can be used in a repeater device according to the *HDCP specification, Rev 1.3*. TDA19988 is able to store the KSV list of a maximum of 127 devices in a register memory.

7.11.1.2 SHA-1

To deal with repeater, a SHA-1 calculation is performed by the transmitter and by the downstream repeater. For security purposes and in order to relieve the microcontroller, the SHA-1 has been implemented within TDA19988.

This calculation is worked out after the transmitter has loaded the KSV list (see *HDCP specification, Rev 1.3*). If SHA-1 calculated by transmitter equals the SHA-1 calculated by repeater, then an interrupt is sent.

7.12 CEC

TDA19988 with its embedded CEC block provides a complete solution to enable Consumer Electronic Control (CEC) in product (DSC, DVC, PMP, UM PC). This eliminates the need of any additional device to handle this feature thus improving BOM (Bill Of Materials). CEC capability allows AV products (CEC enable) to communicate together over the home appliance network which could be controlled using only one remote control.

The CEC block manages low level transactions (compliant to CEC timing specification) over the one bidirectional line. It translates CEC protocol in I²C-bus for the host processor and vice versa. It manages CEC message reception and transmission compliant to CEC protocol and provides the message to the system microcontroller (host processor).

For power consumption optimization purpose CEC could be enable or disable through I²C-bus register. The following sections describe CEC:

- Features
- Clocking scheme

7.12.1 Features

- Receive and transmit CEC messages to host processor
- Supports multiple CEC logical addresses
- Supports CEC messages up to 16 bytes long
- Programmable retry count
- Comprehensive arbitration and collision handling

7.12.2 Clock

CEC clock must be running in Sleep mode (with CEC) to wake up TDA19988 using CEC specific message as described in “*HDMI specification 1.4*”.

CEC module can be clocked using:

- External clock:
 - 12 MHz crystal $\pm 1\%$.
- Internal clock:
 - FRO (Free Running Oscillator). FRO frequency varies and in the range from 12.64 MHz to 12.9 MHz. See [Figure 17](#).

CEC operates normally (i.e. matches the timing requested CEC specification) if and only if its clock frequency is set to 12 MHz.

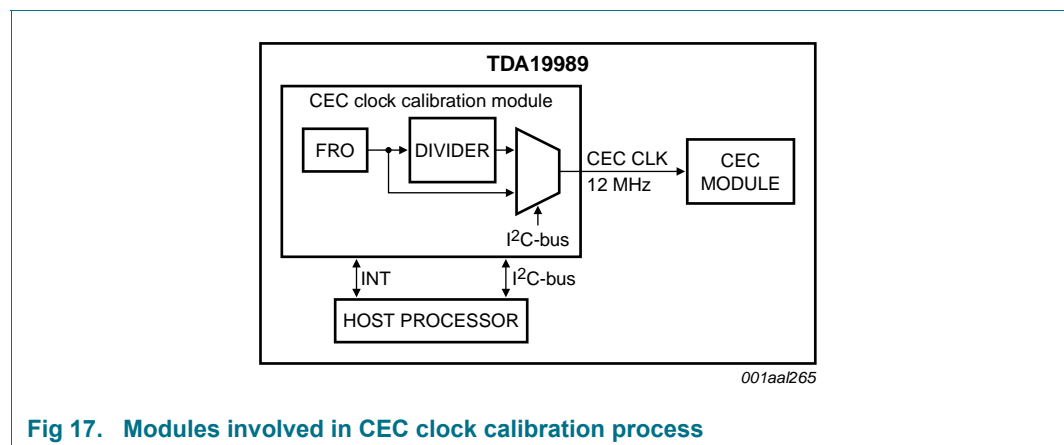


Fig 17. Modules involved in CEC clock calibration process

Calibration procedure is completely handled by the software delivered together with the device, it has the following steps:

- Host processor set TDA19988 in calibration mode
- Host processor generates a negative pulse of 10 ms $\pm 1\%$ on INT pin
- Host processor deselects the calibration mode when it is completed, the chip is ready to operate

CEC clock calibration must be performed at each power-up and each time TDA19988 moves from Standby or Sleep (without CEC) state to normal operating mode.

Non successful calibration will lead to CEC signal not matching timings specification; as a consequence, CEC will not be functional.

7.12.3 CEC interrupt

Pin INT is used by TDA19988 to warn the host processor that HDMI or CEC events (CEC message is available to read) have occurred.

Software interrupt status register reads determine which block between HDMI or CEC has raised the interruption before processing it.

7.12.4 Power-On Reset (POR)

After power-up, TDA19988 is activated by internal reset from POR module. This is used to set TDA19988 to a known state.

7.12.5 Repeater function

TDA19988 can be used in a repeater device according to HDMI 1.4.

7.13 HDMI core

7.13.1 Output TMDS buffers

7.13.1.1 Digitally controlled signal amplitude

The TMDS signal output peak-to-peak voltage (Vswing) is programmable by the software using I²C-bus register vswing_ctrl[3:0]. Vswing varies from 370 mV to 640 mV with $\pm 5\%$ accuracy in 18 mV steps according to the following formula:

$$V_{\text{swing}} = 370 \text{ mV} + 18 \text{ mV} \times \text{vswing_ctrl}[3:0]$$

An external resistor ($10 \text{ k}\Omega \pm 1\%$) must be connected between pin EXT_SWING and analog ground.

7.13.2 Pixel repetition

To transmit video formats with pixel rates below 25 megasamples per second or to increase the number of audio sample packets in each frame, TDA19988 uses pixel repetition to increase the transmitted pixel clock (see [Table 21](#)).

Table 21. Pixel repetition

PR[3]	PR[2]	PR[1]	PR[0]	Pixel repetition factor
0	0	0	0	no repetition: pixel sent once
0	0	0	1	2 times: pixel repeated once
0	0	1	0	3 times
0	0	1	1	4 times
0	1	0	0	5 times
0	1	0	1	6 times
0	1	1	0	7 times
0	1	1	1	8 times
1	0	0	0	9 times
1	0	0	1	10 times
others				reserved

7.13.3 DDC-bus channel

The DDC-bus pins DSDA and DSCL are 5 V tolerant and can work at standard mode (100 kHz). The DDC-bus is used as a master interface when reading the EDID.

When the device is power-off, DSDA and DSCL ports:

- become in high-impedance
- can withstand 5 V from the sink

7.14 E-EDID

7.14.1 E-EDID reading

As a master interface for the EDID process, the DDC-bus is compliant with the I²C-bus specification and has the possibility of repeat/start condition to enable quick access to the EDID content, as well as the possibility of reading a large EDID (with the use of segment pointer).

TDA19988 has a whole I²C-bus (page 09h) dedicated to the EDID where one block (128 bytes) can be stored. The block can be read by the system microcontroller to determine the supported video and audio format of the downstream site.

Remark: When the block is read by TDA19988, it generates an interrupt to warn the main processor that the chip is ready to transmit the content. Once the content is read out by the main processor, it can allow other blocks to be read if required.

7.14.2 HDMI and DVI receiver discrimination

This information is located in the E-EDID receiver part, in the 'vendor-specific data block' within the first CEA EDID timing extension.

If the 24-bit IEEE Registration Identifier contains the value 00 0C03h, then the receiver will support HDMI, otherwise the device will be treated as a DVI device.

However, even though TDA19988 have directly access to that information, it is the task of the host processor to ask to switch from DVI to HDMI mode.

8. I²C-bus interface and register definitions

8.1 I²C-bus protocol

The I²C-bus pins CSDA and CSCL are 1.8 V and 3.3 V tolerant. Both Fast mode (400 kHz) and Standard mode (100 kHz) are supported.

The registers of TDA19988 can be accessed via the I²C-bus. All registers are R/W except for those which are confidential.

HDMI and CEC cores I²C-bus addresses are given in [Table 22](#) and [Table 23](#).

Table 22. HDMI core I²C-bus address

HDMI core address							
A6	A5	A4	A3	A2	A1	A0	R/W
1	1	1	0	0	0	0	0/1

Table 23. CEC core I²C-bus address

CEC core address							
A6	A5	A4	A3	A2	A1	A0	R/W
0	1	1	0	1	0	0	0/1

For read access, the master writes the address of TDA19988 HDMI or CEC core, and the subaddress to access the specific register and then the data.

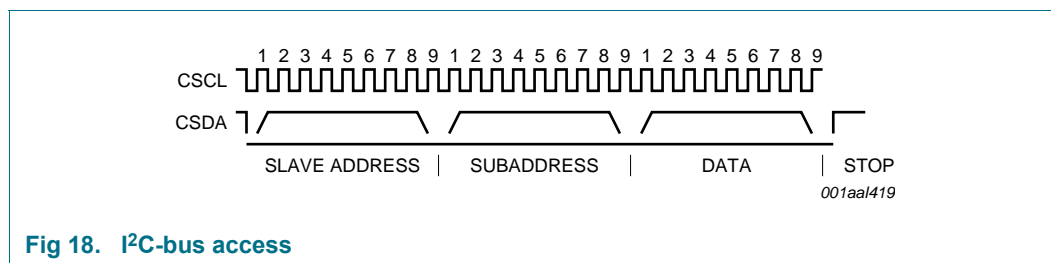


Fig 18. I²C-bus access

8.2 Memory page management

The I²C-bus memory is split into several pages for HDMI core only, and the selection between pages is made with common register CURPAGE_ADR. It is only necessary to write in this register once to change the current page. So multiple read or write operations in the same page need a write register CURPAGE_ADR once at the beginning.

The following memory pages are available for TDA19988:

- Page 00h: general control
- Page 02h: PLL settings
- Page 09h: EDID control page
- Page 10h: information frames and packets
- Page 11h: audio settings and content info packets
- Page 12h: HDCP and OTP
- Page 13h: gamut-related metadata packets

The CEC core does not need memory page mechanism due to its reduced number of registers.

8.3 ID version

The ID version readable via I²C-bus is defined by the concatenation of VERSION_MSB and VERSION registers. The ID version value is 212h.

8.4 Clock stretching

Clock stretching pauses a transaction by holding the CSCL line LOW. The transaction cannot continue until the line is released HIGH again.

For example: on the byte level, a device may be able to receive bytes of data at a fast rate, but needs more time to store a received byte or prepare another byte to be transmitted. Slaves can then hold the CSCL line LOW after reception and acknowledgment of a byte to force the master into a wait state until the slave is ready for the next byte transfer; see [Table 32](#).

Clock stretching must be supported by I²C-bus master especially when CEC feature of TDA19988 is used. If CEC feature of TDA19988 is not used, I²C-bus master does not need to support clock stretching.

9. Input format

In [Table 24](#) the port VPA has been mapped to C_b (YCbCr space)/B (RGB space), VPB has been mapped to Y (YCbCr space)/G (RGB space) and VPC has been mapped to Cr (YCbCr space)/R (RGB space).

Table 24. Input format

L: recommend tied to LOW voltage, e.g. ground

Input pins	Signal	RGB	YCbCr						
		4 : 4 : 4	4 : 4 : 4	4 : 2 : 2 (semi-planar)		4 : 2 : 2 (ITU 656-like)			
Video port A									
VPA[0]	Cb[0]/B[0]	B[0]	Cb[0]	Y ₀ [0]	Y ₁ [0]	Cb[0]	Y ₀ [0]	Cr[0]	Y ₁ [0]
VPA[1]	Cb[1]/B[1]	B[1]	Cb[1]	Y ₀ [1]	Y ₁ [1]	Cb[1]	Y ₀ [1]	Cr[1]	Y ₁ [1]
VPA[2]	Cb[2]/B[2]	B[2]	Cb[2]	Y ₀ [2]	Y ₁ [2]	Cb[2]	Y ₀ [2]	Cr[2]	Y ₁ [2]
VPA[3]	Cb[3]/B[3]	B[3]	Cb[3]	Y ₀ [3]	Y ₁ [3]	Cb[3]	Y ₀ [3]	Cr[3]	Y ₁ [3]
VPA[4]	Cb[4]/B[4]	B[4]	Cb[4]	Cb[0]	Cr[0]	L	L	L	L
VPA[5]	Cb[5]/B[5]	B[5]	Cb[5]	Cb[1]	Cr[1]	L	L	L	L
VPA[6]	Cb[6]/B[6]	B[6]	Cb[6]	Cb[2]	Cr[2]	L	L	L	L
VPA[7]	Cb[7]/B[7]	B[7]	Cb[7]	Cb[3]	Cr[3]	L	L	L	L
Video port B									
VPB[0]	Y[0]/G[0]	G[0]	Y[0]	Y ₀ [4]	Y ₁ [4]	Cb[4]	Y ₀ [4]	Cr[4]	Y ₁ [4]
VPB[1]	Y[1]/G[1]	G[1]	Y[1]	Y ₀ [5]	Y ₁ [5]	Cb[5]	Y ₀ [5]	Cr[5]	Y ₁ [5]
VPB[2]	Y[2]/G[2]	G[2]	Y[2]	Y ₀ [6]	Y ₁ [6]	Cb[6]	Y ₀ [6]	Cr[6]	Y ₁ [6]
VPB[3]	Y[3]/G[3]	G[3]	Y[3]	Y ₀ [7]	Y ₁ [7]	Cb[7]	Y ₀ [7]	Cr[7]	Y ₁ [7]
VPB[4]	Y[4]/G[4]	G[4]	Y[4]	Y ₀ [8]	Y ₁ [8]	Cb[8]	Y ₀ [8]	Cr[8]	Y ₁ [8]
VPB[5]	Y[5]/G[5]	G[5]	Y[5]	Y ₀ [9]	Y ₁ [9]	Cb[9]	Y ₀ [9]	Cr[9]	Y ₁ [9]

Table 24. Input format ...continued

L: recommend tied to LOW voltage, e.g. ground

Input pins	Signal	RGB	YCbCr						
		4 : 4 : 4	4 : 4 : 4	4 : 2 : 2 (semi-planar)		4 : 2 : 2 (ITU 656-like)			
VPB[6]	Y[6]/G[6]	G[6]	Y[6]	Y ₀ [10]	Y ₁ [10]	Cb[10]	Y ₀ [10]	Cr[10]	Y ₁ [10]
VPB[7]	Y[7]/G[7]	G[7]	Y[7]	Y ₀ [11]	Y ₁ [11]	Cb[11]	Y ₀ [11]	Cr[11]	Y ₁ [11]
Video port C									
VPC[0]	Cr[0]/R[0]	R[0]	Cr[0]	Cb[4]	Cr[4]	L	L	L	L
VPC[1]	Cr[1]/R[1]	R[1]	Cr[1]	Cb[5]	Cr[5]	L	L	L	L
VPC[2]	Cr[2]/R[2]	R[2]	Cr[2]	Cb[6]	Cr[6]	L	L	L	L
VPC[3]	Cr[3]/R[3]	R[3]	Cr[3]	Cb[7]	Cr[7]	L	L	L	L
VPC[4]	Cr[4]/R[4]	R[4]	Cr[4]	Cb[8]	Cr[8]	L	L	L	L
VPC[5]	Cr[5]/R[5]	R[5]	Cr[5]	Cb[9]	Cr[9]	L	L	L	L
VPC[6]	Cr[6]/R[6]	R[6]	Cr[6]	Cb[10]	Cr[10]	L	L	L	L
VPC[7]	Cr[7]/R[7]	R[7]	Cr[7]	Cb[11]	Cr[11]	L	L	L	L

9.1 Timing parameters for video supported

TDA19988 supports all EIA/CEA-861B standards and ATSC video input formats.

Table 25. Timing parameters for EIA/CEA-861B

EIA/CEA-861b Video code	Format	V frequency (Hz)	H total	V total	H frequency (kHz)	Pixel frequency (MHz)	Pixel repetition
59.94 Hz systems							
1 (VGA)	640 × 480p	59.9401	800	525	31.469	25.175	1
2, 3	720 × 480p	59.9401	858	525	31.469	27.000	1
4	1280 × 720p	59.9401	1650	750	44.955	74.175	1
5	1920 × 1080i	59.9401	2200	1125	33.716	74.175	1
6, 7 (NTSC)	1440 × 480i	59.9401	1716	525	15.734	27.000	2
16	1920 × 1080p	60.000	2200	1125	67.432	148.350	1
60 Hz systems							
1 (VGA)	640 × 480p	60.000	800	525	31.500	25.200	1
2, 3	720 × 480p	60.000	858	525	31.500	27.027	1
4	1280 × 720p	60.000	1650	750	45.000	74.250	1
5	1920 × 1080i	60.000	2200	1125	33.750	74.250	1
6, 7 (NTSC)	1440 × 480i	60.000	1716	525	15.750	27.027	2
16	1920 × 1080p	60.000	2200	1125	67.500	148.50	1
50 Hz systems							
17, 18	720 × 576p	50.000	864	625	31.250	27.000	1
19	1280 × 720p	50.000	1980	750	37.500	74.250	1
20	1920 × 1080i	50.000	2640	1125	28.125	74.250	1
21, 22 (PAL)	1440 × 576i	50.000	1728	625	15.625	27.000	2
23, 24	1440 × 288p	50.000	1728	312	15.625	27.000	2
23, 24	1440 × 288p	50.000	1728	313	15.625	27.000	2

Table 25. Timing parameters for EIA/CEA-861B ...continued

EIA/CEA-861b Video code	Format	V frequency (Hz)	H total	V total	H frequency (kHz)	Pixel frequency (MHz)	Pixel repetition
23, 24	1440 × 288p	50.000	1728	314	15.625	27.000	2
31	1920 × 1080p	50.000	2640	1125	56.250	148.50	1
Various systems							
32	1920 × 1080p	23.976	2750	1125	26.973	74.175824	1
32	1920 × 1080p	24	2750	1125	27	74.25	1
33	1920 × 1080p	25	2640	1125	28.125	74.25	1
34	1920 × 1080p	29.97	2200	1125	33.716	74.175824	1
34	1920 × 1080p	30	2200	1125	33.75	74.25	1

9.2 Timing parameters for PC standards supported

TDA19988 can support all major PC Standards up to 150 MHz.

Table 26. Timing parameters for PC standards below 150 MHz

Standard	Format	V frequency (Hz)	H total	V total	H frequency (kHz)	Pixel frequency (MHz)	Pixel repetition
0.31M3 VGA	640 × 480p	59.940	800	525	31.469	25.175	-
	640 × 480p	72.809	832	520	37.861	31.500	-
	640 × 480p	75.000	840	500	37.500	31.500	-
	640 × 480p	85.008	832	509	43.269	36.000	-
0.48M3 SVGA	800 × 600p	60.317	1056	628	37.879	40.000	-
	800 × 600p	72.188	1040	666	48.077	50.000	-
	800 × 600p	75.000	1056	625	46.875	49.500	-
	800 × 600p	85.061	1048	631	53.674	56.250	-
0.79M3 XGA	1024 × 768p	60.004	1344	806	48.363	65.000	-
	1024 × 768p	70.069	1328	806	56.476	75.000	-
	1024 × 768p	75.029	1312	800	60.023	78.750	-
1.31M4 SXGA	1280 × 1024p	60.020	1688	1066	63.981	108.000	-
VDMTREV	1600 × 1200p	60.000	2160	1250	75.000	162.000	-

For other PC video formats in the range from VGA to 1600 × 1200 at 60 Hz implementation can be considered on request.

9.3 Primary 3D video formats

Table 27. 3D video formats timing supported

Resolution	3D transmission type
1280 × 720p at 59.94 Hz and 60 Hz	(Frame Packing, Side-by-Side (Half)), Top-and-Bottom
1280 × 720p at 50 Hz	(Frame Packing, Side-by-Side (Half)), Top-and-Bottom
1280 × 720p at 23.98 Hz and 24 Hz	Frame Packing
1280 × 720p at 29.97 Hz and 30 Hz	Frame Packing
1920 × 1080i at 59.94 Hz and 60 Hz	Side-by-Side (Half)

Table 27. 3D video formats timing supported ...continued

Resolution	3D transmission type
1920 × 1080i at 50 Hz	Side-by-Side (Half)
1920 × 1080p at 23.98 Hz and 24 Hz	Side-by-Side (Half), Top-and-Bottom
1920 × 1080p at 29.97 Hz and 30 Hz	Top-and-Bottom
1920 × 1080p at 59.94 Hz and 60 Hz	Top-and-Bottom
1920 × 1080p at 50 Hz	Top-and-Bottom

10. Limiting values

Table 28. Limiting values

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

Symbol	Parameter	Conditions	Min	Max	Unit
V _{DDA(TMDS)(1V8)}	TMDS analog supply voltage (1.8 V)		-0.5	+2.5	V
V _{DDA(PLL)(1V8)}	PLL analog supply voltage (1.8 V)		-0.5	+2.5	V
V _{DDA(1V8)}	analog supply voltage (1.8 V)		-0.5	+2.5	V
V _{DD(I/O)(1V8)}	I/O digital supply voltage (1.8V)		-0.5	+2.5	V
V _{DDDC}	core digital supply voltage		-0.5	+2.5	V
ΔV _{DD}	supply voltage difference		-2	+2	V
V _{ESD}	electrostatic discharge voltage	EIA/JESD22-A114 (HBM)	[1] -2500	+2500	V
		EIA/JESD22-C101-C (FCDM)	[2] 1000	-	V

[1] On TMDS outputs.

[2] It withstands class III of JEDEC classification.

11. Thermal characteristics

Table 29. Thermal characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
R _{th(j-a)}	thermal resistance from junction to ambient	in free air; JEDEC 4L board	-	56.9	-	K/W
R _{th(j-c)}	thermal resistance from junction to case		-	15.1	-	K/W
T _{stg}	storage temperature		-	-	+150	°C
T _{amb}	ambient temperature		-20	-	+85	°C
T _j	junction temperature		-	-	+125	°C

12. Static characteristics

Table 30. Supplies

T_{amb} = -20 °C to +85 °C; without HDCP; unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V _{DDDC}	core digital supply voltage	[1]	1.7	1.8	1.9	V
V _{DDA(TMDS)(1V8)}	TMDS analog supply voltage (1.8 V)		1.7	1.8	1.9	V
V _{DDA(PLL)(1V8)}	PLL analog supply voltage (1.8 V)		1.7	1.8	1.9	V
V _{DDA(1V8)}	analog supply voltage (1.8 V)		1.7	1.8	1.9	V
V _{DD(I/O)(1V8)}	I/O digital supply voltage (1.8V)		1.7	1.8	1.9	V

Table 30. Supplies ...continued $T_{amb} = -20\text{ }^{\circ}\text{C}$ to $+85\text{ }^{\circ}\text{C}$; without HDCP; unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$I_{DDA(sum)(1V8)}$	sum analog supply current (1.8 V)	$I_{DDA(sum)(1V8)} = I_{DDA(TMDS)(1V8)} + I_{DDA(1V8)}$	[2] <tbid>	<tbid>	<tbid>	mA
$I_{DDA(PLL)(1V8)}$	PLL analog supply current (1.8 V)		[2] <tbid>	<tbid>	<tbid>	mA
$I_{DDD(IO)(1V8)}$	input/output digital supply current (1.8 V)		[2] <tbid>	<tbid>	<tbid>	μA
$I_{DDDC(1V8)}$	core digital supply current (1.8 V)		[2] <tbid>	<tbid>	<tbid>	mA
			[3] <tbid>	<tbid>	<tbid>	mA
P_{cons}	power consumption		[2] -	145	230	mW
			[3] -	55	70	mW
		Sleep mode with CEC	-	1.8	4.5	mW
		Sleep mode without CEC	-	1.5	4	mW
		Standby mode	-	30	50	μW
P_{tot}	total power dissipation		[4] -	252	300	mW
			[5] -	202	260	mW

[1] see Table 7.

[2] Input format: 1080p, any color space; output format: 1080p any color space: 30 % activity on video input ports.

[3] Input format: 1080i YCbCr 4 : 2 : 2; output format: YCbCr 4 : 2 : 2; CEC feature disable: 30 % activity on video input ports.

[4] Same as Table note [2] with TMDS output current added.

[5] Same as Table note [3] with TMDS output current added.

Table 31. Digital inputs and outputs $T_{amb} = -20\text{ }^{\circ}\text{C}$ to $+85\text{ }^{\circ}\text{C}$; unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Not 5 V tolerant CMOS 1.8 V and CMOS 3.3 V tolerant digital input pins HSYNC, VSYNC, APn, ACLK, VPA[n], VPB[n], VPC[n], VCLK, DE						
V_{IL}	LOW-level input voltage	-	0	-	0.75	V
V_{IH}	HIGH-level input voltage	-	1.4	-	-	V
I_{IL}	LOW-level input current		-2	-	+2	μA
I_{IH}	HIGH-level input current		-2	-	+2	μA
C_i	input capacitance		-	4.5	-	pF
5 V tolerant input pin HPD						
V_{IL}	LOW-level input voltage	-	0	-	0.8	V
V_{IH}	HIGH-level input voltage	-	2	-	-	V
C_i	input capacitance		-	4.5	-	pF
CMOS 1.8 V and CMOS 3.3 V tolerant digital input/output pin INT						
V_{IL}	LOW-level input voltage	-	0	-	0.85	V
V_{IH}	HIGH-level input voltage	-	1.4	-	-	V
V_{OL}	LOW-level output voltage	$C_L = 10\text{ pF}$; $I_{OL} = 2\text{ mA}$	0	-	0.4	V
5 V tolerant master bus: DDC-bus pins DSDA, DSCL[1]						
V_{OL}	LOW-level output voltage		0	-	0.4	V
V_{IL}	LOW-level input voltage		0	-	0.6	V

Table 31. Digital inputs and outputs ...continued $T_{amb} = -20\text{ }^{\circ}\text{C}$ to $+85\text{ }^{\circ}\text{C}$; unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{IH}	HIGH-level input voltage		1.4	-	5.5	V
1.8 V to 3.3 V tolerant slave bus: I²C-bus input/output pins CSCL, CSDA^[1]						
V_{OL}	LOW-level output voltage		0	-	0.4	V
V_{IL}	LOW-level input voltage		0	-	0.6	V
V_{IH}	HIGH-level input voltage		1.4	-	5.5	V
CEC input/output^[2] pin						
V_{OL}	LOW-level output voltage		0	-	0.4	V
V_{OH}	HIGH-level output voltage		2.5	-	3.6	V
V_{IL}	LOW-level input voltage		0	-	0.60	V
V_{IH}	HIGH-level input voltage		2.5	-	3.6	V
$V_{hys(i)}$	input hysteresis voltage	^[2]	-	0.27	-	V
TMDS output pins: TX0-, TX0+, TX1-, TX1+, TX2-, TX2+, TXC- and TXC+						
$V_{O(dif)}$	differential output voltage	$R_{EXT_SWING} = 10\text{ k}\Omega \pm 1\%$	400	505	600	mV

[1] See [Section 7.1](#) and refer to the *I²C-bus specification version 2.1* (document order number 9398 393 40011).

[2] For information, input hysteresis is normally supplied by the microprocessor input circuit: in this circumstance, external hysteresis circuitry is not needed.

13. Dynamic characteristics

Table 32. Timing characteristics $T_{amb} = -20\text{ }^{\circ}\text{C}$ to $+85\text{ }^{\circ}\text{C}$; unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Clock input: pin VCLK						
$f_{clk(max)}$	maximum clock frequency	-	-	-	148.5	MHz
$t_{su(D)}$	data input set-up time	see Figure 19 and 20	1.6	-	-	ns
$t_{h(D)}$	data input hold time	see Figure 19 and 20	1.2	-	-	ns
δ_{clk}	clock duty cycle	^[1]	30	50	70	%
f_{clk}	clock frequency	CEC	-	12	-	MHz
DDC-bus: pins DSDA, DSCL (5 V tolerant) master bus^[2]						
f_{SCL}	SCL frequency	Standard mode	-	-	100	kHz
C_i	capacitance for each I/O pin		-	7	-	pF
I²C-bus: pins CSCL, CSDA (5 V tolerant) slave bus^[2]						
f_{SCL}	SCL frequency	Standard mode	-	-	100	kHz
		Fast mode	-	-	400	kHz
$t_{stretch}$	stretch time	CEC	-	80	-	μs
CEC input/output^[3]						
t_r	rise time	10 % to 90 %	-	-	50	μs
t_f	fall time	10 % to 90 %	-	-	2	μs

TMDS output pins: TXC- and TXC+

Table 32. Timing characteristics ...continued
T_{amb} = -20 °C to +85 °C; unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f _{clk(max)}	maximum clock frequency	on the TMDS link	-	-	148.5	MHz
TMDS output pins: TX0-, TX0+, TX1-, TX1+, TX2- and TX2+						
f _{clk(max)}	maximum clock frequency		-	-	1.485	GHz

- [1] $\delta_{clk} = t_{clk(H)} / (t_{clk(H)} + t_{clk(L)})$.
- [2] See [Section 7.1](#) and refer to the *I²C-bus specification version 2.1* (document order number 9398 393 40011).
- [3] For details about CEC electrical specification, see *HDMI 1.4 specification*.

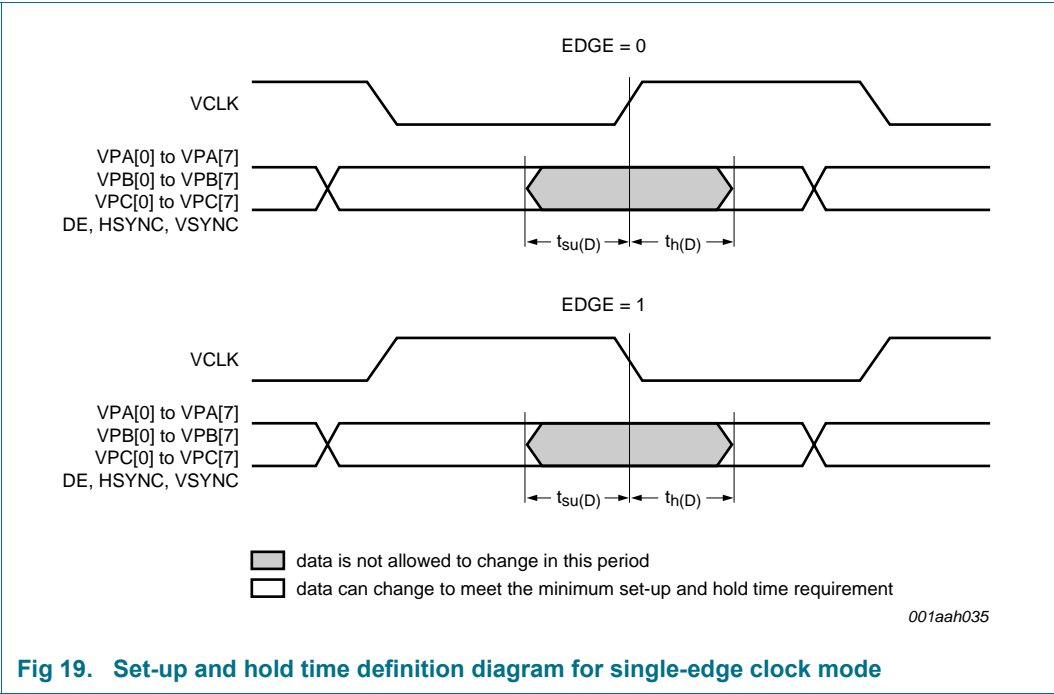


Fig 19. Set-up and hold time definition diagram for single-edge clock mode

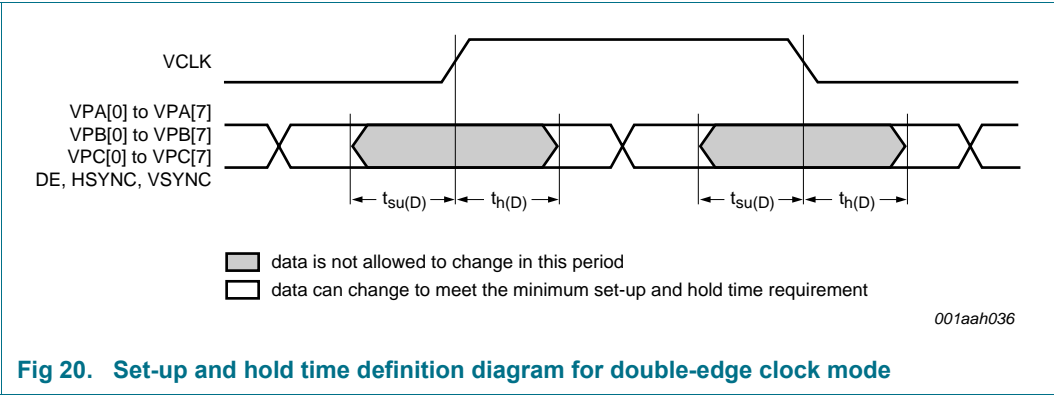


Fig 20. Set-up and hold time definition diagram for double-edge clock mode

14. Application information

14.1 Transmitter connection with external world

[Figure 21](#) and [Figure 22](#) refer to a simple receiver application. However, TDA19988 can be part of a repeater application as described in “*HDMI specification 1.4*”.

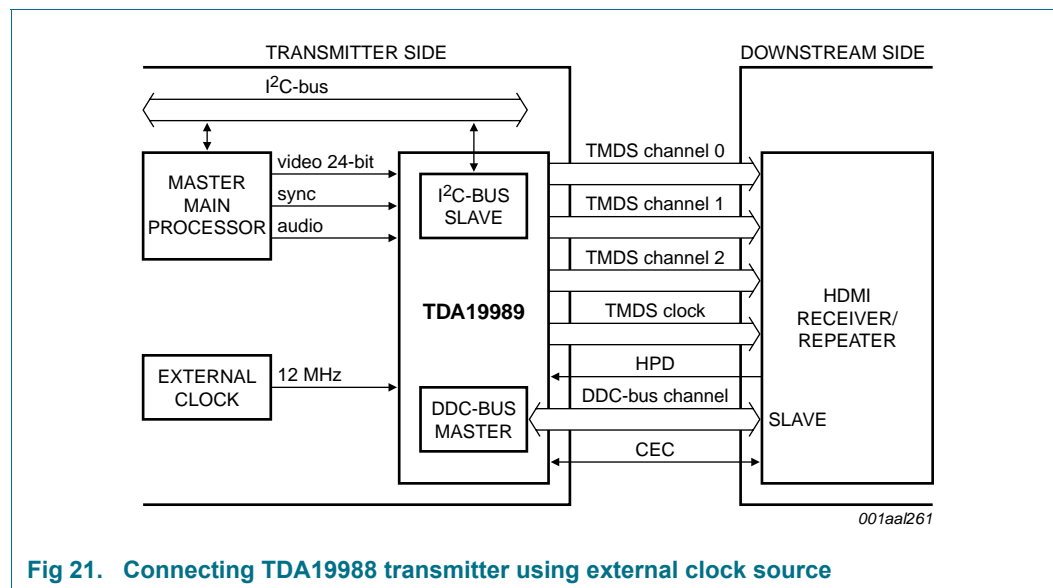


Fig 21. Connecting TDA19988 transmitter using external clock source

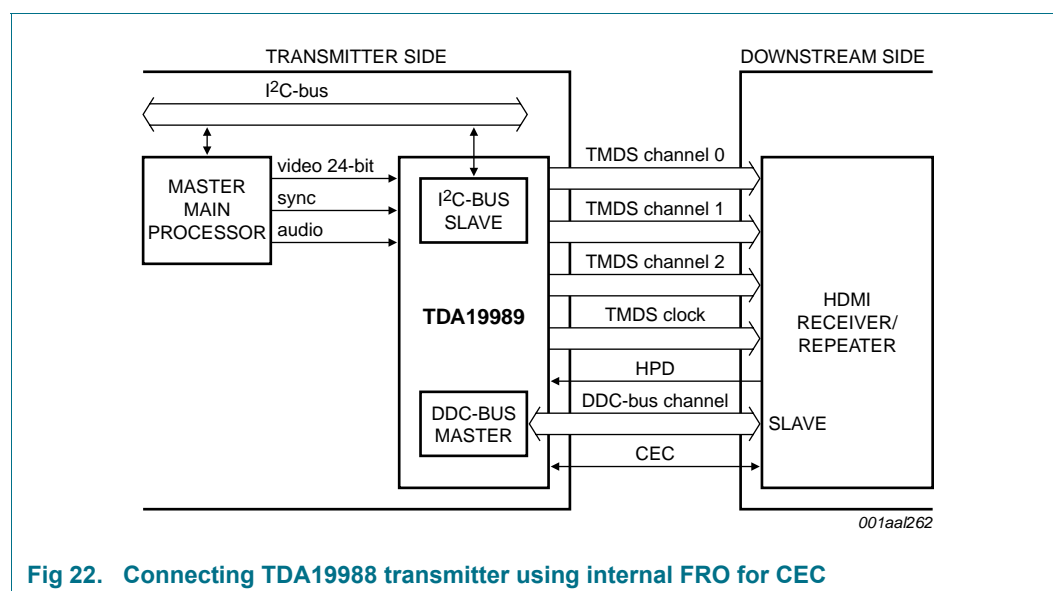


Fig 22. Connecting TDA19988 transmitter using internal FRO for CEC

15. Package outline

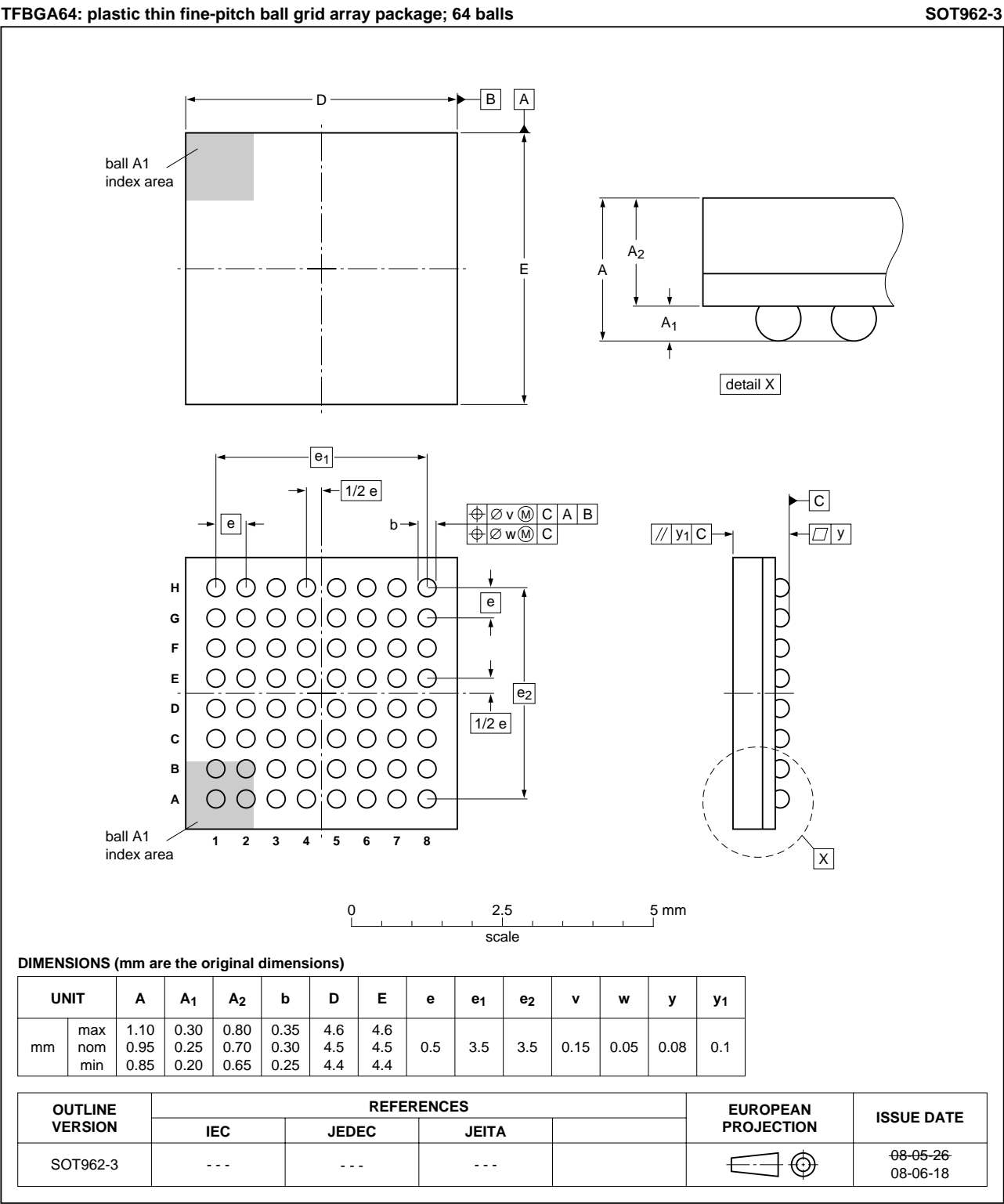


Fig 23. Package outline SOT962-3 (TFBGA64)

HVQFN64: plastic thermal enhanced very thin quad flat package; no leads;
64 terminals; body 9 x 9 x 0.85 mm

SOT804-4

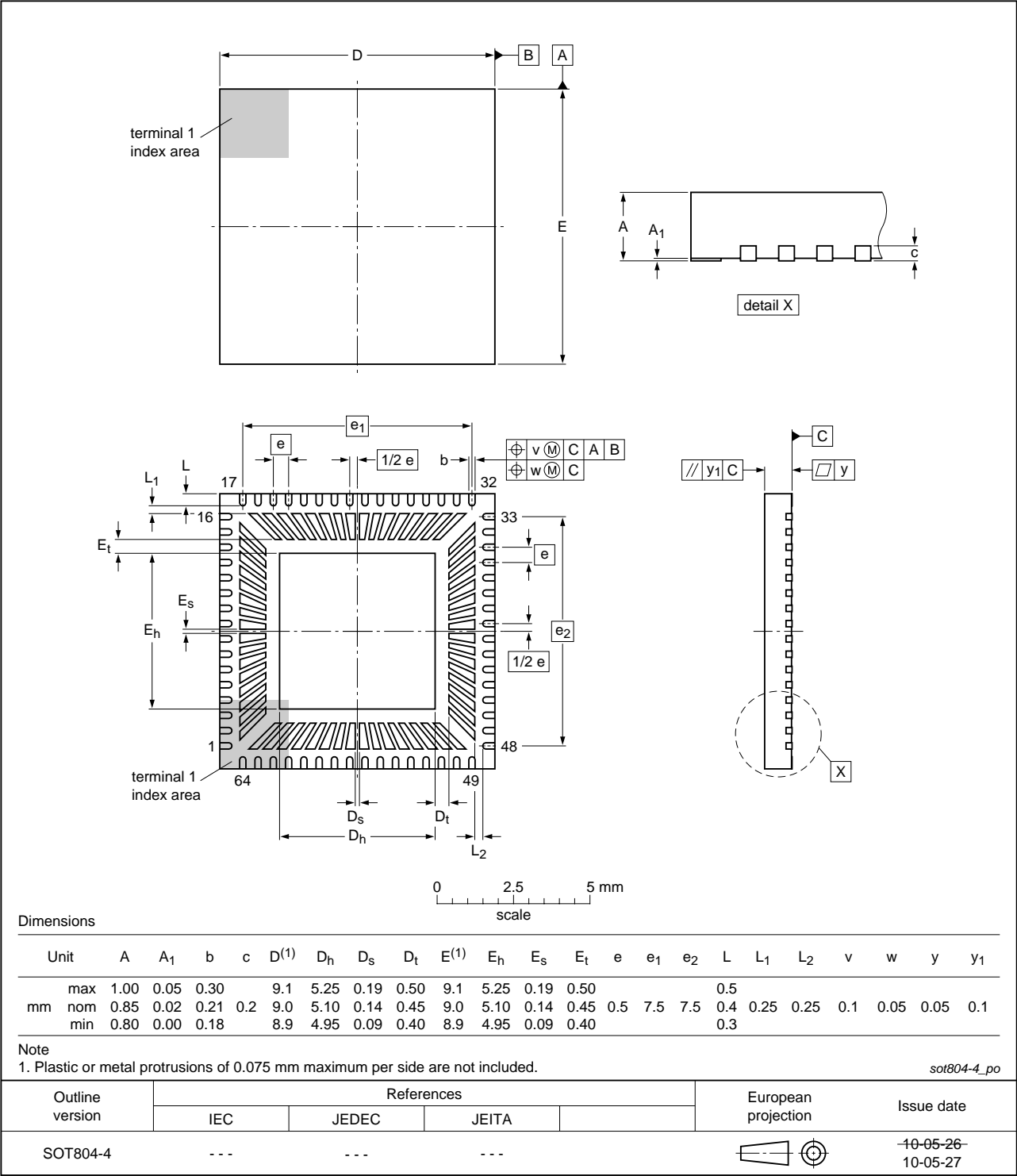


Fig 24. Package outline SOT804-4 (HVQFN64)

16. Soldering of SMD packages

This text provides a very brief insight into a complex technology. A more in-depth account of soldering ICs can be found in Application Note *AN10365 "Surface mount reflow soldering description"*.

16.1 Introduction to soldering

Soldering is one of the most common methods through which packages are attached to Printed Circuit Boards (PCBs), to form electrical circuits. The soldered joint provides both the mechanical and the electrical connection. There is no single soldering method that is ideal for all IC packages. Wave soldering is often preferred when through-hole and Surface Mount Devices (SMDs) are mixed on one printed wiring board; however, it is not suitable for fine pitch SMDs. Reflow soldering is ideal for the small pitches and high densities that come with increased miniaturization.

16.2 Wave and reflow soldering

Wave soldering is a joining technology in which the joints are made by solder coming from a standing wave of liquid solder. The wave soldering process is suitable for the following:

- Through-hole components
- Leadless or leadless SMDs, which are glued to the surface of the printed circuit board

Not all SMDs can be wave soldered. Packages with solder balls, and some leadless packages which have solder lands underneath the body, cannot be wave soldered. Also, leadless SMDs with leads having a pitch smaller than ~0.6 mm cannot be wave soldered, due to an increased probability of bridging.

The reflow soldering process involves applying solder paste to a board, followed by component placement and exposure to a temperature profile. Leadless packages, packages with solder balls, and leadless packages are all reflow solderable.

Key characteristics in both wave and reflow soldering are:

- Board specifications, including the board finish, solder masks and vias
- Package footprints, including solder thieves and orientation
- The moisture sensitivity level of the packages
- Package placement
- Inspection and repair
- Lead-free soldering versus SnPb soldering

16.3 Wave soldering

Key characteristics in wave soldering are:

- Process issues, such as application of adhesive and flux, clinching of leads, board transport, the solder wave parameters, and the time during which components are exposed to the wave
- Solder bath specifications, including temperature and impurities

16.4 Reflow soldering

Key characteristics in reflow soldering are:

- Lead-free versus SnPb soldering; note that a lead-free reflow process usually leads to higher minimum peak temperatures (see [Figure 25](#)) than a SnPb process, thus reducing the process window
- Solder paste printing issues including smearing, release, and adjusting the process window for a mix of large and small components on one board
- Reflow temperature profile; this profile includes preheat, reflow (in which the board is heated to the peak temperature) and cooling down. It is imperative that the peak temperature is high enough for the solder to make reliable solder joints (a solder paste characteristic). In addition, the peak temperature must be low enough that the packages and/or boards are not damaged. The peak temperature of the package depends on package thickness and volume and is classified in accordance with [Table 33](#) and [34](#)

Table 33. SnPb eutectic process (from J-STD-020C)

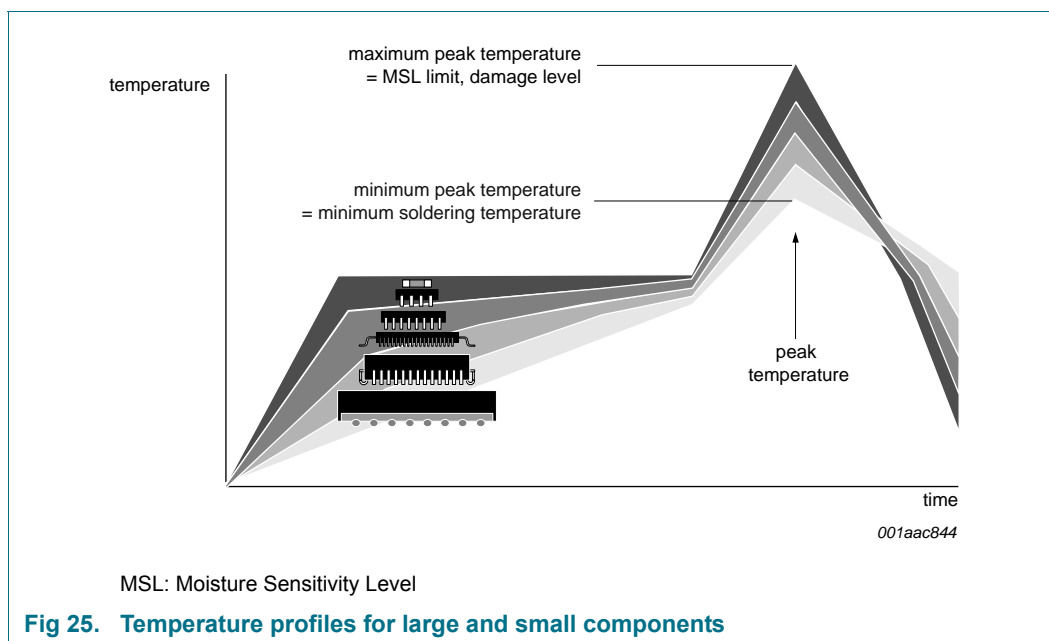
Package thickness (mm)	Package reflow temperature (°C)	
	Volume (mm ³)	
	< 350	≥ 350
< 2.5	235	220
≥ 2.5	220	220

Table 34. Lead-free process (from J-STD-020C)

Package thickness (mm)	Package reflow temperature (°C)		
	Volume (mm ³)		
	< 350	350 to 2000	> 2000
< 1.6	260	260	260
1.6 to 2.5	260	250	245
> 2.5	250	245	245

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

Studies have shown that small packages reach higher temperatures during reflow soldering, see [Figure 25](#).



For further information on temperature profiles, refer to Application Note *AN10365* “Surface mount reflow soldering description”.

17. Abbreviations

Table 35. Abbreviations

Acronym	Description
AC3	Active Coding-3
ACP	Audio Content Protection
ACR	Audio Clock Recovery
ATSC	Advanced Television Systems Committee
AV	Audio Video
BOM	Bill Of Materials
CEA	Consumer Electronics Association
CEC	Consumer Electronics Control
CTS/N	Clock Time Stamp integer divider
DDC	Display Data Channel
DDR	Double Data Rate
DE	Data Enable
DSC	Digital Still Camera
DTS	Digital Transmission System
DTV	Desk Top Video
DVC	Digital Video Camera
DVD	Digital Versatile Disc
DVI	Digital Visual Interface
EAV	End Active Video

Table 35. Abbreviations ...continued

Acronym	Description
EDID	Extended Display Identification Data
E-EDID	Enhanced Extended Display Identification Data
EIA	Electronic Industries Alliance
FCDM	Field Charged Device Model
FIFO	First In, First Out
FREF	Field REFerence
FRO	Free Running Oscillator
HBM	Human Body Model
HDCP	High-bandwidth Digital Content Protection
HDMI	High-Definition Multimedia Interface
HPD	Hot Plug Detection
HREF	Horizontal REFerence
HSYNC	Horizontal SYNChronization
LSB	Least Significant Bit
LV-CMOS	Low Voltage Complementary Metal-Oxide Semiconductor
MPEG	Moving Picture Experts Group
MSB	Most Significant Bit
OTP	One Time Programming
PC	Personal Computer
PCB	Printed Circuit Board
PCM	Pulse Code Modulation
PLL	Phase-Locked Loop
PMP	Portable Multimedia Player
POR	Power-On Reset
RGB	R = red, G = green, B = blue
SAV	Start Active Video
SDR	Single Data Rate
SMPTE	Society of Motion Picture and Television Engineers
S/PDIF	Sony/Philips Digital Interface
STB	Set-Top Box
TMDS	Transition Minimized Differential Signalling
UM PC	Ultra-Mobile Personal Computer
UXGA60	Ultra Extended Graphics Array
VHREF	Vertical Horizontal REFerence
VREF	Vertical REFerence
VSNC	Vertical SYNChronization
YCbCr	Y = luminance, Cb = Chroma component blue, Cr = Chroma component red
WS	Word Select

18. Revision history

Table 36. Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
TDA19988 v.1	<td>	Objective data sheet	-	-

19. Legal information

19.1 Data sheet status

Document status ^{[1][2]}	Product status ^[3]	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
Preliminary [short] data sheet	Qualification	This document contains data from the preliminary specification.
Product [short] data sheet	Production	This document contains the product specification.

[1] Please consult the most recently issued document before initiating or completing a design.

[2] The term 'short data sheet' is explained in section "Definitions".

[3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the Internet at URL <http://www.nxp.com>.

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21. Tables

Table 1.	Ordering information	3	downsampler	24
Table 2.	Pin description	5	Table 17.	Audio port configuration
Table 3.	Pin description	7	Table 18.	TDA19988 typical power consumption in different configurations
Table 4.	Internal assignment	11	Table 19.	Interruptions
Table 5.	Video input swap to VP[23:20]	13	Table 20.	Receiver detection according to averaged terminal voltage
Table 6.	TDA19988 input/output capability	14	Table 21.	Pixel repetition
Table 7.	Inputs of video input formatter	15	Table 22.	HDMI core I ² C-bus address
Table 8.	RGB (3 × 8-bit) external synchronization input (rising edge) mapping	15	Table 23.	CEC core I ² C-bus address
Table 9.	YCbCr 4 : 4 : 4 (3 × 8-bit) external synchronization input (rising edge) mapping	17	Table 24.	Input format
Table 10.	YCbCr 4 : 2 : 2 ITU656-like external synchronization input (rising edge) mapping	18	Table 25.	Timing parameters for EIA/CEA-861B
Table 11.	YCbCr 4 : 2 : 2 ITU656-like external synchronization input (double edge) mapping	19	Table 26.	Timing parameters for PC standards below 150 MHz
Table 12.	YCbCr 4 : 2 : 2 ITU656-like embedded synchronization input (rising edge) mappings	20	Table 27.	3D video formats timing supported
Table 13.	YCbCr 4 : 2 : 2 ITU656-like embedded synchronization input (double edge) mapping	21	Table 28.	Limiting values
Table 14.	YCbCr 4 : 2 : 2 semi-planar external synchronization input (rising edge) mapping	22	Table 29.	Thermal characteristics
Table 15.	YCbCr 4 : 2 : 2 semi-planar embedded synchronization input (rising edge) mapping	23	Table 30.	Supplies
Table 16.	Use of color space converter, upsampler and		Table 31.	Digital inputs and outputs
			Table 32.	Timing characteristics
			Table 33.	SnPb eutectic process (from J-STD-020C)
			Table 34.	Lead-free process (from J-STD-020C)
			Table 35.	Abbreviations
			Table 36.	Revision history

22. Figures

Fig 1.	TDA19988 high-level block diagram	2	single-edge clock mode	41
Fig 2.	TDA19988 Block diagram	4	Fig 20.	Set-up and hold time definition diagram for double-edge clock mode
Fig 3.	Pin configuration (TFBGA64)	5	Fig 21.	Connecting TDA19988 transmitter using external clock source
Fig 4.	Pin configuration (HVQFN64)	7	Fig 22.	Connecting TDA19988 transmitter using internal FRO for CEC
Fig 5.	Internal assignment of VP[23:0]	11	Fig 23.	Package outline SOT962-3 (TFBGA64)
Fig 6.	Pixel encoding RGB 4 : 4 : 4 external synchronization input (rising edge)	16	Fig 24.	Package outline SOT804-4 (HVQFN64)
Fig 7.	Pixel encoding YCbCr 4 : 4 : 4 external synchronization input (rising edge)	17	Fig 25.	Temperature profiles for large and small components
Fig 8.	Pixel encoding YCbCr 4 : 2 : 2 ITU656-like external synchronization input (rising edge)	18		
Fig 9.	Pixel encoding YCbCr 4 : 2 : 2 ITU656-like external synchronization input (double edge)	19		
Fig 10.	Pixel encoding YCbCr 4 : 2 : 2 ITU656-like embedded synchronization input (rising edge)	20		
Fig 11.	Pixel encoding YCbCr 4 : 2 : 2 ITU656-like embedded synchronization input (double edge)	21		
Fig 12.	Pixel encoding YCbCr 4 : 2 : 2 semi-planar external input synchronization (rising edge)	22		
Fig 13.	Pixel encoding YCbCr 4 : 2 : 2 semi-planar embedded synchronization input (rising edge)	23		
Fig 14.	I ² S-bus formats	26		
Fig 15.	Audio input swap to I ² S-bus channel 0 or S/PDIF27			
Fig 16.	Receiver sensitivity detection	29		
Fig 17.	Modules involved in CEC clock calibration process.	31		
Fig 18.	I ² C-bus access	34		
Fig 19.	Set-up and hold time definition diagram for			

23. Contents

1	General description	1	7.10.2	Receiver sensitivity	28
2	Features and benefits	2	7.11	HDCP processing	30
3	Applications	3	7.11.1	High-bandwidth digital content protection	30
4	Ordering information	3	7.11.1.1	Repeater function	30
5	Block diagram	4	7.11.1.2	SHA-1	30
6	Pinning information	5	7.12	CEC	30
6.1	Pinning	5	7.12.1	Features	30
6.2	Pin description	5	7.12.2	Clock	31
6.3	Pinning	7	7.12.3	CEC interrupt	31
6.4	Pin description	7	7.12.4	Power-On Reset (POR)	32
7	Functional description	9	7.12.5	Repeater function	32
7.1	System clock	10	7.13	HDMI core	32
7.2	Video input formatter	11	7.13.1	Output TMDS buffers	32
7.2.1	Description	11	7.13.1.1	Digitally controlled signal amplitude	32
7.2.2	Internal assignment	11	7.13.2	Pixel repetition	32
7.2.3	Input format mappings	15	7.13.3	DDC-bus channel	32
7.2.3.1	RGB 4 : 4 : 4 external synchronization (rising edge)	15	7.14	E-EDID	33
7.2.3.2	YCbCr 4 : 4 : 4 external synchronization (rising edge)	17	7.14.1	E-EDID reading	33
7.2.3.3	YCbCr 4 : 2 : 2 ITU656-like external synchronization (rising edge)	18	7.14.2	HDMI and DVI receiver discrimination	33
7.2.3.4	YCbCr 4 : 2 : 2 ITU656-like external synchronization (double edge)	19	8	I²C-bus interface and register definitions	34
7.2.3.5	YCbCr 4 : 2 : 2 ITU656-like embedded synchronization (rising edge)	20	8.1	I ² C-bus protocol	34
7.2.3.6	YCbCr 4 : 2 : 2 ITU656-like embedded synchronization (double edge)	21	8.2	Memory page management	34
7.2.3.7	YCbCr 4 : 2 : 2 semi-planar external synchronization (rising edge)	22	8.3	ID version	35
7.2.3.8	YCbCr 4 : 2 : 2 semi-planar embedded synchronization (rising edge)	23	8.4	Clock stretching	35
7.2.4	Synchronization	23	9	Input format	35
7.2.4.1	Timing extraction generator	23	9.1	Timing parameters for video supported	36
7.2.4.2	Data enable generator	23	9.2	Timing parameters for PC standards supported	37
7.3	Input and output video format	23	9.3	Primary 3D video formats	37
7.4	Upsampler	24	10	Limiting values	38
7.5	Color space converter	24	11	Thermal characteristics	38
7.6	Gamut-related metadata	24	12	Static characteristics	38
7.7	Downsampler	25	13	Dynamic characteristics	40
7.8	Audio input format	25	14	Application information	42
7.8.1	S/PDIF	25	14.1	Transmitter connection with external world	42
7.8.2	I ² S-bus	25	15	Package outline	43
7.8.3	Audio port internal assignment	27	16	Soldering of SMD packages	45
7.9	Power management	27	16.1	Introduction to soldering	45
7.10	Interrupt controller	28	16.2	Wave and reflow soldering	45
7.10.1	Hot plug/unplug detect	28	16.3	Wave soldering	45
			16.4	Reflow soldering	46
			17	Abbreviations	47
			18	Revision history	49
			19	Legal information	50
			19.1	Data sheet status	50

continued >>

19.2 Definitions 50

19.3 Disclaimers 50

19.4 Licenses 51

19.5 Trademarks 51

20 Contact information 51

21 Tables 52

22 Figures 52

23 Contents 53

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