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Dual Interface for Flat Panel Displays

AD9887

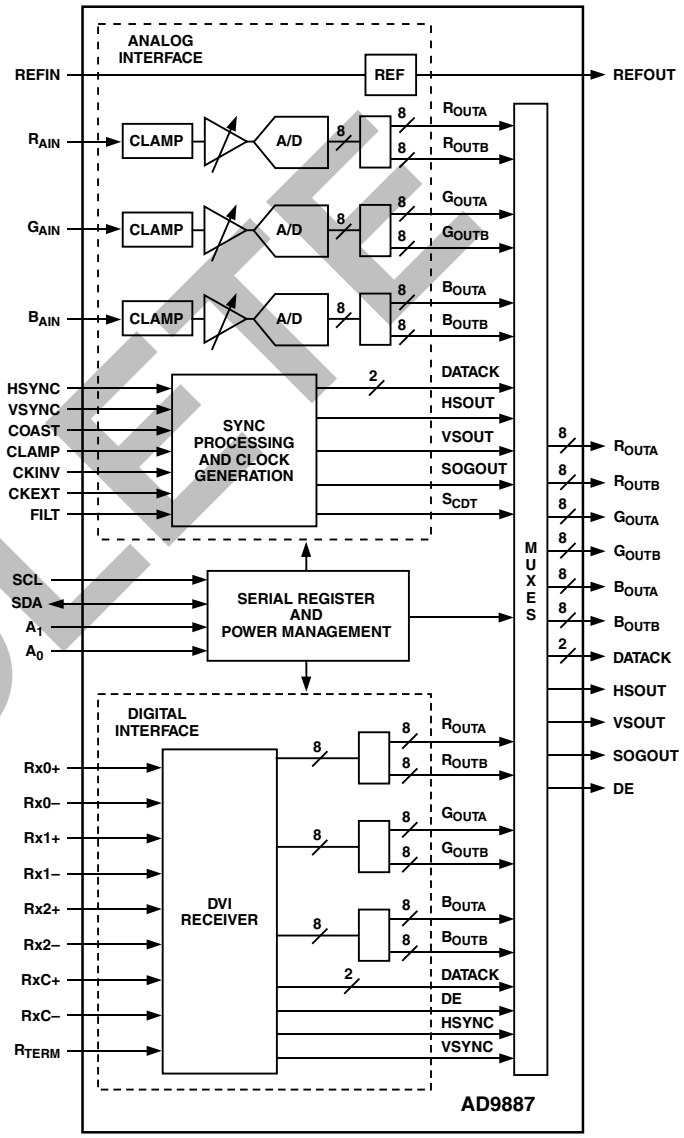
FEATURES

Analog Interface
- 140 MSPS Maximum Conversion Rate
- 330 MHz Analog Bandwidth
- 0.5 V to 1.0 V Analog Input Range
- 500 ps p-p PLL Clock Jitter at 140 MSPS
- 3.3 V Power Supply
- Full Sync Processing
- Midscale Clamp
- 4:2:2 Output Format Mode

Digital (DVI 1.0 Compatible) Interface
- 112 MHz Operation (1 Pixel/Clock Mode)
- High Skew Tolerance of One Full Input Clock
- Sync Detect for "Hot Plugging"

APPLICATIONS
- RGB Graphics Processing
- LCD Monitors and Projectors
- Plasma Display Panels
- Scan Converters
- Micro Displays
- Digital TV

FUNCTIONAL BLOCK DIAGRAM



GENERAL DESCRIPTION

The AD9887 offers designers the flexibility of a dual analog and digital interface for flat panel displays (FPDs) on a single chip. Both interfaces are optimized for excellent image quality supporting display resolutions up to SXGA (1280 × 1024 at 75 Hz). Either the analog or the digital interface can be selected by the user.

Analog Interface

For ease of design and to minimize cost, the AD9887 is a fully integrated interface solution for FPDs. The AD9887 includes an analog interface with a 140 MHz triple ADC with internal 1.25 V reference, PLL to generate a pixel clock from HSYNC, programmable gain, offset, and clamp control. The user provides only a 3.3 V power supply, analog input, and HSYNC. Three-state CMOS outputs may be powered from 2.5 V to 3.3 V.

The AD9887's on-chip PLL generates a pixel clock from HSYNC. Pixel clock output frequencies range from 12 MHz to 140 MHz. PLL clock jitter is 500 ps p-p typical at 140 MSPS. When a COAST signal is presented, the PLL maintains its output frequency in the absence of HSYNC. A sampling phase adjustment is provided. Data, HSYNC and Clock output phase relationships are maintained. The PLL can be disabled and an external clock input provided as the pixel clock. The AD9887 also offers full sync processing for composite sync and sync-on-green applications.

A clamp signal is generated internally or may be provided by the user through the CLAMP input pin. The analog interface is fully programmable via a 2-wire serial interface.

Digital Interface

The AD9887 contains a Digital Video Interface (DVI 1.0) compatible receiver. This receiver supports displays ranging from VGA to SXGA (25 MHz to 112 MHz). The receiver operates with true color (24-bit) panels in 1 or 2 pixel(s)/clock mode, and also features an intrapair skew tolerance up to one full clock cycle.

Fabricated in an advanced CMOS process, the AD9887 is provided in a 160-lead MQFP surface mount plastic package and is specified over the 0°C to 70°C temperature range.

REV. 0

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AD9887–SPECIFICATIONS

ANALOG INTERFACE (V_D = 3.3 V, V_{DD} = 3.3 V, ADC Clock = Maximum Conversion Rate, unless otherwise noted.)

Parameter	Temp	Test Level	AD9887KS-100 Min	AD9887KS-100 Typ	AD9887KS-100 Max	AD9887KS-140 Min	AD9887KS-140 Typ	AD9887KS-140 Max	Unit
RESOLUTION				8			8		Bits
DC ACCURACY									
Differential Nonlinearity	25°C	I		±0.5	+1.15/–1.0		±0.5	+1.25/–1.0	LSB
	Full	VI			+1.15/–1.0			+1.25/–1.0	LSB
Integral Nonlinearity	25°C	I		±0.5	±1.40		±0.5	±1.4	LSB
	Full	VI			±1.75			±2.5	LSB
No Missing Codes	Full	VI		Guaranteed			Guaranteed		
ANALOG INPUT									
Input Voltage Range									
Minimum	Full	VI			0.5			0.5	V p-p
Maximum	Full	VI	1.0			1.0			V p-p
Gain Tempco	25°C	V		135			150		ppm/°C
Input Bias Current	25°C	IV			1			1	µA
	Full	IV			1			1	µA
Input Offset Voltage	Full	VI		7	50		7	50	mV
Input Full-Scale Matching	Full	VI			8.0			8.0	% FS
Offset Adjustment Range	Full	VI	44	50	56	44	50	56	% FS
REFERENCE OUTPUT									
Output Voltage	Full	VI	1.20	1.25	1.30	1.20	1.25	1.30	V
Temperature Coefficient	Full	V		±50			±50		ppm/°C
SWITCHING PERFORMANCE[1]									
Maximum Conversion Rate	Full	VI	100			140			MSPS
Minimum Conversion Rate	Full	IV			10			10	MSPS
Clock to Data Skew, t_{SKEW}	Full	IV	–0.5		+2.0	–0.5		+2.0	ns
t_{BUFF}	Full	VI	4.7			4.7			µs
t_{STAH}	Full	VI	4.0			4.0			µs
t_{DHO}	Full	VI	0			0			µs
t_{DAL}	Full	VI	4.7			4.7			µs
t_{DAH}	Full	VI	4.0			4.0			µs
t_{DSU}	Full	VI	250			250			ns
t_{STASU}	Full	VI	4.7			4.7			µs
t_{STOSU}	Full	VI	4.0			4.0			µs
HSYNC Input Frequency	Full	IV	15		110	15		110	kHz
Maximum PLL Clock Rate	Full	VI	100			140			MHz
Minimum PLL Clock Rate	Full	IV			12			12	MHz
PLL Jitter	25°C	IV		400	700[2]		400	700[3]	ps p-p
	Full	IV			1000[2]			1000[3]	ps p-p
Sampling Phase Tempco	Full	IV		15			15		ps/°C
DIGITAL INPUTS									
Input Voltage, High (V_{IH})	Full	VI	2.6			2.6			V
Input Voltage, Low (V_{IL})	Full	VI			0.8			0.8	V
Input Current, High (V_{IH})	Full	IV			–1.0			–1.0	µA
Input Current, Low (V_{IL})	Full	IV			1.0			1.0	µA
Input Capacitance	25°C	V		3			3		pF
DIGITAL OUTPUTS									
Output Voltage, High (V_{OH})	Full	VI	2.4			2.4			V
Output Voltage, Low (V_{OL})	Full	VI			0.4			0.4	V
Duty Cycle									
DATACK, $\overline{DATACK}$	Full	IV	45	50	55	45	50	55	%
Output Coding				Binary			Binary		

Parameter	Temp	Test Level	AD9887KS-100 Min	AD9887KS-100 Typ	AD9887KS-100 Max	AD9887KS-140 Min	AD9887KS-140 Typ	AD9887KS-140 Max	Unit
POWER SUPPLY									
V_D Supply Voltage	Full	IV	3.0	3.3	3.6	3.0	3.3	3.6	V
V_{DD} Supply Voltage	Full	IV	2.2	3.3	3.6	2.2	3.3	3.6	V
P_{VD} Supply Voltage	Full	IV	3.0	3.3	3.6	3.0	3.3	3.6	V
I_D Supply Current (V_D)	25°C	V		140			155		mA
I_{DD} Supply Current (V_{DD})[4]	25°C	V		34			48		mA
IP_{VD} Supply Current (P_{VD})	25°C	V		15			16		mA
Total Supply Current[4]	Full	VI		170	258		215	258	mA
Power-Down Supply Current	Full	VI		18	25		18	25	mA
DYNAMIC PERFORMANCE									
Analog Bandwidth, Full Power	25°C	V		330			330		MHz
Transient Response	25°C	V		2			2		ns
Overvoltage Recovery Time	25°C	V		1.5			1.5		ns
Signal-to-Noise Ratio (SNR)[5]	25°C	V		46			46		dB
(Without Harmonics)	Full	V		45			45		dB
f_{IN} = 40.7 MHz									
Crosstalk	Full	V		60			60		dBc
THERMAL CHARACTERISTICS									
θ_{JA} Junction-to-Ambient[6] Thermal Resistance		V		30			30		°C/W

NOTES
[1]Drive Strength = 11.
[2]VCO Range = 01, Charge Pump Current = 001, PLL Divider = 1693.
[3]VCO Range = 10, Charge Pump Current = 110, PLL Divider = 1600.
[4]DEMUX = 1, DATACK and $\overline{\text{DATACK}}$ Load = 10 pF, Data Load = 5 pF.
[5]Using external pixel clock.
[6]Simulated typical performance with package mounted to a 4-layer board.

Specifications subject to change without notice.

AD9887–SPECIFICATIONS

DIGITAL INTERFACE (V_D = 3.3 V, V_{DD} = 3 V, Clock = Maximum)

Parameter	Conditions	Test Level	AD9887KS Min	Typ	Max	Unit
RESOLUTION				8		Bits
DC DIGITAL I/O SPECIFICATIONS						
High-Level Input Voltage, (V_{IH})		VI	2.6			V
Low-Level Input Voltage, (V_{IL})		VI			0.8	V
High-Level Output Voltage, (V_{OH})		VI	2.4			V
Low-Level Output Voltage, (V_{OL})		VI			0.4	V
Input Clamp Voltage, (V_{CINL})	(I_{CL} = –18 mA)	IV			GND – 0.8	V
Input Clamp Voltage, (V_{CIPL})	(I_{CL} = +18 mA)	IV			V_{DD} + 0.8	V
Output Clamp Voltage, (V_{CONL})	(I_{CL} = –18 mA)	IV			GND – 0.8	V
Output Clamp Voltage, (V_{COPL})	(I_{CL} = +18 mA)	IV			V_{DD} + 0.8	V
Output Leakage Current, (I_{OL})	(High Impedance)	IV	–10		+10	µA
DC SPECIFICATIONS						
Output High Drive	Output Drive = High	IV		13		mA
(I_{OHD}) (V_{OUT} = V_{OH})	Output Drive = Med	IV		8		mA
	Output Drive = Low	IV		5		mA
	Output Drive = High	IV		–9		mA
(I_{OLD}) (V_{OUT} = V_{OL})	Output Drive = Med	IV		–7		mA
	Output Drive = Low	IV		–5		mA
	Output Drive = High	IV		25		mA
(V_{OHC}) (V_{OUT} = V_{OH})	Output Drive = Med	IV		12		mA
	Output Drive = Low	IV		8		mA
DATACK Low Drive	Output Drive = High	IV		–25		mA
(V_{OLC}) (V_{OUT} = V_{OL})	Output Drive = Med	IV		–19		mA
	Output Drive = Low	IV		–8		mA
Differential Input Voltage Single-Ended Amplitude		IV	75		800	mV
POWER SUPPLY						
V_D Supply Voltage		IV	3.0	3.3	3.6	V
V_{DD} Supply Voltage	Minimum Value for 2 Pixels per Clock Mode	IV	2.2	3.3	3.6	V
P_{VD} Supply Voltage		IV	3.0	3.3	3.6	V
V_D Supply Current (Typical Pattern)[1]		V		274		mA
V_{DD} Supply Current (Typical Pattern)[1, 4]		V		38		mA
P_{VD} Supply Current (Typical Pattern)[1]		V		21		mA
Total Supply Current (Typical Pattern)[1, 4]		VI		362		mA
V_D Supply Current (Worst-Case Pattern)[2]		V		280		mA
V_{DD} Supply Current (Worst-Case Pattern)[2, 4]		V		75		mA
P_{VD} Supply Current (Worst-Case Pattern)[2]		V		21		mA
Total Supply Current (Worst-Case Pattern)[2, 4]		VI		400		mA
Power-Down Supply Current (I_{PD})		VI		13	25	mA
AC SPECIFICATIONS						
Intrapair (+ to –) Differential Input Skew (T_{DPS})		IV			360	ps
Channel-to-Channel Differential Input Skew (T_{CCS})		IV			1.0	Clock Period
Low-to-High Transition Time for Data and Controls (D_{LHT})	Output Drive = High; C_L = 10 pF	IV			2.0	ns
	Output Drive = Med; C_L = 7 pF	IV			3.0	ns
	Output Drive = Low; C_L = 5 pF	IV			3.4	ns
Low-to-High Transition Time for DATACK (D_{LHT})	Output Drive = High; C_L = 10 pF	IV			1.3	ns
	Output Drive = Med; C_L = 7 pF	IV			1.9	ns
	Output Drive = Low; C_L = 5 pF	IV			2.5	ns
High-to-Low Transition Time for Data and Controls (D_{HLT})	Output Drive = High; C_L = 10 pF	IV			2.7	ns
	Output Drive = Med; C_L = 7 pF	IV			3.0	ns
	Output Drive = Low; C_L = 5 pF	IV			3.3	ns

Parameter	Conditions	Test Level	AD9887KS Min	Typ	Max	Unit
AC SPECIFICATIONS (continued)						
High-to-Low Transition Time for DATACK (D_{HLT})	Output Drive = High; C_L =10 pF	IV			1.4	ns
	Output Drive = Med; C_L = 7 pF	IV			1.7	ns
	Output Drive = Low; C_L = 5 pF	IV			2.1	ns
Clock to Data Skew, t_{SKEW}		IV	–0.5		+2.0	ns
Duty Cycle, t_{DCYCLE}		IV	45		55	% of Period High
DATACK Frequency (F_{CIP}) (1 Pixel/Clock)		VI	20		112	MHz
DATACK Frequency (F_{CIP}) (2 Pixels/Clock)		IV	10		56	MHz

NOTES
[1]The typical pattern contains a gray scale area, Output Drive = High.
[2]The worst-case pattern contains a black and white checkerboard pattern, Output Drive = High.
[3]The setup and hold times with respect to the DATACK rising edge are the same as the falling edge.
[4]1 Pixel/clock mode, DATACK and $\overline{DATACK}$ Load = 10 pF, Data Load = 5 pF.

ABSOLUTE MAXIMUM RATINGS*

V_D . . . . . 3.6 V
V_{DD} . . . . . 3.6 V
Analog Inputs . . . . . V_D to 0.0 V
VREF IN . . . . . V_D to 0.0 V
Digital Inputs . . . . . 5 V to 0.0 V
Digital Output Current . . . . . 20 mA
Operating Temperature . . . . . –25°C to +85°C
Storage Temperature . . . . . –65°C to +150°C
Maximum Junction Temperature . . . . . 150°C
Maximum Case Temperature . . . . . 150°C

*Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions outside of those indicated in the operation sections of this specification is not implied. Exposure to absolute maximum ratings for extended periods may affect device reliability.

EXPLANATION OF TEST LEVELS

Test Level	Explanation
I	100% production tested.
II	100% production tested at 25°C and sample tested at specified temperatures.
III	Sample tested only.
IV	Parameter is guaranteed by design and characterization testing.
V	Parameter is a typical value only.
VI	100% production tested at 25°C; guaranteed by design and characterization testing.

ORDERING GUIDE

Model	Temperature Range	Package Description	Package Option
AD9887KS-140	0°C to 70°C	Plastic Quad Flatpack	S-160
AD9887KS-100	0°C to 70°C	Plastic Quad Flatpack	S-160
AD9887/PCB	25°C	Evaluation Board	

CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although the AD9887 features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high-energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.

PIN CONFIGURATION

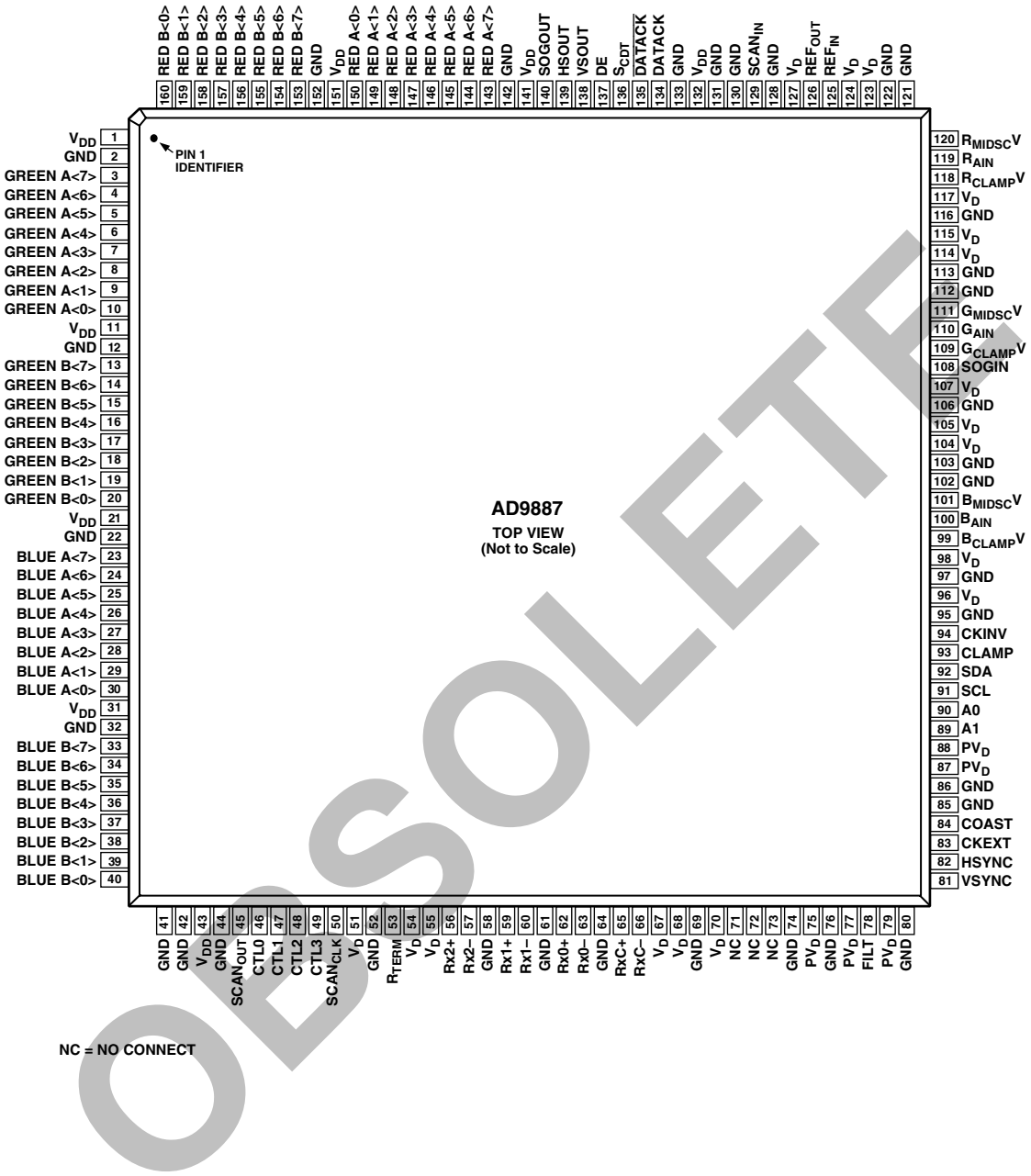

Table I. Complete Pinout List

Pin Type	Pin Name	Function	Value	Pin Number	Interface
Analog Video Inputs	R_{AIN}	Analog Input for Converter R	0.0 V to 1.0 V	119	Analog
	G_{AIN}	Analog Input for Converter G	0.0 V to 1.0 V	110	Analog
	B_{AIN}	Analog Input for Converter B	0.0 V to 1.0 V	100	Analog
External Sync/Clock Inputs	HSYNC	Horizontal SYNC Input	3.3 V CMOS	82	Analog
	VSYNC	Vertical SYNC Input	3.3 V CMOS	81	Analog
	SOGIN	Input for Sync-on-Green	0.0 V to 1.0 V	108	Analog
	CLAMP	Clamp Input (External CLAMP Signal)	3.3 V CMOS	93	Analog
	COAST	PLL COAST Signal Input	3.3 V CMOS	84	Analog
	CKEXT	External Pixel Clock Input (to Bypass the PLL) to V_{DD} or Ground	3.3 V CMOS	83	Analog
	CKINV	ADC Sampling Clock Invert	3.3 V CMOS	94	Analog
Sync Outputs	HSOUT	HSYNC Output Clock (Phase-Aligned with DATACK)	3.3 V CMOS	139	Both
	VSOUT	VSYNC Output Clock (Phase-Aligned with DATACK)	3.3 V CMOS	138	Both
	SOGOUT	Sync on Green Slicer Output	3.3 V CMOS	140	Analog
Voltage Reference	REFOUT	Internal Reference Output (Bypass with 0.1 µF to Ground)	1.25 V	126	Analog
	REFIN	Reference Input (1.25 V ± 10%)	1.25 V ± 10%	125	Analog
Clamp Voltages	$R_{MIDSC}V$	Red Channel Midscale Clamp Voltage Output		120	Analog
	$R_{CLAMP}V$	Red Channel Midscale Clamp Voltage Input	0.0 V to 0.75 V	118	Analog
	$G_{MIDSC}V$	Green Channel Midscale Clamp Voltage Output		111	Analog
	$G_{CLAMP}V$	Green Channel Midscale Clamp Voltage Input	0.0 V to 0.75 V	109	Analog
	$B_{MIDSC}V$	Blue Channel Midscale Clamp Voltage Output		101	Analog
	$B_{CLAMP}V$	Blue Channel Midscale Clamp Voltage Input	0.0 V to 0.75 V	99	Analog
PLL Filter	FILT	Connection for External Filter Components for Internal PLL		78	Analog
Power Supply	V_D	Analog Power Supply	3.3 V ± 10%		Both
	V_{DD}	Output Power Supply	3.3 V ± 10%		Both
	PV_D	PLL Power Supply	3.3 V ± 10%		Both
	GND	Ground	0 V		Both
Serial Port (2-Wire Serial Interface)	SDA	Serial Port Data I/O	3.3 V CMOS	92	Both
	SCL	Serial Port Data Clock (100 kHz Max)	3.3 V CMOS	91	Both
	A0	Serial Port Address Input 1	3.3 V CMOS	90	Both
	A1	Serial Port Address Input 2	3.3 V CMOS	89	Both
Data Outputs	Red B[7:0]	Port B/Odd Outputs of Converter "Red," Bit 7 Is the MSB	3.3 V CMOS	153–160	Both
	Green B[7:0]	Port B/Odd Outputs of Converter "Green," Bit 7 Is the MSB	3.3 V CMOS	13–20	Both
	Blue B[7:0]	Port B/Odd Outputs of Converter "Blue," Bit 7 Is the MSB	3.3 V CMOS	33–40	Both
	Red A[7:0]	Port A/Even Outputs of Converter "Red," Bit 7 Is the MSB	3.3 V CMOS	143–150	Both
	Green A[7:0]	Port A/Even Outputs of Converter "Green," Bit 7 Is the MSB	3.3 V CMOS	3–10	Both
	Blue A[7:0]	Port A/Even Outputs of Converter "Blue," Bit 7 Is the MSB	3.3 V CMOS	23–30	Both
Data Clock Outputs	$\overline{DATACK}$	Data Output Clock for the Analog and Digital Interface	3.3 V CMOS	134	Both
	DATACK	Data Output Clock Complement for the Analog Interface Only	3.3 V CMOS	135	Both
Sync Detect	S_{CDT}	Sync Detect Output	3.3 V CMOS	136	Both
Scan Function	$SCAN_{IN}$	Input for SCAN Function	3.3 V CMOS	129	Both
	$SCAN_{OUT}$	Output for SCAN Function	3.3 V CMOS	45	Both
	$SCAN_{CLK}$	Clock for SCAN Function	3.3 V CMOS	50	Both
No Connect	NC	These Pins Should be Left Unconnected		71–73	Both
Digital Video Data Inputs	R_{x0}+	Digital Input Channel 0 True		62	Digital
	R_{x0}–	Digital Input Channel 0 Complement		63	Digital
	R_{x1}+	Digital Input Channel 1 True		59	Digital
	R_{x1}–	Digital Input Channel 1 Complement		60	Digital
	R_{x2}+	Digital Input Channel 2 True		56	Digital
	R_{x2}–	Digital Input Channel 2 Complement		57	Digital
Digital Video Clock Inputs	R_{xc}+	Digital Data Clock True		65	Digital
	R_{xc}–	Digital Data Clock Complement		66	Digital
Data Enable	DE	Data Enable	3.3 V CMOS	137	Digital
Control Bits	CTL[0:3]	Decoded Control Bits	3.3 V CMOS	46–49	Digital
R_{TERM}	R_{TERM}	Sets Internal Termination Resistance		53	Digital

DESCRIPTIONS OF PINS SHARED BETWEEN ANALOG AND DIGITAL INTERFACES

HSOUT — Horizontal Sync Output

A reconstructed and phase-aligned version of the video HSYNC. The polarity of this output can be controlled via a serial bus bit. In analog interface mode the placement and duration are variable. In digital interface mode the placement and duration are set by the graphics transmitter.

VSOUT — Vertical Sync Output

The separated VSYNC from a composite signal or a direct pass through of the VSYNC input. The polarity of this output can be controlled via a serial bus bit. The placement and duration in all modes is set by the graphics transmitter.

Serial Port (2-Wire)

SDA — Serial Port Data I/O

SCL — Serial Port Data Clock

A0 — Serial Port Address Input 1

A1 — Serial Port Address Input 2

For a full description of the 2-wire serial register and how it works, refer to the Control Register section.

Data Outputs

RED A — Data Output, Red Channel, Port A/Even

RED B — Data Output, Red Channel, Port B/Odd

GREEN A — Data Output, Green Channel, Port A/Even

GREEN B — Data Output, Green Channel, Port B/Odd

BLUE A — Data Output, Blue Channel, Port A/Even

BLUE B — Data Output, Blue Channel, Port B/Odd

The main data outputs. Bit 7 is the MSB. These outputs are shared between the two interfaces and behave according to which interface is active. Refer to the sections on the two interfaces for more information on how these outputs behave.

Data Clock Outputs

DATACK — Data Output Clock

$\overline{\text{DATACK}}$ — Data Output Clock Complement

Just like the data outputs, the data clock outputs are shared between the two interfaces. They also behave differently depending on which interface is active. Refer to the sections on the two interfaces to determine how these pins behave.

Various

S_{CDT} — Chip Active/Inactive Detect Output

The logic for the S_{CDT} pin is [analog interface HSYNC detection] OR [digital interface DE detection]. So, the S_{CDT} pin will switch to logic LOW under two conditions, when neither interface is active *or* when the chip is in full chip power-down mode. The data outputs are automatically three-stated when S_{CDT} is LOW. This pin can be read by a controller in order to determine periods of inactivity.

SCAN Function

$SCAN_{IN}$ — Data Input for SCAN Function

Data can be loaded serially into the 48-bit SCAN register through this pin, clocking it in with the $SCAN_{CLK}$ pin. It then comes out of the 48 data outputs in parallel. This function is useful for loading known data into a graphics controller chip for testing purposes.

$SCAN_{OUT}$ — Data Output for SCAN Function

The data in the 48-bit SCAN register can be read through this pin. Data is read on a FIFO basis and is clocked via the $SCAN_{CLK}$ pin.

$SCAN_{CLK}$ — Data Clock for SCAN Function

This pin clocks the data through the SCAN register. It controls both data input and data output.

Table II. Analog Interface Pin List

Pin Type	Pin Name	Function	Value	Pin No.
Analog Video Inputs	R_{AIN}	Analog Input for Converter R	0.0 V to 1.0 V	119
	G_{AIN}	Analog Input for Converter G	0.0 V to 1.0 V	110
	B_{AIN}	Analog Input for Converter B	0.0 V to 1.0 V	100
External	HSYNC	Horizontal SYNC Input	3.3 V CMOS	82
	VSYNC	Vertical SYNC Input	3.3 V CMOS	81
Sync/Clock	SOGIN	Sync-on-Green Input	0.0 V to 1.0 V	108
Inputs	CLAMP	Clamp Input (External CLAMP Signal)	3.3 V CMOS	93
	COAST	PLL COAST Signal Input	3.3 V CMOS	84
	CKEXT	External Pixel Clock Input (to Bypass Internal PLL) or 10 kΩ to V_{DD}	3.3 V CMOS	83
	CKINV	ADC Sampling Clock Invert	3.3 V CMOS	94
Sync Outputs	HSOUT	HSYNC Output (Phase-Aligned with DATACK and $\overline{DATACK}$)	3.3 V CMOS	139
	VSOUT	VSYNC Output (Asynchronous)	3.3 V CMOS	138
	SOGOUT	Sync-on-Green Slicer Output or Raw HSYNC Output	3.3 V CMOS	140
Voltage Reference	REFOUT	Internal Reference Output (bypass with 0.1 µF to ground)	1.25 V	126
	REFIN	Reference Input (1.25 V ± 10%)	1.25 V ± 10%	125
Clamp Voltages	$R_{MIDSC}V$	Voltage output equal to the RED converter midscale voltage.	0.5 V ± 50%	120
	$R_{CLAMP}V$	During midscale clamping, the RED Input is clamped to this pin.	0.0 V to 0.75 V	118
	$G_{MIDSC}V$	Voltage output equal to the GREEN converter midscale voltage.	0.5 V ± 50%	111
	$G_{CLAMP}V$	During midscale clamping, the GREEN Input is clamped to this pin.	0.0 V to 0.75 V	109
	$B_{MIDSC}V$	Voltage output equal to the BLUE converter midscale voltage.	0.5 V ± 50%	101
	$B_{CLAMP}V$	During midscale clamping, the BLUE Input is clamped to this pin.	0.0 V to 0.75 V	99
PLL Filter	FILT	Connection for External Filter Components for Internal PLL		78
Power Supply	V_D	Main Power Supply	3.3 V ± 5%	
	PV_D	PLL Power Supply (Nominally 3.3 V)	3.3 V ± 5%	
	V_{DD}	Output Power Supply	3.3 V or 2.5 V ± 5%	
	GND	Ground	0 V	

PIN FUNCTION DETAILS (ANALOG INTERFACE)

Inputs

R_{AIN} Analog Input for RED Channel

G_{AIN} Analog Input for GREEN Channel

B_{AIN} Analog Input for BLUE Channel

High-impedance inputs that accept the RED, GREEN, and BLUE channel graphics signals, respectively. For RGB, the three channels are identical and can be used for any colors, but colors are assigned for convenient reference. For proper 4:2:2 formatting in a YUV application, the Y channel must be connected to the G_{AIN} input, U must be connected to the B_{AIN} input, and V must be connected to the R_{AIN} input.

They accommodate input signals ranging from 0.5 V to 1.0 V full scale. Signals should be ac-coupled to these pins to support clamp operation.

HSYNC Horizontal Sync Input

This input receives a logic signal that establishes the horizontal timing reference and provides the frequency reference for pixel clock generation.

The logic sense of this pin is controlled by serial register 0Fh Bit 7 (HSYNC Polarity). Only the leading edge of HSYNC is active, the trailing edge is ignored. When HSYNC Polarity = 0, the falling edge of HSYNC is used. When HSYNC Polarity = 1, the rising edge is active.

The input includes a Schmitt trigger for noise immunity, with a nominal input threshold of 1.5 V.

Electrostatic Discharge (ESD) protection diodes will conduct heavily if this pin is driven more than 0.5 V above the maximum tolerance voltage (3.3 V), or more than 0.5 V below ground.

VSYNC Vertical Sync Input

This is the input for vertical sync.

SOGIN Sync-on-Green Input

This input is provided to assist with processing signals with embedded sync, typically on the GREEN channel. The pin is connected to a high-speed comparator with an internally generated threshold, which is set to 0.15 V above the negative peak of the input signal.

When connected to an ac-coupled graphics signal with embedded sync, it will produce a noninverting digital output on SOGOUT.

When not used, this input should be left unconnected. For more details on this function and how it should be configured, refer to the Sync-on-Green section.

CLAMP — External Clamp Input (Optional)

This logic input may be used to define the time during which the input signal is clamped to the reference dc level, (ground for RGB or midscale for YUV). It should be exercised when the reference dc level is known to be present on the analog input channels, typically during the back porch of the graphics signal. The CLAMP pin is enabled by setting control bit EXTCLMP to 1, (the default power-up is 0). When disabled, this pin is ignored and the clamp timing is determined internally by counting a delay and duration from the trailing edge of the HSYNC input. The logic sense of this pin is controlled by CLAMPOL. When not used, this pin must be grounded and EXTCLMP programmed to 0.

COAST — Clock Generator Coast Input (Optional)

This input may be used to cause the pixel clock generator to stop synchronizing with HSYNC and continue producing a clock at its current frequency and phase. This is useful when processing signals from sources that fail to produce horizontal sync pulses when in the vertical interval. The COAST signal is generally *not* required for PC-generated signals. Applications requiring COAST can do so through the internal COAST found in the SYNC processing engine.

The logic sense of this pin is controlled by COAST Polarity.

When not used, this pin may be grounded and COAST Polarity programmed to 1, or tied HIGH and COAST Polarity programmed to 0. COAST Polarity defaults to 1 at power-up.

CKEXT — External Clock Input (Optional)

This pin may be used to provide an external clock to the AD9887, in place of the clock internally generated from HSYNC.

It is enabled by programming EXTCLK to 1. When an external clock is used, all other internal functions operate normally. When unused, this pin should be tied to V_{DD} or to GROUND, and EXTCLK programmed to 0. The clock phase adjustment still operates when an external clock source is used.

CKINV — Sampling Clock Inversion (Optional)

This pin may be used to invert the pixel sampling clock, which has the effect of shifting the sampling phase 180°. This is in support of Alternate Pixel Sampling mode, wherein higher-frequency input signals (up to 280 Mpps) may be captured by first sampling the odd pixels, then capturing the even pixels on the subsequent frame.

This pin should be exercised only during blanking intervals (typically vertical blanking) as it may produce several samples of corrupted data during the phase shift.

CKINV should be grounded when not used.

Outputs

D_RA_{7-0} — Data Output, Red Channel, Port A

D_RB_{7-0} — Data Output, Red Channel, Port B

D_GA_{7-0} — Data Output, Green Channel, Port A

D_GB_{7-0} — Data Output, Green Channel, Port B

D_BA_{7-0} — Data Output, Blue Channel, Port A

D_BB_{7-0} — Data Output, Blue Channel, Port B

These are the main data outputs. Bit 7 is the MSB.

Each channel has two ports. When the part is operated in single-channel mode (DEMUX = 0), all data are presented to Port A, and Port B is placed in a high-impedance state.

Programming DEMUX to 1 established dual-channel mode, wherein alternate pixels are presented to Port A and Port B of each channel. These will appear simultaneously, two pixels presented at the time of every second input pixel, when PAR is set to 1 (parallel mode). When PAR = 0, pixel data appear alternately on the two ports, one new sample with each incoming pixel (interleaved mode).

In dual channel mode, the first pixel after HSYNC is routed to Port A. The second pixel goes to Port B, the third to A, etc.

The delay from pixel sampling time to output is fixed. When the sampling time is changed by adjusting the PHASE register, the output timing is shifted as well. The DATACK, $\overline{\text{DATACK}}$, and HSOUT outputs are also moved, so the timing relationship among the signals is maintained.

DATACK — Data Output Clock

$\overline{\text{DATACK}}$ — Data Output Clock Complement

Differential data clock output signals to be used to strobe the output data and HSOUT into external logic.

They are produced by the internal clock generator and are synchronous with the internal pixel sampling clock.

When the AD9887 is operated in single-channel mode, the output frequency is equal to the pixel sampling frequency. When operating in dual channel mode, the clock frequency is one-half the pixel frequency.

When the sampling time is changed by adjusting the PHASE register, the output timing is shifted as well. The Data, DATACK, $\overline{\text{DATACK}}$, and HSOUT outputs are all moved, so the timing relationship among the signals is maintained.

Either or both signals may be used, depending on the timing mode and interface design employed.

HSOUT — Horizontal Sync Output

A reconstructed and phase-aligned version of the Hsync input. Both the polarity and duration of this output can be programmed via serial bus registers.

By maintaining alignment with DATACK, $\overline{\text{DATACK}}$, and Data, data timing with respect to horizontal sync can always be determined.

SOGOUT — Sync-On-Green Slicer Output

This pin can be programmed to output either the output from the Sync-On-Green slicer comparator or an unprocessed but delayed version of the HSYNC input. See the Sync Block Diagram to view how this pin is connected.

(Note: The output from this pin is the sliced SOG, without additional processing from the AD9887.)

Analog Interface

REFOUT — Internal Reference Output

Output from the internal 1.25 V bandgap reference. This output is intended to drive relatively light loads. It can drive the AD9887 Reference Input directly, but should be externally buffered if it is used to drive other loads as well.

The absolute accuracy of this output is ±4%, and the temperature coefficient is ±50 ppm, which is adequate for most AD9887 applications. If higher accuracy is required, an external reference may be employed instead.

If an external reference is used, connect this pin to ground through a 0.1 µF capacitor.

REFIN — Reference Input

The reference input accepts the master reference voltage for all AD9887 internal circuitry (1.25 V ±10%). It may be driven directly by the REFOUT pin. Its high impedance presents a very light load to the reference source.

This pin should always be bypassed to Ground with a 0.1 µF capacitor.

FILT — External Filter Connection

For proper operation, the pixel clock generator PLL requires an external filter. Connect the filter shown Figure 7 to this pin. For optimal performance, minimize noise and parasitics on this node.

Power Supply

V_D — Main Power Supply

These pins supply power to the main elements of the circuit. It should be filtered to be as quiet as possible.

V_{DD} — Digital Output Power Supply

These supply pins are identified separately from the V_D pins so special care can be taken to minimize output noise transferred into the sensitive analog circuitry.

If the AD9887 is interfacing with lower-voltage logic, V_{DD} may be connected to a lower supply voltage (as low as 2.2 V) for compatibility.

PV_D — Clock Generator Power Supply

The most sensitive portion of the AD9887 is the clock generation circuitry. These pins provide power to the clock PLL and help the user design for optimal performance. The designer should provide noise-free power to these pins.

GND — Ground

The ground return for all circuitry on chip. It is recommended that the application circuit board have a single, solid ground plane.

THEORY OF OPERATION (INTERFACE DETECTION)

Active Interface Detection and Selection

The AD9887 includes circuitry to detect whether or not an interface is active.

For detecting the *analog* interface, the circuitry monitors the presence of HSYNC, VSYNC, and Sync-on-Green. The result of the detection circuitry can be read from the 2-wire serial interface bus at address 11H Bits 7, 6, and 5 respectively. If one of these sync signals disappears, the maximum time it takes for the circuitry to detect it is 100 ms.

There are two stages for detecting the *digital* interface. The first stage searches for the presence of the digital interface clock. The circuitry for detecting the digital interface clock is active even when the digital interface is powered down. The result of this detection stage can be read from the 2-wire serial interface bus at address 11H Bit 4. If the clock disappears, the maximum time it takes for the circuitry to detect it is 100 ms. The second stage attempts to detect DE on the digital interface. Detection is accomplished when 32 DEs have been counted. DE can only be detected when the digital interface is powered up, so it is not always active. The DE detection circuitry is one of the logic inputs used to set the SyncDT output pin (Pin 136). The logic for the SyncDT pin is [DE detect] OR [HSYNC detect].

There is an override for the automatic interface selection. It is the AIO bit (Active Interface Override). When the AIO bit is set to Logic 0, the automatic circuitry will be used. When the AIO bit is set to Logic 1, the AIS bit will be used to determine the active interface rather than the automatic circuitry.

Power Management

The AD9887 is a dual interface device with shared outputs. Only one interface can be used at a time. For this reason, the chip automatically powers down the unused interface. When the analog interface is being used, most of the digital interface circuitry is powered down and vice-versa. This helps to minimize the AD9887 total power dissipation. In addition, if neither interface has activity on it, the chip powers down both interfaces.

The AD9887 uses the activity detect circuits, the active interface bits in the serial registers, the active interface override bits, and the power-down bit to determine the correct power state. In a given power mode not all circuitry in the inactive interface is powered down completely. When the digital interface is active, the bandgap reference and HSYNC detect circuitry is not powered down. When the analog interface is active, the digital interface clock detect circuit is not powered down. Table IV summarizes how the AD9887 determines which power mode to be in and what circuitry is powered on/off in each of these modes. The power-down command has priority, followed by the active interface override, and then the automatic circuitry.

Table III. Interface Selection Controls

AIO	Analog Interface Detect	Digital Interface Detect	AIS	Active Interface	Description
1	X	X	0	Analog	Force the analog interface active.
			1	Digital	Force the digital interface active.
0	0	0	X	None	Neither interface was detected. Both interfaces are powered down and the SyncDT pin gets set to Logic 0.
	0	1	X	Digital	The digital interface was detected. Power down the analog interface.
	1	0	X	Analog	The analog interface was detected. Power down the digital interface.
	1	0	X	Analog	Both interfaces were detected. The analog interface has priority.
			1	Digital	Both interfaces were detected. The digital interface has priority.

Table IV. Power-Down Mode Descriptions

Mode	Inputs					Powered On or Comments
	Power-Down[1]	Analog Interface Detect[2]	Digital Interface Detect[3]	Active Interface Override	Active Interface Select	
Soft Power-Down (Seek Mode)	1	0	0	0	X	Serial Bus, Digital Interface Clock Detect, Analog Interface Activity Detect, SOG, Bandgap Reference
Digital Interface On	1	0	1	0	X	Serial Bus, Digital Interface, Analog Interface Activity Detect, SOG, Outputs, Bandgap Reference
Analog Interface On	1	1	0	0	X	Serial Bus, Analog Interface, Digital Interface Clock Detect, SOG, Outputs, Bandgap Reference
Serial Bus Arbitrated Interface	1	1	1	0	0	Same as Analog Interface On Mode
Serial Bus Arbitrated Interface	1	1	1	0	1	Same as Digital Interface On Mode
Override to Analog Interface	1	X	X	1	0	Same as Analog Interface On Mode
Override to Digital Interface	1	X	X	1	1	Same as Digital Interface On Mode
Absolute Power-Down	0	X	X	X	X	Serial Bus

NOTES

[1]Power-down is controlled via bit 0 in serial bus Register 12h.

[2]Analog Interface Detect is determined by OR-ing Bits 7, 6, and 5 in serial bus Register 11h.

[3]Digital Interface Detect is determined by Bit 4 in serial bus Register 11h.

THEORY OF OPERATION AND DESIGN GUIDE (ANALOG INTERFACE)

General Description

The AD9887 is a fully integrated solution for capturing analog RGB signals and digitizing them for display on flat panel monitors or projectors. The device is ideal for implementing a computer interface in HDTV monitors or as the front end to high-performance video scan converters.

Implemented in a high-performance CMOS process, the interface can capture signals with pixel rates of up to 140 MHz and, with an Alternate Pixel Sampling mode, up to 280 MHz.

The AD9887 includes all necessary input buffering, signal dc restoration (clamping), offset and gain (brightness and contrast) adjustment, pixel clock generation, sampling phase control, and output data formatting. All controls are programmable via a 2-wire serial interface. Full integration of these sensitive analog functions makes system design straightforward and less sensitive to the physical and electrical environment.

With a typical power dissipation of less than 725 mW and an operating temperature range of 0°C to 70°C, the device requires no special environmental considerations.

Input Signal Handling

The AD9887 has three high-impedance analog input pins for the Red, Green, and Blue channels. They will accommodate signals ranging from 0.5 V to 1.0 V p-p.

Signals are typically brought onto the interface board via a DVI-I connector, a 15-lead D connector, or BNC connectors. The AD9887 should be located as close as practical to the input connector. Signals should be routed via matched-impedance traces (normally 75 Ω) to the IC input pins.

At that point the signal should be resistively terminated (75 Ω to the signal ground return) and capacitively coupled to the AD9887 inputs through 47 nF capacitors. These capacitors form part of the dc restoration circuit.

In an ideal world of perfectly matched impedances, the best performance can be obtained with the widest possible signal bandwidth. The wide bandwidth inputs of the AD9887 (330 MHz) can track the input signal continuously as it moves from one pixel level to the next, and digitize the pixel during a long, flat pixel time. In many systems, however, there are mismatches, reflections, and noise, which can result in excessive ringing and distortion of the input waveform. This makes it more difficult to establish a sampling phase that provides good image quality. It has been shown that a small inductor in series with the input is effective in rolling off the input bandwidth slightly, and providing a high quality signal over a wider range of conditions. Using a Fair-Rite #2508051217Z0 High-Speed Signal Chip Bead inductor in the circuit of Figure 1 gives good results in most applications.

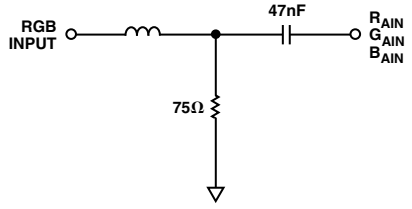

Figure 1. Analog Input Interface Circuit

HSYNC, VSYNC Inputs

The AD9887 receives a horizontal sync signal and uses it to generate the pixel clock and clamp timing. It is possible to operate the AD9887 without applying HSYNC (using an external clock, external clamp) but a number of features of the chip will be unavailable, so it is recommended that HSYNC be provided. This can be either a sync signal directly from the graphics source, or a preprocessed TTL or CMOS level signal.

The HSYNC input includes a Schmitt trigger buffer and is capable of handling signals with long rise times, with superior noise immunity. In typical PC-based graphic systems, the sync signals are simply TTL-level drivers feeding unshielded wires in the monitor cable. As such, no termination is required or desired.

When the VSYNC input is selected as the source for V_{SYNC}, it is used for COAST generation and is passed through to the VSOUT pin.

Serial Control Port

The serial control port is designed for 3.3 V logic. If there are 5 V drivers on the bus, these pins should be protected with 150 Ω series resistors placed between the pull-up resistors and the input pins.

Output Signal Handling

The digital outputs are designed and specified to operate from a 3.3 V power supply (V_{DD}). They can also work with a V_{DD} as low as 2.5 V for compatibility with other 2.5 V logic.

Clamping

RGB Clamping

To digitize the incoming signal properly, the dc offset of the input must be adjusted to fit the range of the on-board A/D converters.

Most graphics systems produce RGB signals with black at ground and white at approximately 0.75 V. However, if sync signals are embedded in the graphics, the sync tip is often at ground and black is at 300 mV. The white level will then be approximately 1.0 V. Some common RGB line amplifier boxes use emitter-follower buffers to split signals and increase drive capability. This introduces a 700 mV dc offset to the signal, which is removed by clamping for proper capture by the AD9887.

The key to clamping is to identify a portion (time) of the signal when the graphic system is known to be producing black. Originating from CRT displays, the electron beam is "blanked" by sending a black level during horizontal retrace to prevent disturbing the image. Most graphics systems maintain this format of sending a black level between active video lines.

An offset is then introduced which results in the A/D converters producing a black output (code 00h) when the known black input is present. The offset then remains in place when other signal levels are processed, and the entire signal is shifted to eliminate offset errors.

In systems with embedded sync, a blacker-than-black signal (HSYNC) is produced briefly to signal the CRT that it is time to begin a retrace. For obvious reasons, it is important to avoid

clamping on the tip of HSYNC. Fortunately, there is virtually always a period following HSYNC called the back porch where a good black reference is provided. This is the time when clamping should be done.

The clamp timing can be established by exercising the CLAMP pin at the appropriate time (with EXTCLMP = 1). The polarity of this signal is set by the Clamp Polarity bit.

An easier method of clamp timing employs the AD9887 internal clamp timing generator. The Clamp Placement register is programmed with the number of pixel clocks that should pass after the trailing edge of HSYNC before clamping starts. A second register (Clamp Duration) sets the duration of the clamp. These are both 8-bit values, providing considerable flexibility in clamp generation. The clamp timing is referenced to the trailing edge of HSYNC, the back porch (black reference) always follows HSYNC. A good starting point for establishing clamping is to set the clamp placement to 08h (providing eight pixel periods for the graphics signal to stabilize after sync) and set the clamp duration to 14h (giving the clamp 20 pixel periods to reestablish the black reference).

The value of the external input coupling capacitor affects the performance of the clamp. If the value is too small, there can be an amplitude change during a horizontal line time (between clamping intervals). If the capacitor is too large, it will take excessively long for the clamp to recover from a large change in incoming signal offset. The recommended value (47 nF) results in recovery from a step error of 100 mV to within 1/2 LSB in 10 lines using a clamp duration of 20 pixel periods on a 60 Hz SXGA signal.

YUV Clamping

YUV signals are slightly different from RGB signals in that the dc reference level (black level in RGB signals) will be at the midpoint of the U and V video signal. For these signals it can be necessary to clamp to the midscale range of the A/D converter range (80h) rather than bottom of the A/D converter range (00h).

Clamping to midscale rather than ground can be accomplished by setting the clamp select bits in the serial bus register. Each of the three converters has its own selection bit so that they can be clamped to either midscale or ground independently. These bits are located in Register 0Fh and are Bits 0–2.

The midscale reference voltage that each A/D converter clamps to is provided independently on the $R_{MIDSC}V$, $G_{MIDSC}V$, and $B_{MIDSC}V$ pins. Each converter must have its own midscale reference because both offset adjustment and gain adjustment for each converter will affect the dc level of midscale.

During clamping, the Y and V converters are clamped to their respective midscale reference input. These inputs are pins $B_{CLAMP}V$, and $R_{CLAMP}V$ for the U and V converters respectively. The typical connections for both RGB and YUV clamping are shown below in Figure 2. Note: if midscale clamping is not required, all of the midscale voltage outputs should still be connected to ground through a 0.1 µF capacitor.

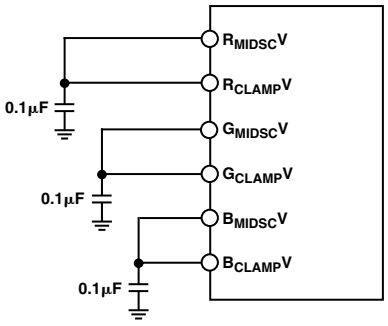

Figure 2. Typical Clamp Configuration for RBG/YUV Applications

Gain and Offset Control

The AD9887 can accommodate input signals with inputs ranging from 0.5 V to 1.0 V full scale. The full-scale range is set in three 8-bit registers (Red Gain, Green Gain, and Blue Gain).

A code of 0 establishes a minimum input range of 0.5 V; 255 corresponds with the maximum range of 1.0 V. Note that *increasing* the gain setting results in an image with *less* contrast.

The offset control shifts the entire input range, resulting in a change in image brightness. Three 7-bit registers (Red Offset, Green Offset, Blue Offset) provide independent settings for each channel.

The offset controls provide a ±63 LSB adjustment range. This range is connected with the full-scale range, so if the input range is doubled (from 0.5 V to 1.0 V) then the offset step size is also doubled (from 2 mV per step to 4 mV per step).

Figure 3 illustrates the interaction of gain and offset controls. The magnitude of an LSB in offset adjustment is proportional to the full-scale range, so changing the full-scale range also changes the offset. The change is minimal if the offset setting is near midscale. When changing the offset, the full-scale *range* is not affected, but the full-scale *level* is shifted by the same amount as the zero-scale level.

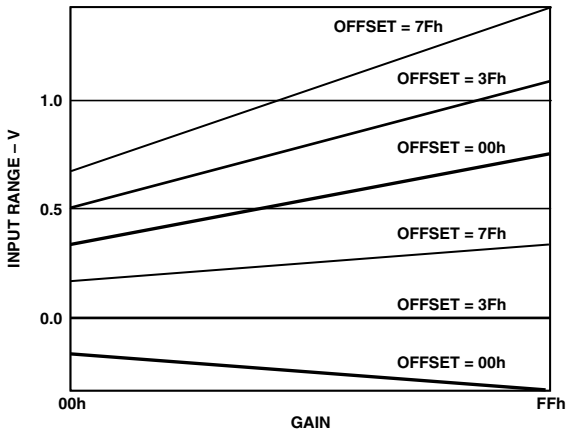

Figure 3. Gain and Offset Control

Sync-on-Green

The Sync-on-Green input operates in two steps. First, it sets a baseline clamp level from the incoming video signal with a negative peak detector. Second, it sets the Sync trigger level (nominally 150 mV above the negative peak). The exact trigger level is variable and can be programmed via register 11H. The Sync-on-Green input must be ac-coupled to the green analog input through its own capacitor as shown in Figure 4. The value of the capacitor must be 1 nF ±20%. If Sync-on-Green is not used, this connection is not required and SOGIN should be left unconnected. (Note: The Sync-on-Green signal is always negative polarity.) Please refer to the Sync Processing section for more information.

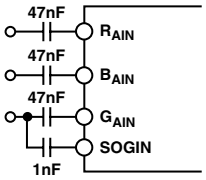

Figure 4. Typical Clamp Configuration for RGB/YUV Applications

Clock Generation

A Phase Locked Loop (PLL) is employed to generate the pixel clock. The HSYNC input provides a reference frequency for the PLL. A Voltage Controlled Oscillator (VCO) generates a much higher pixel clock frequency. This pixel clock is divided by the PLL divide value (Registers 01H and 02H) and phase compared with the Hsync input. Any error is used to shift the VCO frequency and maintain lock between the two signals.

The stability of this clock is a very important element in providing the clearest and most stable image. During each pixel time, there is a period when the signal is slewing from the old pixel amplitude and settling at its new value. Then there is a time when the input voltage is stable, before the signal must slew to a new value (see Figure 5). The ratio of the slewing time to the stable time is a function of the bandwidth of the graphics DAC and the bandwidth of the transmission system (cable and termination). It is also a function of the overall pixel rate. Clearly, if the dynamic characteristics of the system remain fixed, the slewing and settling times are likewise fixed. This time must be subtracted from the total pixel period, leaving the stable period. At higher pixel frequencies, the total cycle time is shorter, and the stable pixel time becomes shorter as well.

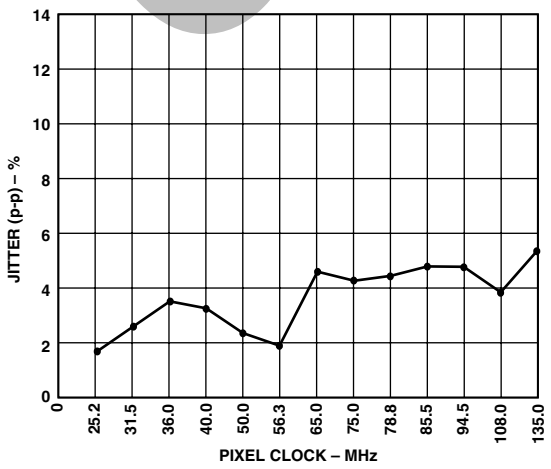

Figure 6. Pixel Clock Jitter vs. Frequency

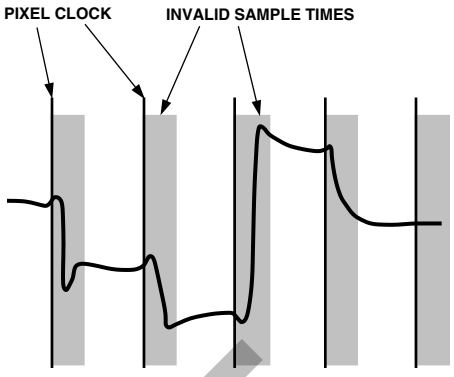

Figure 5. Pixel Sampling Times

Any jitter in the clock reduces the precision with which the sampling time can be determined, and must also be subtracted from the stable pixel time.

Considerable care has been taken in the design of the AD9887's clock generation circuit to minimize jitter. As indicated in Figure 6, the clock jitter of the AD9887 is less than 6% of the total pixel time in all operating modes, making the reduction in the valid sampling time due to jitter negligible.

The PLL characteristics are determined by the loop filter design, by the PLL charge pump current and by the VCO range setting. The loop filter design is illustrated in Figure 7. Recommended settings of VCO range and charge pump current for VESA standard display modes are listed in Table VII.

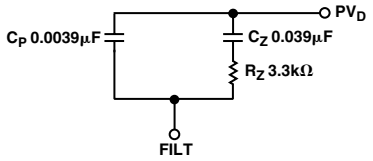

Figure 7. PLL Loop Filter Detail

Four programmable registers are provided to optimize the performance of the PLL. These registers are:

1. The 12-Bit Divisor Register. The input Hsync frequencies range from 15 kHz to 110 kHz. The PLL multiplies the frequency of the Hsync signal, producing pixel clock frequencies in the range of 12 MHz to 140 MHz. The Divisor Register controls the exact multiplication factor. This register may be set to any value between 221 and 4095. (The divide ratio that is actually used is the programmed divide ratio plus one.)
2. The 2-Bit VCO Range Register. To lower the sensitivity of the output frequency to noise on the control signal, the VCO operating frequency range is divided into four overlapping regions. The VCO Range register sets this operating range. Because there are only four possible regions, only the two least-significant bits of the VCO Range register are used. The frequency ranges for the lowest and highest regions are shown in Table V.

Table V. VCO Frequency Ranges

PV1	PV0	Pixel Clock Range (MHz)	K_{VCO} Gain (MHz/V)
0	0	12–35	150
0	1	35–70	150
1	0	70–110	150
1	1	110–140	180

Table VI. Charge Pump Current/Control Bits

Ip2	Ip1	Ip0	Current (μA)
0	0	0	50
0	0	1	100
0	1	0	150
0	1	1	250
1	0	0	350
1	0	1	500
1	1	0	750
1	1	1	1500

3. The 3-Bit Charge Pump Current Register. This register allows the current that drives the low pass loop filter to be varied. The possible current values are listed in Table VI. provides 32 phase-shift steps of 11.25° each. The Hsync signal with an identical phase shift is available through the HSOUT pin. Phase adjustment is still available if the pixel clock is being provided externally.
4. The 5-Bit Phase Adjust Register. The phase of the generated sampling clock may be shifted to locate an optimum sampling point within a clock cycle. The Phase Adjust register

The COAST allows the PLL to continue to run at the same frequency, in the absence of the incoming Hsync signal. This may be used during the vertical sync period, or any other time that the Hsync signal is unavailable. The polarity of the COAST signal may be set through the Coast Polarity Bit. Also, the polarity of the Hsync signal may be set through the HSYNC polarity Bit. If not using automatic polarity detection, the HSYNC and COAST polarity bits should be set to match the Polarity of their respective signals.

Table VII. Recommended VCO Range and Charge Pump Current Settings for Standard Display Formats

Standard	Resolution	Refresh Rate (Hz)	Horizontal Frequency (kHz)	Pixel Rate (MHz)	VCORNGE	CURRENT
VGA	640 × 480	60	31.5	25.175	00	101
		72	37.7	31.500	00	101
		75	37.5	31.500	00	110
		85	43.3	36.000	00	110
SVGA	800 × 600	56	35.1	36.000	00	101
		60	37.9	40.000	01	101
		72	48.1	50.000	01	101
		75	46.9	49.500	01	101
		85	53.7	56.250	01	110
XGA	1024 × 768	60	48.4	65.000	01	110
		70	56.5	75.000	10	101
		75	60.0	78.750	10	101
		80	64.0	85.500	10	101
		85	68.3	94.500	10	101
SXGA	1280 × 1024	60	64.0	108.000	10	110
		75	80.0	135.000	11	110
		85	91.1	157.500*	10	110
UXGA	1600 × 1200	60	75.0	162.000*	10	110
		65	81.3	175.500*	10	110
		70	87.5	189.000*	10	110
		75	93.8	202.500*	10	110
		85	106.3	229.500*	11	110

*Graphics sampled at one-half the incoming pixel rate using Alternate Pixel Sampling mode.

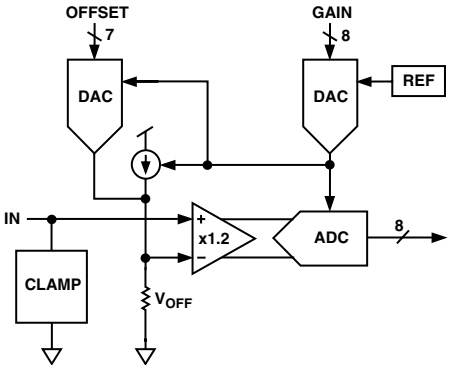

Figure 8. ADC Block Diagram (Single Channel Output)

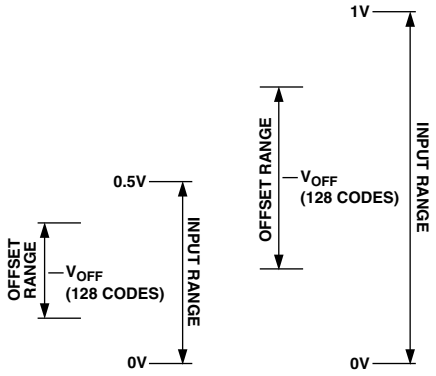

Figure 9. Relationship of Offset Range to Input Range

SCAN Function

The SCAN function is intended as a pseudo JTAG function for manufacturing test of the board. The ordinary operation of the AD9887 is disabled during SCAN.

To enable the SCAN function, set register 14h, bit 2 to 1. To SCAN in data to all 48 digital outputs, apply 48 serial bits of data and 48 clocks (typically 5 MHz, max of 20 MHz) to the $SCAN_{IN}$ and $SCAN_{CLK}$ pins respectively. The data is shifted in on the rising edge of $SCAN_{CLK}$. The first serial bit shifted in will appear at the RED A<7> output after one clock cycle. After 48 clocks, the first bit is shifted all the way to the BLU B<0>. The 48th bit will now be at the RED A<7> output. If $SCAN_{CLK}$ continues after 48 cycles, the data will continue to be shifted from RED A<7> to BLU B<0> and will come out of the $SCAN_{OUT}$ pin as serial data on the falling edge of $SCAN_{CLK}$. This is illustrated in Figure 10. A setup time (t_{SU}) of 3 ns should be plenty and no hold time (t_{HOLD}) is required (≥ 0 ns). This is illustrated in Figure 11.

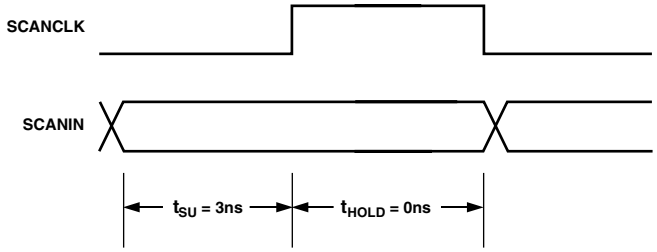

Figure 11. SCAN Setup and Hold

Alternate Pixel Sampling Mode

A Logic 1 input on Clock Invert (CKINV, Pin 94) inverts the nominal ADC clock. CKINV can be switched between frames to implement the alternate pixel sampling mode. This allows higher effective image resolution to be achieved at lower pixel rates but with lower frame rates.

On one frame, only even pixels are digitized. On the subsequent frame, odd pixels are sampled. By reconstructing the entire frame in the graphics controller, a complete image can be reconstructed. This is very similar to the interlacing process that is employed in broadcast television systems, but the interlacing is vertical instead of horizontal. The frame data is still presented to the display at the full desired refresh rate (usually 60 Hz) so no flicker artifacts are added.

O	E	O	E	O	E	O	E	O	E	O	E
O	E	O	E	O	E	O	E	O	E	O	E
O	E	O	E	O	E	O	E	O	E	O	E
O	E	O	E	O	E	O	E	O	E	O	E
O	E	O	E	O	E	O	E	O	E	O	E
O	E	O	E	O	E	O	E	O	E	O	E
O	E	O	E	O	E	O	E	O	E	O	E
O	E	O	E	O	E	O	E	O	E	O	E
O	E	O	E	O	E	O	E	O	E	O	E
O	E	O	E	O	E	O	E	O	E	O	E
O	E	O	E	O	E	O	E	O	E	O	E

Figure 12. Odd and Even Pixels in a Frame

O1	O1	O1	O1	O1	O1
O1	O1	O1	O1	O1	O1
O1	O1	O1	O1	O1	O1
O1	O1	O1	O1	O1	O1
O1	O1	O1	O1	O1	O1
O1	O1	O1	O1	O1	O1
O1	O1	O1	O1	O1	O1
O1	O1	O1	O1	O1	O1
O1	O1	O1	O1	O1	O1
O1	O1	O1	O1	O1	O1
O1	O1	O1	O1	O1	O1

Figure 13. Odd Pixels from Frame 1

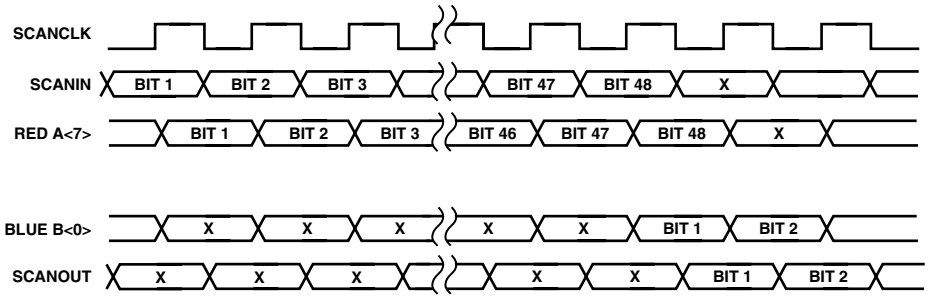

Figure 10. SCAN Timing

E2	E2	E2	E2	E2	E2
E2	E2	E2	E2	E2	E2
E2	E2	E2	E2	E2	E2
E2	E2	E2	E2	E2	E2
E2	E2	E2	E2	E2	E2
E2	E2	E2	E2	E2	E2
E2	E2	E2	E2	E2	E2
E2	E2	E2	E2	E2	E2
E2	E2	E2	E2	E2	E2
E2	E2	E2	E2	E2	E2

Figure 14. Even Pixels from Frame 2

O1E2O1E2O1E2O1E2O1E2O1E2
O1E2O1E2O1E2O1E2O1E2O1E2
O1E2O1E2O1E2O1E2O1E2O1E2
O1E2O1E2O1E2O1E2O1E2O1E2
O1E2O1E2O1E2O1E2O1E2O1E2
O1E2O1E2O1E2O1E2O1E2O1E2
O1E2O1E2O1E2O1E2O1E2O1E2
O1E2O1E2O1E2O1E2O1E2O1E2
O1E2O1E2O1E2O1E2O1E2O1E2
O1E2O1E2O1E2O1E2O1E2O1E2
O1E2O1E2O1E2O1E2O1E2O1E2

Figure 15. Combine Frame Output from Graphics Controller

O3E2O3E2O3E2O3E2O3E2O3E2
O3E2O3E2O3E2O3E2O3E2O3E2
O3E2O3E2O3E2O3E2O3E2O3E2
O3E2O3E2O3E2O3E2O3E2O3E2
O3E2O3E2O3E2O3E2O3E2O3E2
O3E2O3E2O3E2O3E2O3E2O3E2
O3E2O3E2O3E2O3E2O3E2O3E2
O3E2O3E2O3E2O3E2O3E2O3E2
O3E2O3E2O3E2O3E2O3E2O3E2
O3E2O3E2O3E2O3E2O3E2O3E2
O3E2O3E2O3E2O3E2O3E2O3E2

Figure 16. Subsequent Frame from Controller

Timing (Analog Interface)

The following timing diagrams show the operation of the AD9887 analog interface in all clock modes. The part establishes timing by having the sample that corresponds to the pixel digitized when the leading edge of HSYNC occurs sent to the "A" data port. In Dual Channel Mode, the next sample is sent to the "B" port. Future samples are alternated between the "A" and "B" data ports. In Single Channel Mode, data is only sent to the "A" data port, and the "B" port is placed in a high impedance state.

The Output Data Clock signal is created so that its rising edge always occurs between "A" data transitions, and can be used to latch the output data externally.

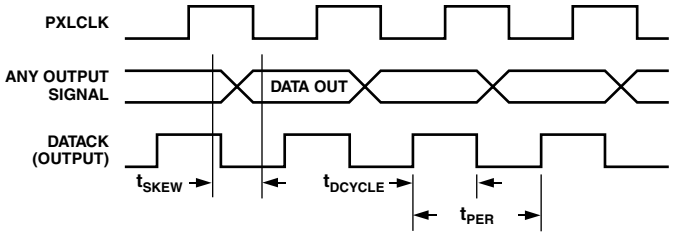

Figure 17. Analog Output Timing

Hsync Timing

Horizontal sync is processed in the AD9887 to eliminate ambiguity in the timing of the leading edge with respect to the phase-delayed pixel clock and data.

The Hsync input is used as a reference to generate the pixel sampling clock. The sampling phase can be adjusted, with respect to Hsync, through a full 360° in 32 steps via the Phase Adjust register (to optimize the pixel sampling time). Display systems use Hsync to align memory and display write cycles, so it is important to have a stable timing relationship between Hsync output (HSOUT) and data clock (DATACK).

Three things happen to Horizontal Sync in the AD9887. First, the polarity of Hsync input is determined and will thus have a known output polarity. The known output polarity can be programmed either active high or active low (Register 04H, Bit 4). Second, HSOUT is aligned with DATACK and data outputs. Third, the duration of HSOUT (in pixel clocks) is set via Register 07H. HSOUT is the sync signal that should be used to drive the rest of the display system.

Coast Timing

In most computer systems, the Hsync signal is provided continuously on a dedicated wire. In these systems, the COAST input and function are unnecessary, and should not be used.

In some systems, however, Hsync is disturbed during the Vertical Sync period (Vsync). In some cases, Hsync pulses disappear. In other systems, such as those that employ Composite Sync (Csync) signals or embed Sync-On-Green (SOG), Hsync includes equalization pulses or other distortions during Vsync. To avoid upsetting the clock generator during Vsync, it is important to ignore these distortions. If the pixel clock PLL sees extraneous pulses, it will attempt to lock to this new frequency, and will have changed frequency by the end of the Vsync period. It will then take a few lines of correct Hsync timing to recover at the beginning of a new frame, resulting in a "tearing" of the image at the top of the display.

The COAST input is provided to eliminate this problem. It is an asynchronous input that disables the PLL input and allows the clock to free-run at its then-current frequency. The PLL can free-run for several lines without significant frequency drift.

Coast can be provided by the graphics controller or it can be internally generated by the AD9887 Sync processing engine.

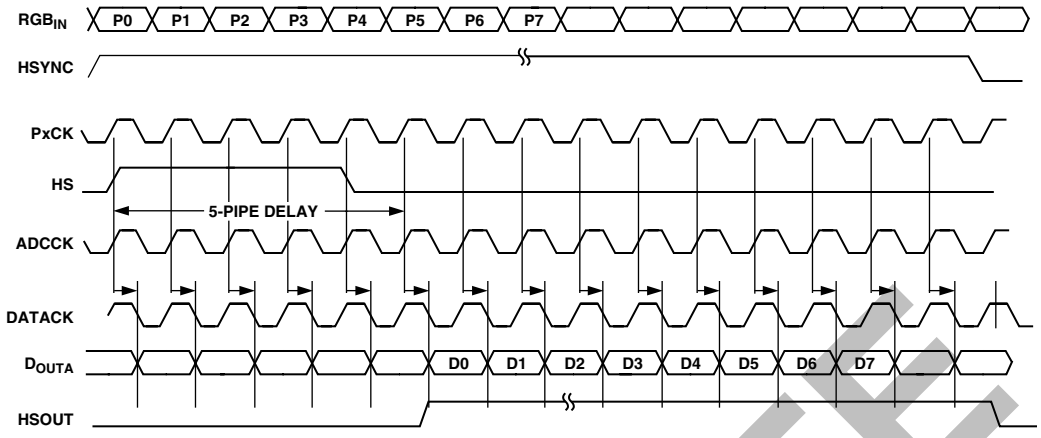

Figure 18. Single Channel Mode (Analog Interface)

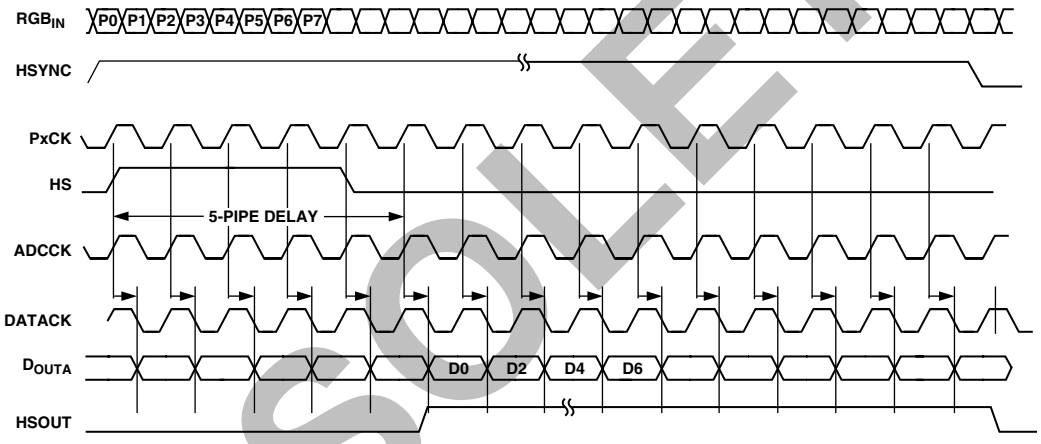

Figure 19. Single Channel Mode, 2 Pixels/Clock (Even Pixels) (Analog Interface)

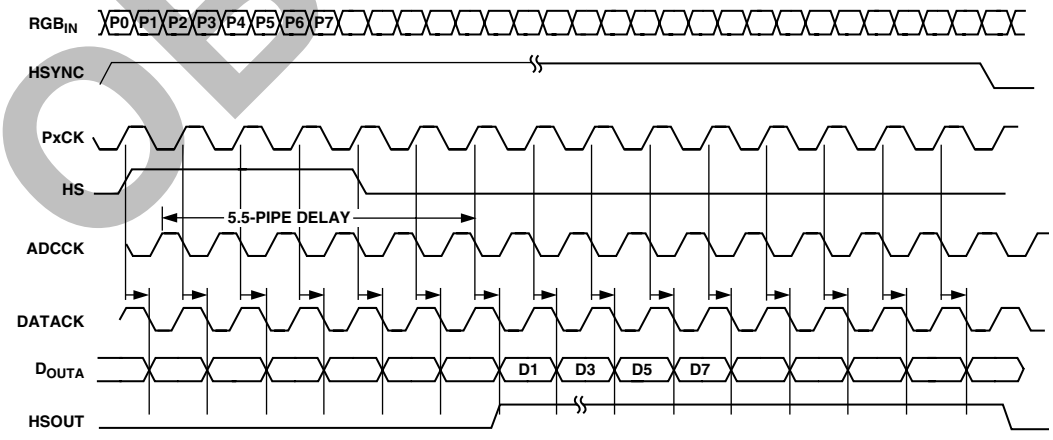

Figure 20. Single Channel Mode, 2 Pixels/Clock (Odd Pixels) (Analog Interface)

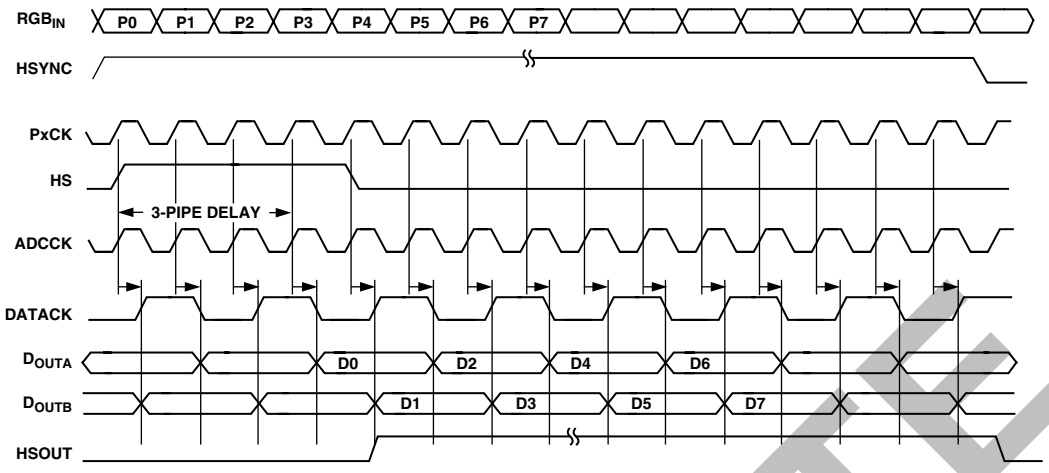

Figure 21. Dual Channel Mode, Interleaved Outputs (Analog Interface), Outphase = 1

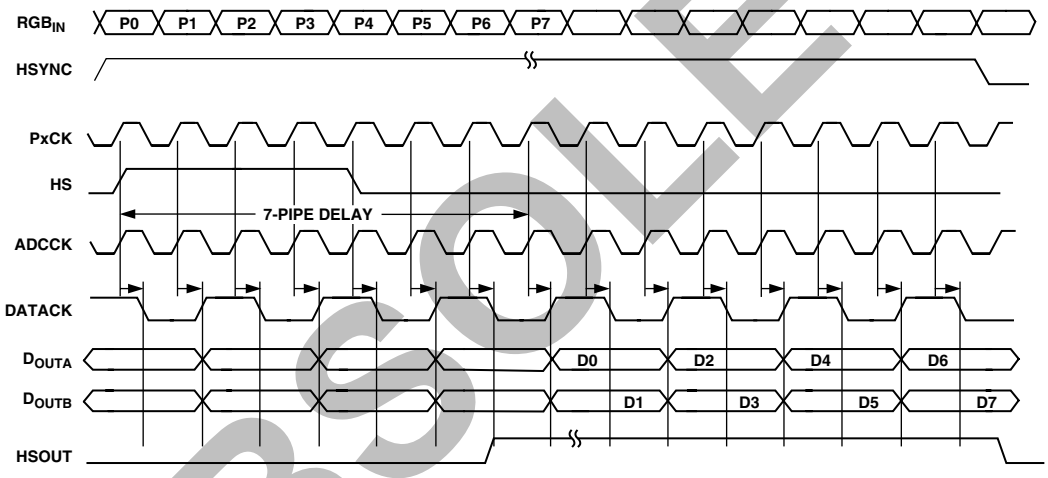

Figure 22. Dual Channel Mode, Parallel Outputs (Analog Interface), Outphase = 1

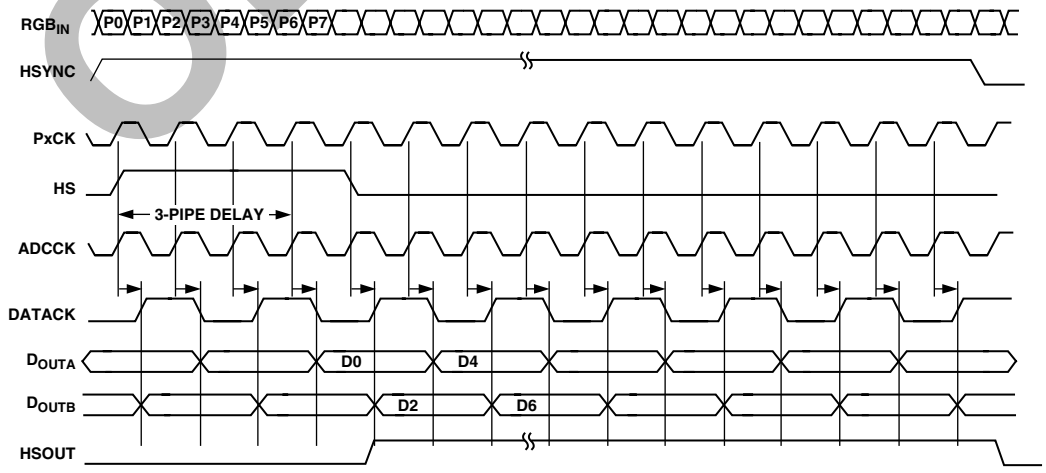

Figure 23. Dual Channel Mode, Interleaved Outputs, 2 Pixels/Clock (Even Pixels) (Analog Interface), Outphase = 1

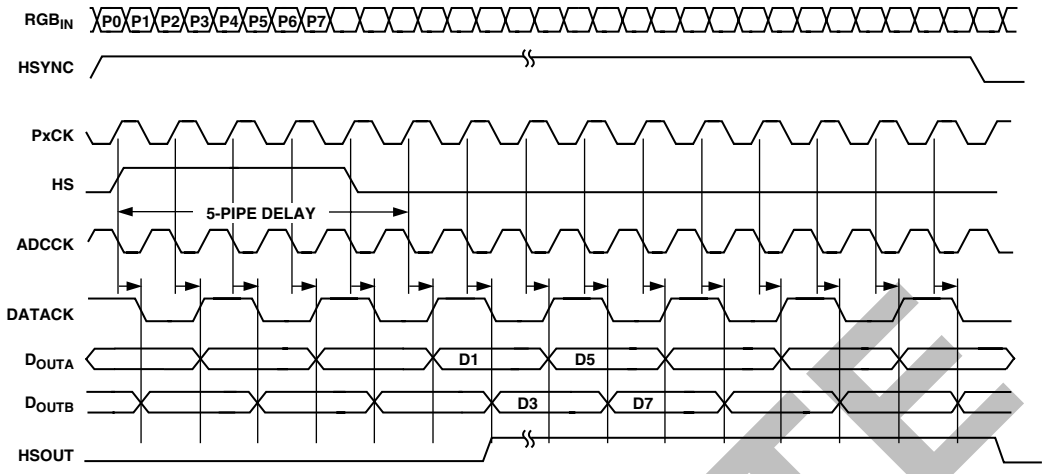

Figure 24. Dual Channel Mode, Interleaved Outputs, 2 Pixels/Clock (Odd Pixels) (Analog Interface), Outphase = 1

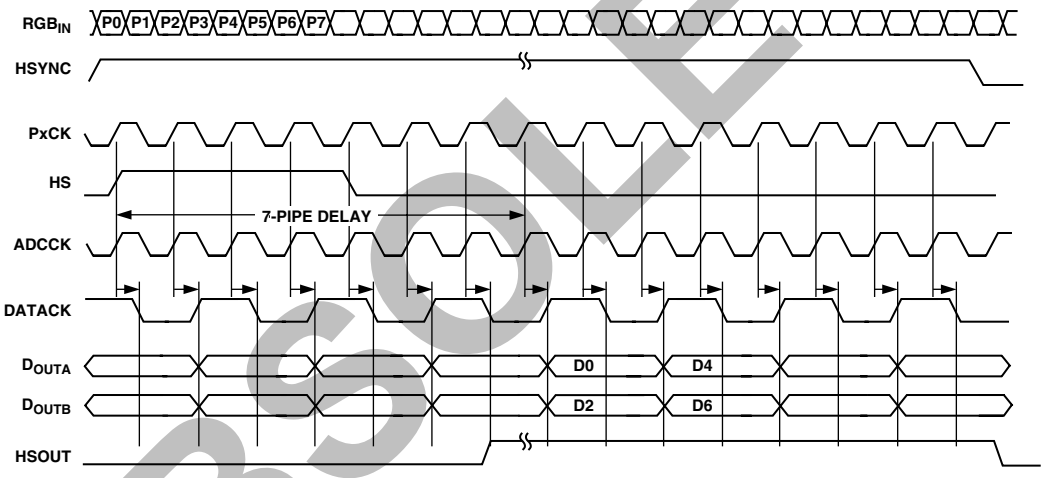

Figure 25. Dual Channel Mode, Parallel Outputs, 2 Pixels/Clock (Even Pixels) (Analog Interface), Outphase = 1

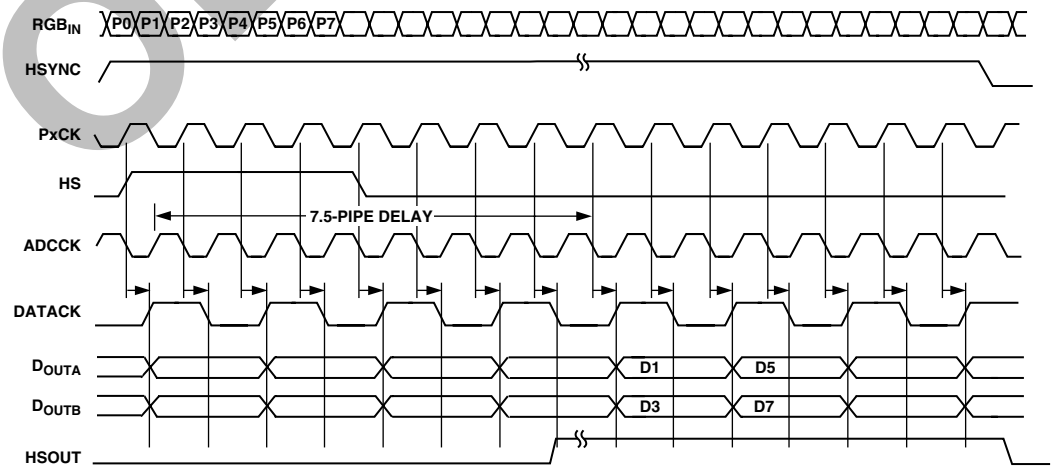

Figure 26. Dual Channel Mode, Parallel Outputs, 2 Pixels/Clock (Odd Pixels) (Analog Interface), Outphase = 1

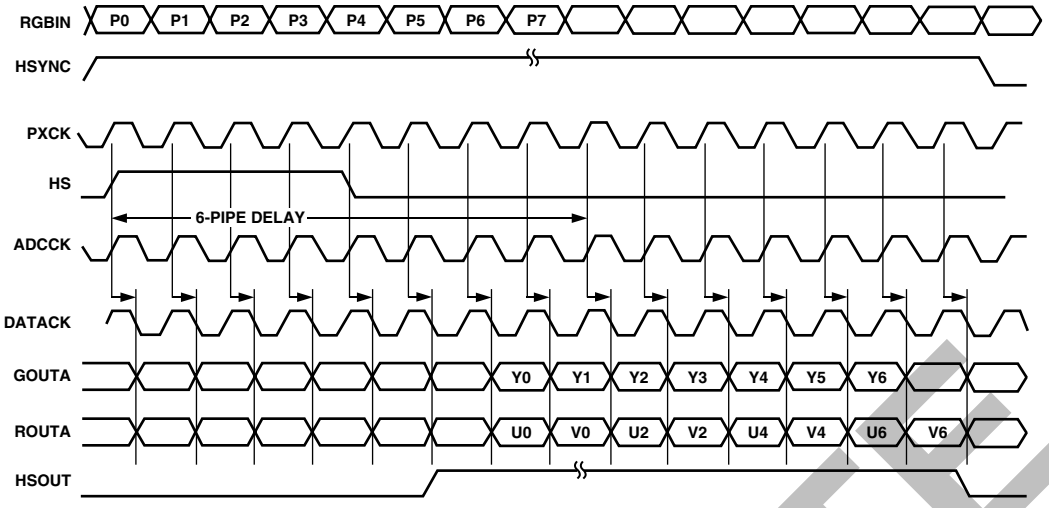

Figure 27. 4:2:2 Output Mode

Table VIII. Digital Interface Pin List

Pin Type	Pin Name	Function	Value	Pin No.
Digital Video Data Inputs	Rx0+	Digital Input Channel 0 True		62
	Rx0–	Digital Input Channel 0 Complement		63
	Rx1+	Digital Input Channel 1 True		59
	Rx1–	Digital Input Channel 1 Complement		60
	Rx2+	Digital Input Channel 2 True		56
	Rx2–	Digital Input Channel Two's Complement		57
Digital Video Clock Inputs	RxC+	Digital Data Clock True		65
	RxC–	Digital Data Clock Complement		66
Termination Control	R_{TERM}	Control Pin for Setting the Internal Termination Resistance		53
Outputs	DE	Data Enable	3.3 V CMOS	137
	HSYNC	HSYNC Output	3.3 V CMOS	139
	VSYNC	VSYNC Output	3.3 V CMOS	138
	CTL0, CTL1, CTL2, CTL3	Decoded Control Bit Outputs	3.3 V CMOS	46–49
Power Supply	V_D	Main Power Supply	3.3 V ± 5%	
	PV_D	PLL Power Supply	3.3 V ± 5%	
	V_{DD}	Output Power Supply	3.3 V or 2.5 V ± 5%	
	GND	Ground Supply	0 V	
	GND	Ground Supply	0 V	

DIGITAL INTERFACE PIN DESCRIPTIONS

Digital Video Data Inputs

Rx0+ Positive Differential Input Video Data (Channel 0)

Rx0– Negative Differential Input Video Data (Channel 0)

Rx1+ Positive Differential Input Video Data (Channel 1)

Rx1– Negative Differential Input Video Data (Channel 1)

Rx2+ Positive Differential Input Video Data (Channel 2)

Rx2– Negative Differential Input Video Data (Channel 2)

These six pins receive three pairs of differential, low voltage swing input pixel data from a digital graphics transmitter.

Digital Video Clock Inputs

RxC+ Positive Differential Input Video Clock

RxC– Negative Differential Input Video Clock

These two pins receive the differential, low voltage swing input pixel clock from a digital graphics transmitter.

Termination Control

R_{TERM} Internal Termination Set Pin

This pin is used to set the termination resistance for all of the digital interface high-speed inputs. To set, place a resistor of value equal to 10× the desired input termination resistance between this pin (Pin 53) and ground supply. Typically, the value of this resistor should be 500 Ω.

Outputs

DE Data Enable Output

This pin outputs the state of data enable, (DE). The AD9887 decodes DE from the incoming stream of data. The DE signal will be HIGH during active video and will be LOW while there is no active video.

Power Supply

V_D Main Power Supply

It should be as quiet and as filtered as possible.

PV_D PLL Power Supply

It should be as quiet and as filtered as possible.

V_{DD} Outputs Power Supply

The power for the data and clock outputs. It can run at 3.3 V or 2.5 V.

THEORY OF OPERATION (DIGITAL INTERFACE)

Capturing of the Encoded Data

The first step in recovering the encoded data is to capture the raw data. To accomplish this, the AD9887 employs a high-speed Phase Locked Loop (PLL), to generate clocks capable of oversampling the data at the correct frequencies. The data capture circuitry continuously monitors the incoming data during horizontal and vertical blanking times (when DE is low), and independently selects the best sampling phase for each data channel. The phase information is stored and used until the next blanking period (one video line).

Data Frames

The digital interface data is captured in groups of 10 bits each, called a data frame. During the active data period, each frame is made up the nine encoded video data bits and one dc balancing bit. The data capture block receives this data serially, but outputs each frame in parallel 10-bit words.

Special Characters

During periods of horizontal or vertical blanking time (when DE is low), the digital transmitter will transmit special characters. The AD9887 will receive these characters and use them to set the video frame boundaries and the phase recovery loop for each channel. There are four special characters that can be received. They are used to identify the top, bottom, left side, and right side of each video frame. The data receiver can differentiate these special characters from active data because the special characters have a different number of transitions per data frame.

Channel Resynchronization

The purpose of the channel resynchronization block is to resynchronize the three data channels to a single internal data clock. Coming into this block, all three data channels can be on different phases of the three times oversampling PLL clock (0°, 120°, and 240°). This block can resynchronize the channels from a worst-case skew of one full input period (8.93 ns at 112 MHz).

Data Decoder

The data decoder receives frames of data and sync signals from the data capture block (in 10-bit parallel words), and decodes them into groups of eight RGB/YUV bits, two control bits, and a data enable bit (DE).

GENERAL TIMING DIAGRAMS (DIGITAL INTERFACE)

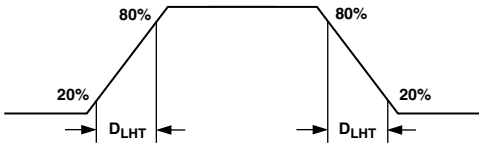

Figure 28. Digital Output Rise and Fall Time

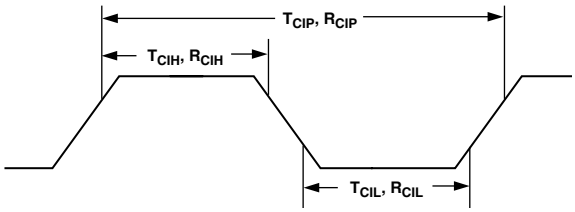

Figure 29. Clock Cycle/High/Low Times

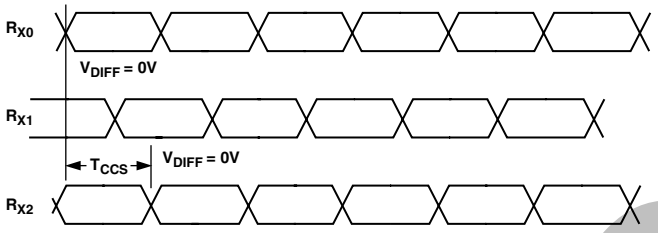

Figure 30. Channel-to-Channel Skew Timing

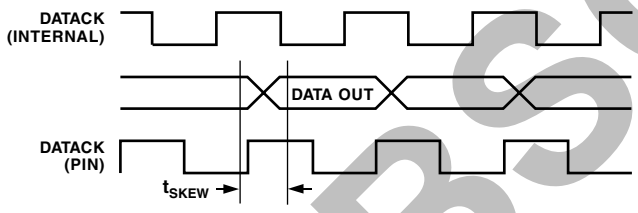

Figure 31. DVI Output Timing

TIMING MODE DIAGRAMS (DIGITAL INTERFACE)

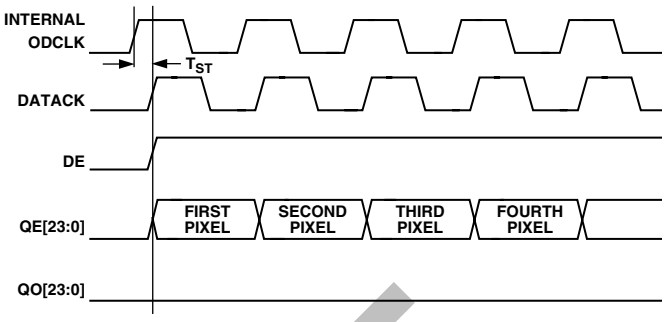

Figure 32. 1 Pixel per Clock (DATACK Inverted)

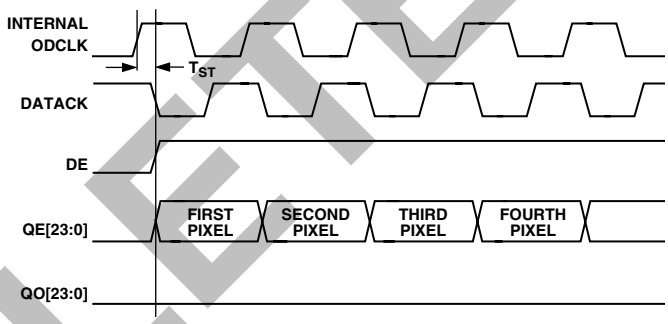

Figure 33. 1 Pixels per Clock (DATACK Inverted)

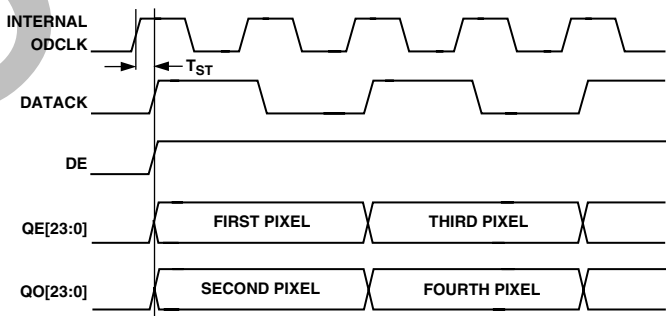

Figure 34. 2 Pixel per Clock

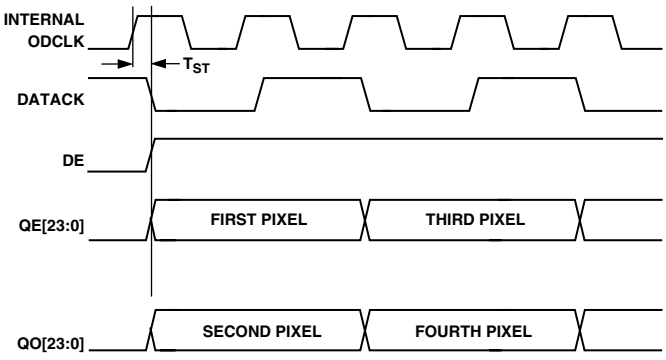

Figure 35. 2 Pixels per Clock (DATACK Inverted)

2-Wire Serial Register Map

The AD9887 is initialized and controlled by a set of registers, which determine the operating modes. An external controller is employed to write and read the Control Registers through the 2-line serial interface port.

Table IX. Control Register Map

Hex Address	Read and Write or Read Only	Bits	Default Value	Register Name	Function
00H	RO	7:0		Chip Revision	Bits 7 through 4 represent functional revisions to the analog interface. Bits 3 through 0 represent nonfunctional related revisions. Revision 0 = 0000 0000
01H	R/$\overline{W}$	7:0	01101001	PLL Div MSB	This register is for Bits [11:4] of the PLL divider. Larger values mean the PLL operates at a faster rate. This register should be loaded first whenever a change is needed. (This will give the PLL more time to lock.) See Note 1.
02H	R/$\overline{W}$	7:4	1101****	PLL Div LSB	Bits [7:4] LSBs of the PLL divider word. See Note 1.
03H	R/$\overline{W}$	7:2	1******* *01***** ***001**	VCO/CPMP	Bit 7—Must be set to 1 for proper device operation. Bits [6:5] VCO Range. Selects VCO frequency range. (See PLL description.) Bits [4:2] Charge Pump Current. Varies the current that drives the low-pass filter. (See PLL description.)
04H	R/$\overline{W}$	7:3	10000***	Phase Adjust	ADC Clock phase adjustment. Larger values mean more delay. (1 LSB = T/32)
05H	R/$\overline{W}$	7:0	10000000	Clamp Placement	Places the Clamp signal an integer number of clock periods after the trailing edge of the Hsync signal.
06H	R/$\overline{W}$	7:0	10000000	Clamp Duration	Number of clock periods that the Clamp signal is actively clamping.
07H	R/$\overline{W}$	7:0	00100000	Hsync Output Pulsewidth	Sets the number of pixel clocks that HSOUT will remain active.
08H	R/$\overline{W}$	7:0	10000000	Red Gain	Controls ADC input range (Contrast) of each respective channel. Bigger values give less contrast.
09H	R/$\overline{W}$	7:0	10000000	Green Gain	
0AH	R/$\overline{W}$	7:0	10000000	Blue Gain	
0BH	R/$\overline{W}$	7:1	1000000*	Red Offset	Controls dc offset (Brightness) of each respective channel. Bigger values decrease brightness.
0CH	R/$\overline{W}$	7:1	1000000*	Green Offset	
0DH	R/$\overline{W}$	7:1	1000000*	Blue Offset	
0EH	R/$\overline{W}$	7:3	1******* *1****** **0***** ***0**** ****0***	Mode Control 1	Bit 7—Channel Mode. Determines Single Channel or Dual Channel Output Mode. (Logic 0 = Single Channel Mode, Logic 1 = Dual Channel Mode.) Bit 6—Output Mode. Determine Interleaved or Parallel Output Mode. (Logic 0 = Interleaved Mode, Logic 1 = Parallel Mode.) Bit 5—OUTPHASE. Determines which port outputs the first data byte after Hsync. (Logic 0 = B Port, Logic 1 = A Port.) Bit 4—Hsync Output polarity. (Logic 0 = Logic High Sync, Logic 1 = Logic Low Sync.) Bit 3—Vsync Output Invert. (Logic 0 = Invert, Logic 1 = No Invert.)