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XRD9825

16-Bit Linear CIS/CCD Sensor Signal Processor with Serial Control

May 2000-3

FEATURES

- 16-Bit Resolution
- One-channel 12MSPS Pixel Rate
- Triple-channel 4MSPS Pixel Rate
- 6-Bit Programmable Gain Amplifier
- 8-Bit Programmable Offset Adjustment
- CIS or CCD Compatibility
- Internal Clamp for CIS or CCD AC Coupled Configurations
- No Missing Codes at 10MHz ADC Clock
- 3.3V or 5V Operation & I/O Compatibility
- Serial Load Control Registers
- Low Power CMOS: 200mW-typ
- Low Cost 20-Lead Packages
- USB Compliant

APPLICATIONS

- Color and Grayscale Flatbed Scanners
- Color and Grayscale Sheetfed Scanners
- Multifunction Peripherals
- Digital Color Copiers
- General Purpose CIS or CCD Imaging
- Low Cost Data Acquisition
- Simple and Direct Interface to Canon 600 DPI Sensors

GENERAL DESCRIPTION

The XRD9825 is a complete linear CIS or CCD sensor signal processor on a single monolithic chip. The XRD9825 includes a high speed 16-bit resolution ADC, a 6-bit Programmable Gain Amplifier with gain adjustment of 1 to 10, and 8-bit programmable input referred offset calibration range of 800mV.

In the CCD configuration the input signal is AC coupled with an external capacitor. An internal clamp sets the black level. In the CIS configuration, the clamp switch can be disabled and the CIS output signal is DC coupled from the CIS sensor to the XRD9825. The CIS signal is level shifted to VRB in order to use the full range of the ADC. In the CIS configuration the input can also be AC coupled similar to the CCD configuration. This enables CIS signals with large black levels to be internally clamped to a DC reference equal to the black level. The DC reference is internally subtracted from the input signal.

The CIS configuration can also be used in other applications that do not require CDS function, such as low cost data acquisition.

ORDERING INFORMATION

Package Type	Temperature Range	Part Number
20-Lead SOIC	0°C to +70°C	XRD9825ACD
20-Lead SSOP	0°C to +70°C	XRD9825ACU

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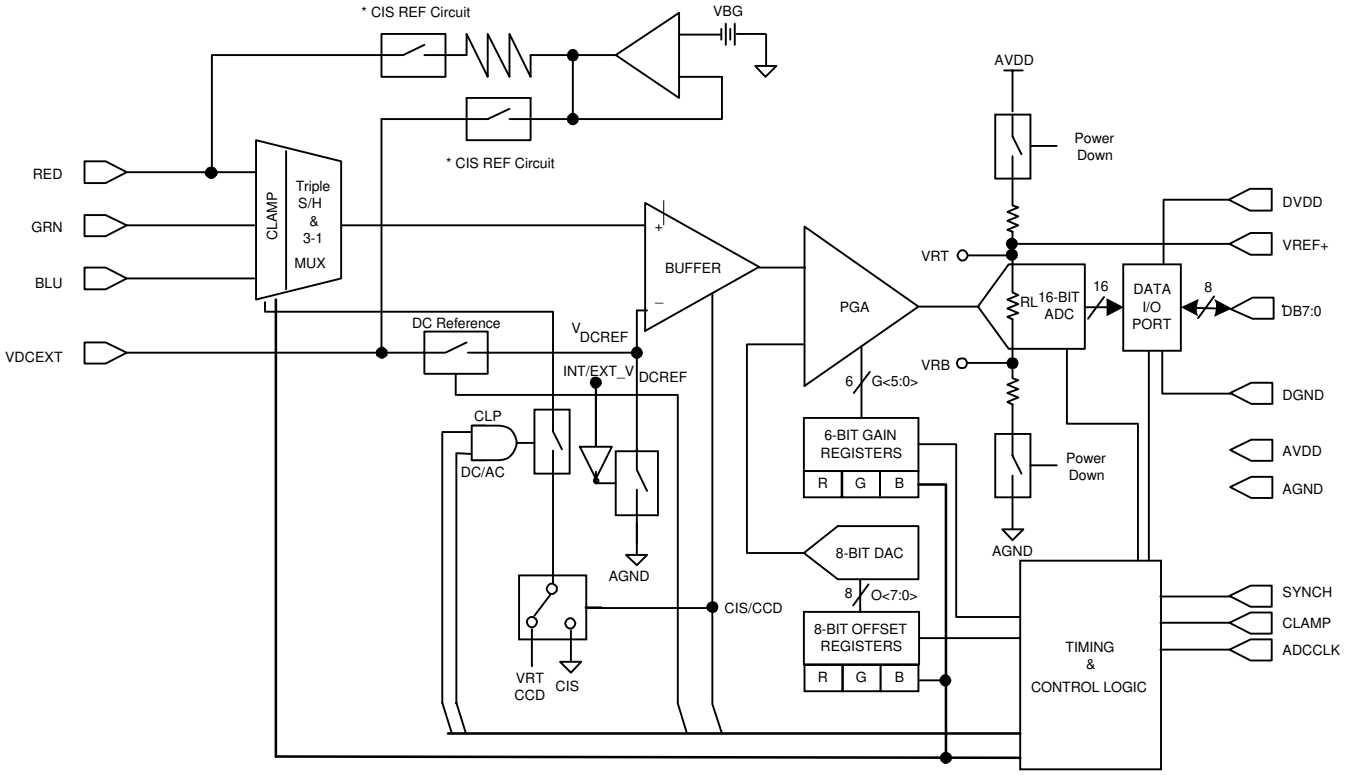
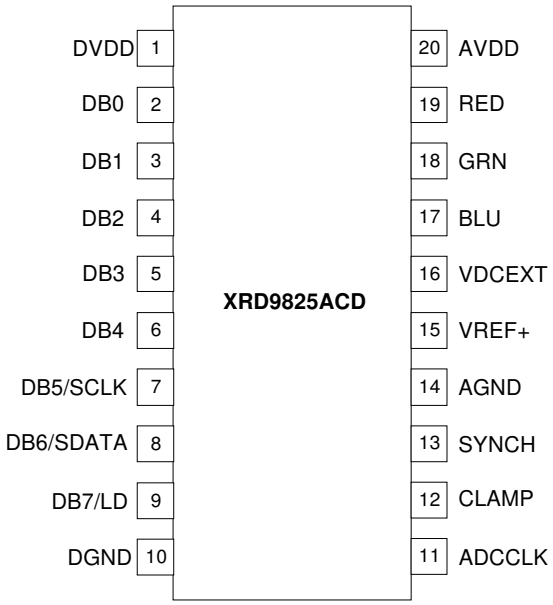


Note: ** For Canon CIS Sensor*

Figure 1. Functional Block Diagram

PIN CONFIGURATION



20-Lead SOIC

PIN DESCRIPTION

Pin #	Symbol	Description
1	DVDD	Digital VDD (for Output Drivers)
2	DB0	Data Output Bit 0
3	DB1	Data Output Bit 1
4	DB2	Data Output Bit 2
5	DB3	Data Output Bit 3
6	DB4	Data Output Bit 4
7	DB5/SCLK	Data Output Bit 5 & Data Input SCLK
8	DB6/SDATA	Data Output Bit 6 & Data Input SDATA
9	DB7/LD	Data Output Bit 7 & LD
10	DGND	Digital Ground (for Output Drivers)
11	ADCCLK	A/D Converter Clock
12	CLAMP	Clamp and Video Sample Clock
13	SYNCH	Start of New Line and Serial Data Input Control
14	AGND	Analog Ground
15	VREF+	A/D Positive Reference for Decoupling Cap
16	VDCEXT	External DC Reference
17	BLU	Blue Input
18	GRN	Green Input
19	RED	Red Input
20	AVDD	Analog Power Supply

ELECTRICAL CHARACTERISTICS

Test Conditions: AV_{DD}=DV_{DD}=5V, ADCCLK=12MHz, 50% Duty Cycle, T_A=25°C unless otherwise specified.

Symbol	Parameter	Min.	Typ.	Max.	Unit	Conditions
Power Supplies						
AV_{DD}	Analog Power Supply	3.0	3.3	5.5	V	(Note 2)
DV_{DD}	Digital I/O Power Supply	3.0	3.3	5.5	V	$DV_{DD} \leq AV_{DD}$
I_{DD}	Supply Current	25	40	60	mA	V_{DD}=5V
IDD_{PD}	Power Down Power Supply Current			50	µA	V_{DD}=5V
ADC Specifications						
RES	Resolution	16			Bits	
F_s	Maximum Sampling Rate	12			MSPS	
DNL	Differential Non-Linearity		-0.7, +1.5		LSB	ADCCLK = 10MHz
			-0.8, +2.0			ADCCLK = 12MHz
V_{RB}	Bottom Reference Voltage		AV_{DD}/10		V	
ΔV_{REF}	Differential Reference Voltage (V_{RT} - V_{RB})	0.3	0.67AV_{DD}		V	
R_L	Ladder Resistance	300	600	780	Ω	
PGA & Offset DAC Specifications						
PGARES	PGA Resolution	6			Bits	
$PGAG_{MIN}$	Minimum Gain	0.950	1.0	1.050	V/V	
$PGAG_{MAX}$	Maximum Gain	9.5	10.0	10.50	V/V	
PGAGD	Gain Adjustment Step Size		0.14		V/V	
V_{BLACK}	Black Level Input Range	-100		500	mV	DC Configuration
DACRES	Offset DAC Resolution	8			Bits	
OFF_{MIN}	Minimum Offset Adjustment	-250	-200	-150	mV	Mode 111, D5=0 (Note 1)
OFF_{MAX}	Maximum Offset Adjustment	+500	+600	+700	mV	Mode 111, D5=0
OFF_{MIN}	Minimum Offset Adjustment	-450	-400	-350	mV	Mode 111, D5=1 (Note 1)
OFF_{MAX}	Maximum Offset Adjustment	+350	+400	+450	mV	Mode 111, D5=1
OFFΔ	Offset Adjustment Step Size		3.125		mV	

Note 1: *The additional ±100 mV of adjustment with respect to the black level input range is needed to compensate for any additional offset introduced by the XRD9825 Buffer/PGA internally.*

Note 2: *It is not recommended to operate the part between 3.6V and 4.4V.*

ELECTRICAL CHARACTERISTICS (CONT'D)
Test Conditions: AV_{DD}=DV_{DD}=5V, ADCCLK=12MHz, 50% Duty Cycle, T_A=25°C unless otherwise specified.

Symbol	Parameter	Min.	Typ.	Max.	Unit	Conditions
Buffer Specifications						
I_{IL}	Input Leakage Current			100	nA	
CIN	Input Capacitance		10		pF	
VIN_{PP}	AC Input Voltage Range	0		AV_{DD}-1.4	V	CIS AC; INT V_{DCREF} Config Reg => XXX010XX Gain=1 (Note 1)
	AC Input Voltage Range	0		ΔV_{REF}	V	CCD AC; INT V_{DCREF} Config Reg => XXX011XX Gain=1 (Note 1)
VIN	DC Input Voltage Range	-0.1		AV_{DD}-1.4	V	CIS DC; INT V_{DCREF} Config Reg => XXX000XX Gain=1 (Note 2)
	DC Input Voltage Range	V_{DCEXT}-0.1		V_{DCEXT}+ ΔV_{REF}	V	CIS DC; EXT V_{DCREF} Config Reg => XXX100XX Gain=1 (Note 3) $V_{DCEXT}+DV_{REF} \leq AV_{DD}$
V_{DCEXT}	External DC Reference	0.3		AV_{DD}/2	V	CIS DC; EXT V_{DCREF} Config Reg => XXX100XX
VIN_{BW}	Input Bandwidth (small signal)		10		MHz	
VIN_{CT}	Channel to Channel Crosstalk		-60	-50	dB	f_{in}=3MHz
Internal Clamp Specifications						
V_{CLAMP}	Clamp Voltage		AGND	50	mV	CIS (AC) Config
		3.5	V_{RT}		V	CCD (AC) Config
R_{INT}	Clamp Switch On Resistance		100	150	Ω	
R_{OFF}	Clamp Switch Off Resistance	10			MΩ	

Note 1: *VIN_{PP} is the signal swing before the external capacitor tied to the MUX inputs.*

Note 2: *The -0.1V minimum is specified in order to accommodate black level signals lower than the external DC reference (clamp) voltage.*

Note 3: *The V_{DCEXT}-0.1V minimum is specified in order to accommodate black level signals lower than the external DC reference voltage.*

ELECTRICAL CHARACTERISTICS (CONT'D)

Test Conditions: AV_{DD}=DV_{DD}= 5V, ADCCLK=6MHz, 50% Duty Cycle, T_A=25°C unless otherwise specified.

Symbol	Parameter	Min.	Typ.	Max.	Unit	Conditions
System Specifications (MUX + Buffer + PGA + ADC)						**Note 1**
SYS_{DNL}	System DNL	-1.0	±0.5	+2.3	LSB	
SYS_{LIN}	System Linearity		±6.0		LSB	
SYS_{GE}	System Gain Error	-5.0		+5.0	%	
IRN	Input Referred Noise		1.5		mV_{rms}	Gain=1
	Input Referred Noise		0.5		mV_{rms}	Gain=10
System Timing Specifications						
tcklw	ADCCLK Low Pulse Width	50	83		ns	
tckhw	ADCCLK High Pulse Width	70	83		ns	
tckpd	ADCCLK Period	120	166		ns	
tsypw	SYNCH Pulse Width	30			ns	
trars	Rising ADCCLK to rising SYNCH	0				SYNCH must rise equal to or after ADCCLK, See Figure 18
tclpw	CLAMP Pulse Width	30			ns	Note 2
Write Timing Specifications						
tsclkw	SCLK Pulse Width	40			ns	
tdz	LD Low to SCLK High	20			ns	
tds	Input Data Set-up Time	20			ns	
tdh	Input Data Hold Time	0			ns	
tdl	SCLK High to LD High	50			ns	
ADC Digital Output Specifications						
tap	Aperture Delay		10		ns	
tdv	Output Data Valid	40			ns	
tsa	SYNCH to ADCCLK	15			ns	3ch Pixel Md
tlat	Latency		8		cycles	Config 00, 11
tlat	Latency		6		pixels	Config 01, 10
Digital Input Specifications						
V_{IH}	Input High Voltage	AV_{DD}-2.5			V	
V_{IL}	Input Low Voltage			1	V	
I_{IH}	High Voltage Input Current		5		µA	
I_{IL}	Low Voltage Input Current		5		µA	
C_{IN}	Input Capacitance		10		pF	

Note 1: *System performance is specified for typical digital system timing specifications.*

Note 2: *The actual minimum 'tclpw' is dependent on the external capacitor value, the CIS output impedance. During 'clamp' operation, sufficient time needs to be allowed for the external capacitor to charge up to the correct operating level. Refer to the description in Theory of Operation, CIS Config.*

ELECTRICAL CHARACTERISTICS (CONT'D)

Test Conditions: AV_{DD}=DV_{DD}=5V, ADCCLK=12MHz, 50% Duty Cycle, T_A=25°C unless otherwise specified.

Symbol	Parameter	Min.	Typ.	Max.	Unit	Conditions
Digital Output Specifications						
V_{OH}	Output High Voltage	80			% DV_{DD}	I_L = 1mA
V_{OL}	Output Low Voltage			20	% DV_{DD}	I_L = -1mA
I_{OZ}	Output High-Z Leakage Current	-10		10	µA	
C_{OUT}	Output Capacitance		10		pF	
SR	Slew Rate (10% to 90% DVDD)	2		15	ns	CL=10pF, DVDD=3.3V

THEORY OF OPERATION

CIS Configuration (Contact Image Sensor)

The XRD9825 has two configurations for CIS applications. Each configuration is set by the control registers accessed through the serial port.

Mode 1. DC Coupled

If the CIS does not have leading or trailing black pixels as shown in Figure 2, then DC couple the CIS output to the XRD9825 input.

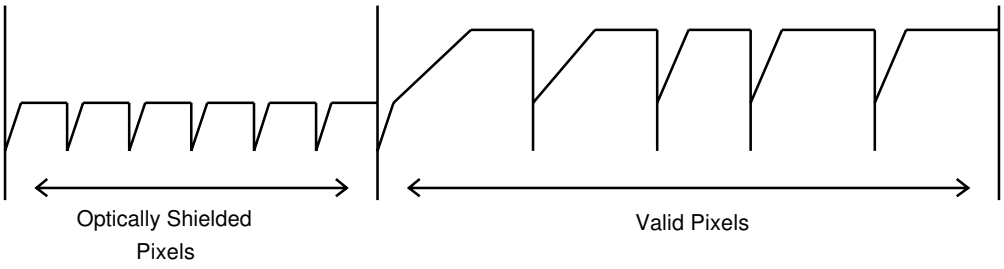


Figure 2. Typical Output CIS Mode

Adjust the offset of the CIS (-100 mV to 500 mV) by setting the internal registers of the XRD9825 to set the black pixel value when the LEDs of the CIS are off. When the LEDs are on, use the XRD9825 Programmable Gain to maximize the ADCs dynamic range. Figure 3, shows a typical application for a CIS with an offset of -100mV to 500mV.

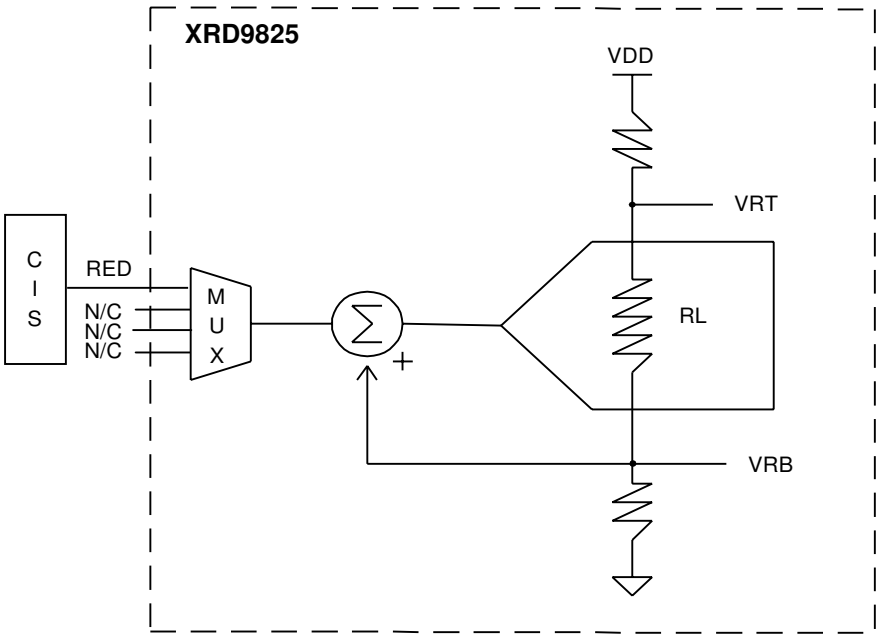


Figure 3. Application with Offset in the Range (-100mv to 500mv)

The input is added to VRB before the signal passes through the ADC. If the CIS output is zero, then the output of the ADC will be zero code. This enables the CIS to be referenced to the bottom ladder reference voltage to use the full range of the ADC.

Some CIS sensors have an output with an offset voltage of greater than 500mV. If the CIS output is beyond the offset range of the XRD9825 (see Offset Control DAC, Pg. 22) set the internal mode registers to external reference. An external reference voltage equal to the value of the CIS offset voltage can be applied to VDCEXT (Figure 4) in order to meet the dynamic range of the XRD9825. Figure 4, is a diagram of the XRD9825 in the external reference mode for CIS, DC coupled applications.

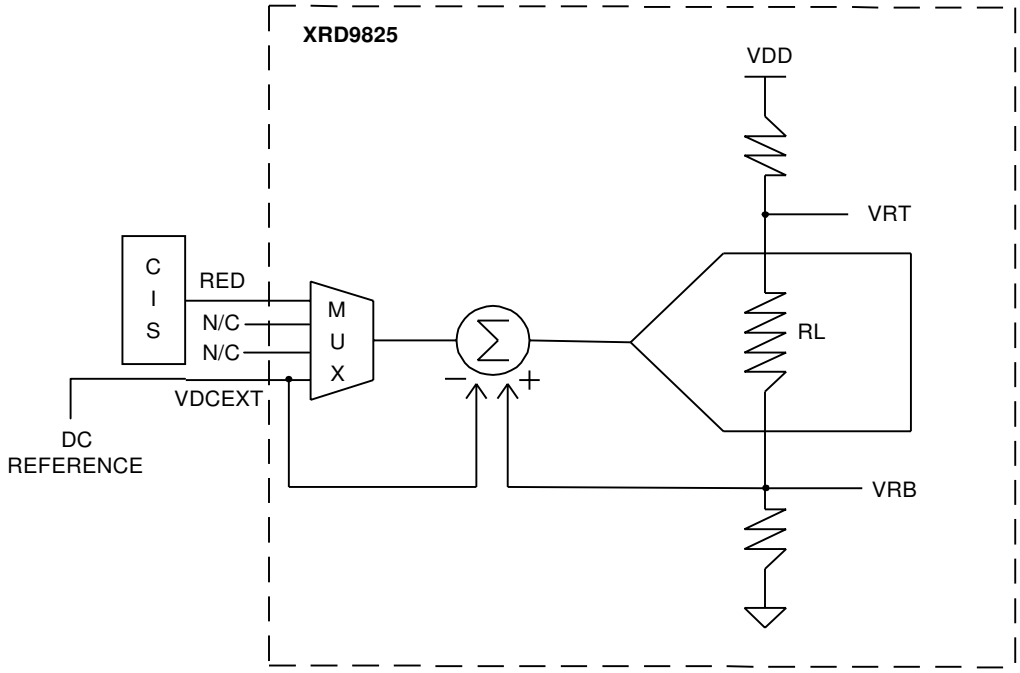


Figure 4. Application with Offset Greater Than (-100mv to 500mv)

The DC reference voltage applied to VDCEXT does not have to be accurate. The internal offset DAC voltage is still used in this mode for fine adjustment. VDCEXT cannot be used as an input from the CIS. Any signal applied to VDCEXT will be subtracted from the output signal of the multiplexer.

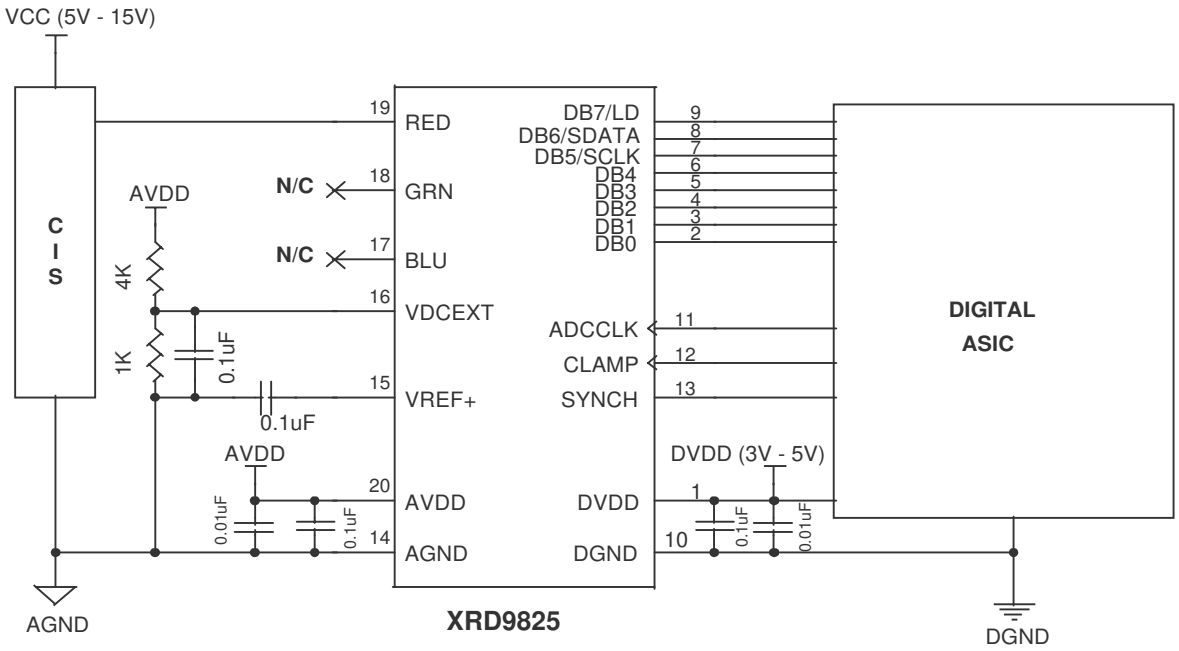


Figure 5. Typical Application Circuitry CIS DC Coupled Non-Inverted Mode

CIS Mode Timing -- DC Coupled
(CLAMP disabled)

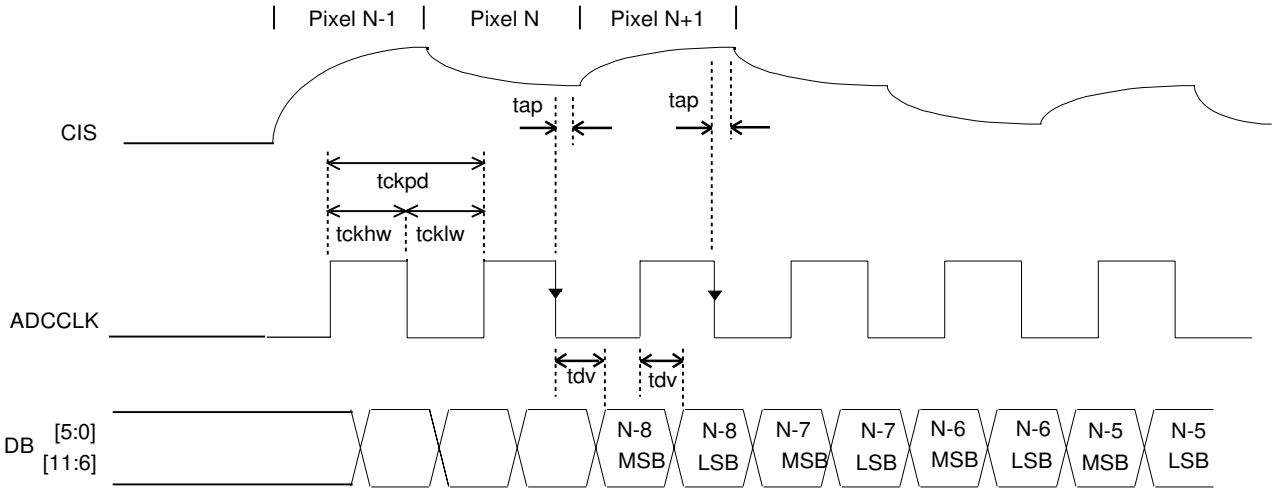


Figure 6. Timing Diagram for Figure 5

ADCCLK	Events
↓	ADC Sample & PGA Start Tracking next Pixel
	MSB Data Out
↑	LSB Data Out
HI	ADC Track PGA Output
LO	ADC Hold/Convert

Table 1.

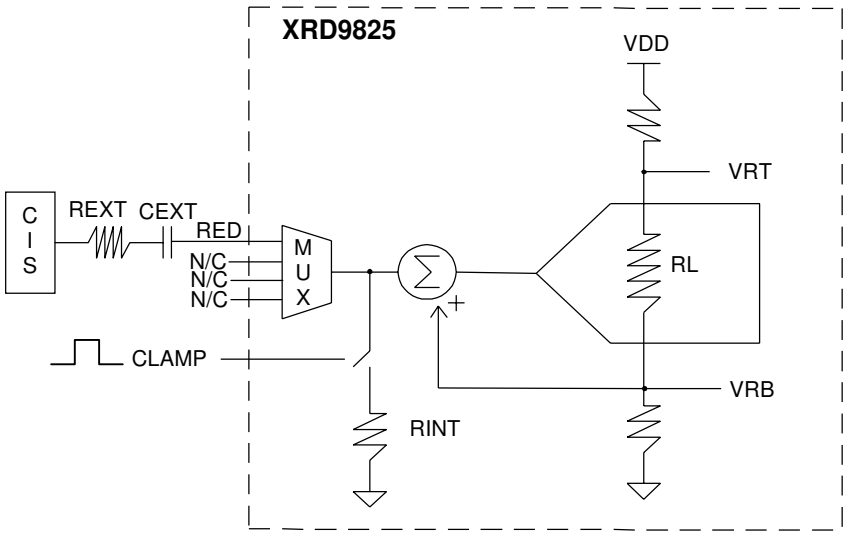


Figure 7. CIS AC Coupled Application

Mode 2. AC Coupled

If the CIS signal has a black reference for the video signal, an external capacitor C_{EXT} is used. When CLAMP (clamp) pin is set high an internal switch allows one side of the external capacitor to be set to ground. It then is level shifted to correspond to the bottom ladder reference voltage of the ADC (Figure 7).

This value corresponds to the black reference of the image sensor. When the CLAMP pin is set back to low, the ADC samples the video signal with respect to the black reference. The typical value for the external capacitor is 100pF. This value should be adjusted according to the time constant (Tc) needed in a particular application. The CLAMP pin has an internal 150 ohm impedance (R_{INT}) which is in series with the external capacitor (C_{EXT}).
Therefore, $Tc = 1/R_{INT}C_{EXT}$

If the input to the external capacitor has a source impedance (R_{EXT}), then:

$T_c = 1/(R_{INT}+R_{EXT})C_{EXT}$

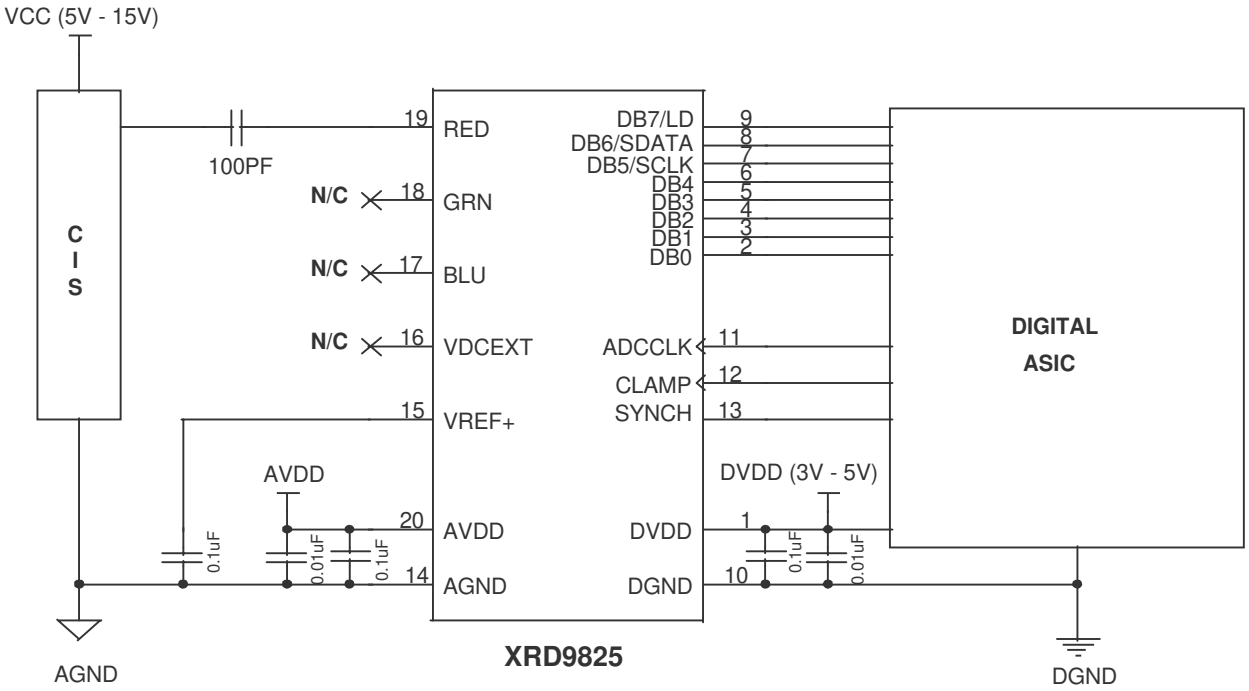
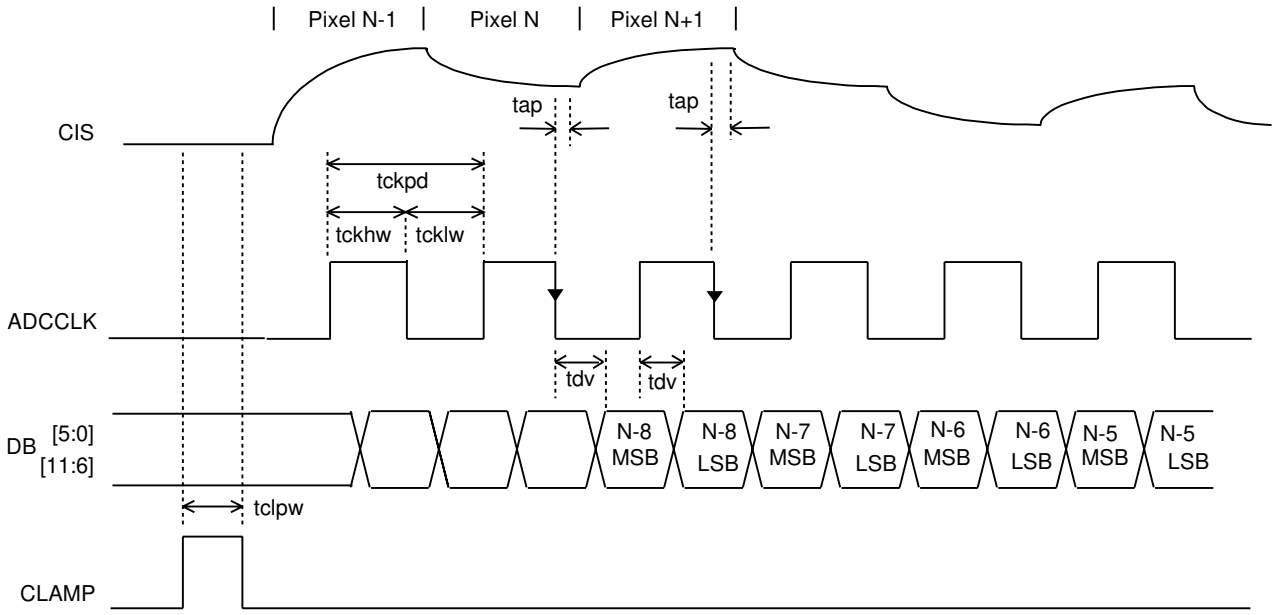


Figure 8. Typical Application Circuitry CIS AC Coupled Non-Inverted

CIS Mode Timing -- AC Coupled
(CLAMP enabled)



Note: *There is an 8 clock latency for the output*

Figure 9. Timing Diagram for Figure 8

ADCCLK	Events
↓	ADC Sample & PGA Start Track of next Pixel MSB Data Out (8 Upper Bits)
↑	LSB Data Out (8 Lower Bits)
HI	ADC Track PGA Output
LO	ADC Hold/Convert

Table 3.

CLAMP	Events
HI	PGA Tracks V_{CLAMP} & C_{EXT} is Charged to
LO	V_{BLACK} - V_{CLAMP}, which is equal to V_{BLACK} PGA Tracks VIN_{PP}

Table 4.

Internal CIS Reference Circuit (DB 4 = 1)

The XRD9825 has an internal register reserved for interfacing to the Canon CIS model number CVA-60216K. When this register is selected, the VDCEXT (Pin 16) becomes an output voltage of 1.24 volts. This voltage can be directly connected to the VREF (Pin 5) of the Canon sensor. This reduces the amount of components needed for biasing the Canon CIS sensor (the external diodes and resistors typically used in this application have been included inside the XRD9825 for this mode of operation). Below is a typical application circuit using the XRD9825 and the Canon CVA-60216K CIS sensor.

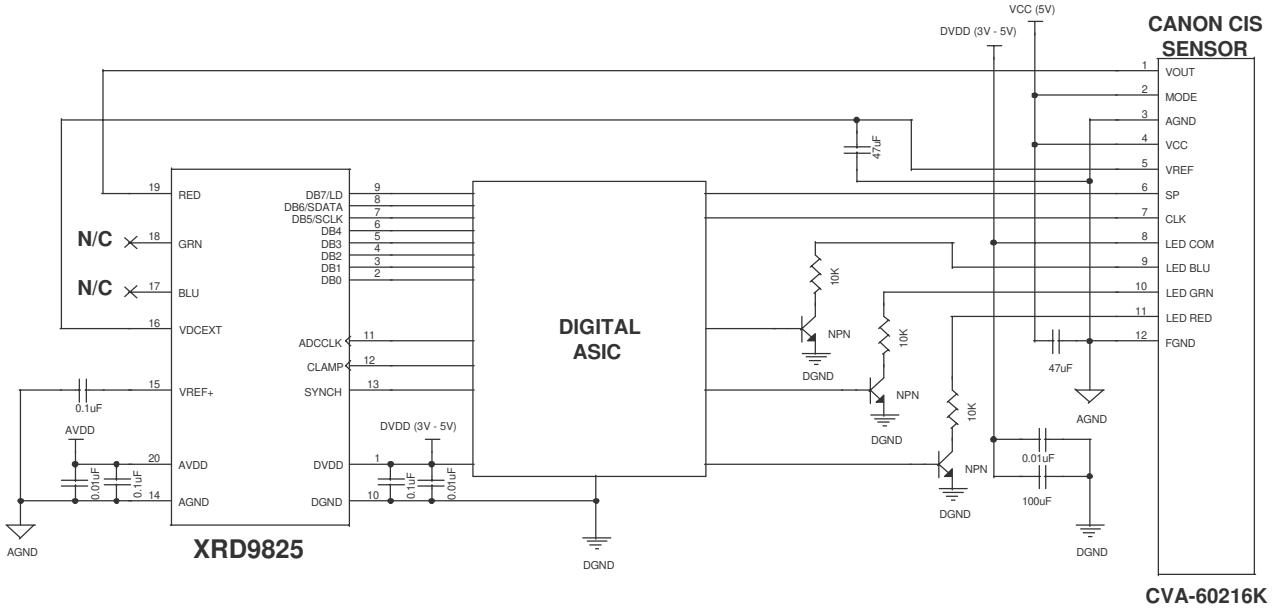


Figure 10. Typical Application Circuitry Internal CIS Reference Circuit Mode CANON CIS Sensor, Model #CVA=60216k

CIS Line-By-Line Rotating Gain and Offset (Configuration DB1 = 1, DB0 = 1)

Line-by-line rotating gain and offset minimizes the amount of write cycles per scan. Pre-loaded values of gain and offset can be loaded for each color before the first line is scanned. Each gain and offset is cycled through line-by-line so that the gain and offset do not have to be loaded in between lines. Below is the typical application circuit and timing for this configuration.

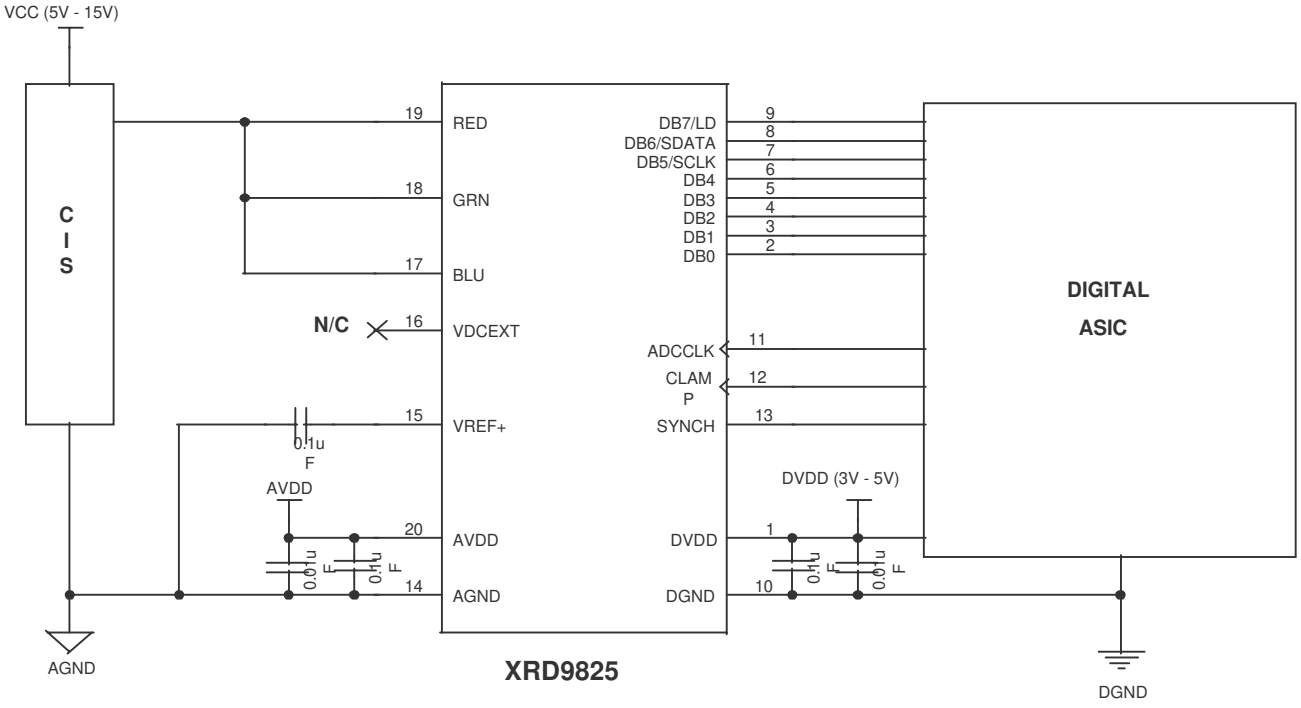
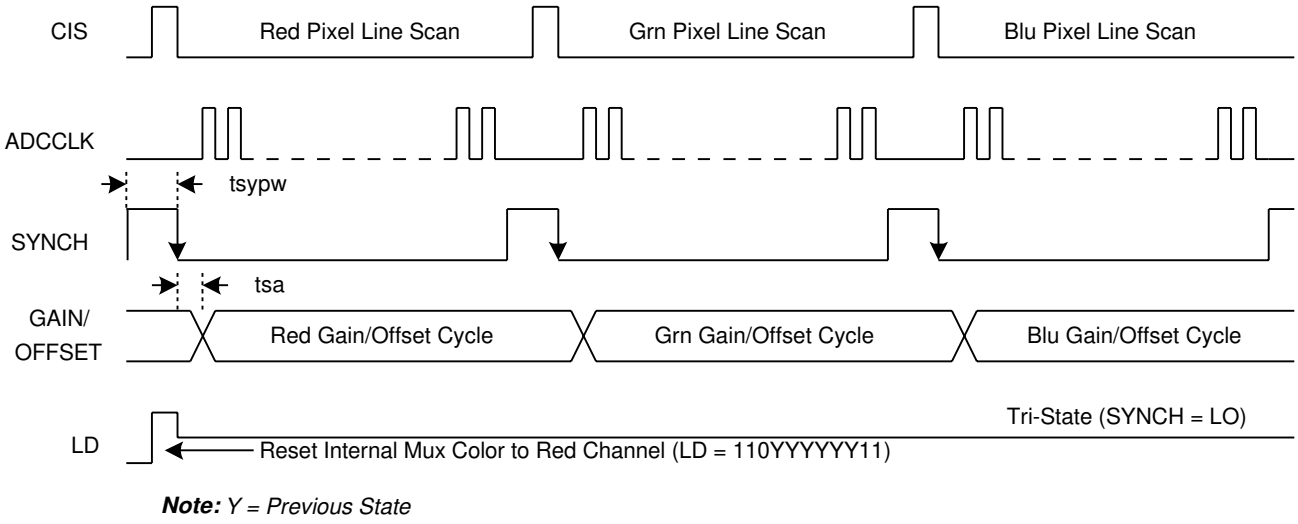


Figure 11. Typical Application Circuitry Internal CIS Rotating Gain and Offset Line-By-Line

CIS Rotating Gain and Offset

Line-By-Line (Md 11)



Note: *Y = Previous State*

Figure 12. Timing Diagram for Figure 11

CCD Configuration (Charge Coupled Device)

Mode 1. AC Coupled

In the CCD configuration of operation, an external capacitor needs to be chosen according to the equations below. The typical value for the external capacitor is 100pF. This value should be adjusted according to the time constant (Tc) needed in a particular application. The CLAMP pin has an internal 150 ohm impedance (R_{INT}) which is in series with the external capacitor (C_{EXT}).

Therefore, $Tc = 1/R_{INT}C_{EXT}$

If the input to the external capacitor has a load impedance (R_{EXT}), then

$T_c = 1/(R_{INT}+R_{EXT})C_{EXT}$

When CLAMP (clamp) pin is set high an internal switch allows one side of the external capacitor to be set to VRT (Figure 13). This value corresponds to the black reference of the CCD. When the CLAMP pin is set back to low, the ADC samples the video signal with respect to the black reference. The difference between the black reference and the video signal is the actual pixel value of the video content. Since this value is referenced to the top ladder reference voltage of the ADC a zero input signal would yield a full scale output code. Therefore, the output of the conversion is inverted (internally) to correspond to zero scale output code.

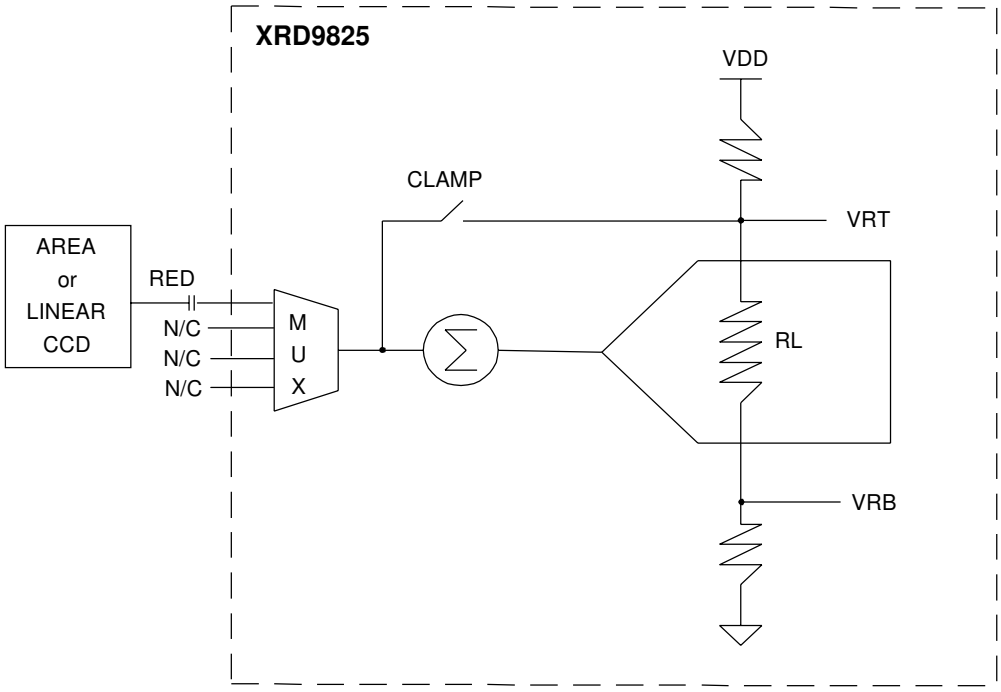


Figure 13. CCD AC Coupled Application

Area or Linear CCD Applications

Figure 13 is a block diagram for applications with Area or Linear CCDs (The timing for Area CCDs and B/W CCDs is the same). For Area or Linear CCD applications, a global offset is loaded into the serial port at the beginning of a line. The gain is set to adjust for the highest color intensity of the CCD output. Once the pixel values have been sampled, the gain and offset are adjusted at the beginning of the next line. For example, if there is a line-to-line variation between the black reference pixels, the offset is adjusted. The gain is always adjusted for the highest color intensity.

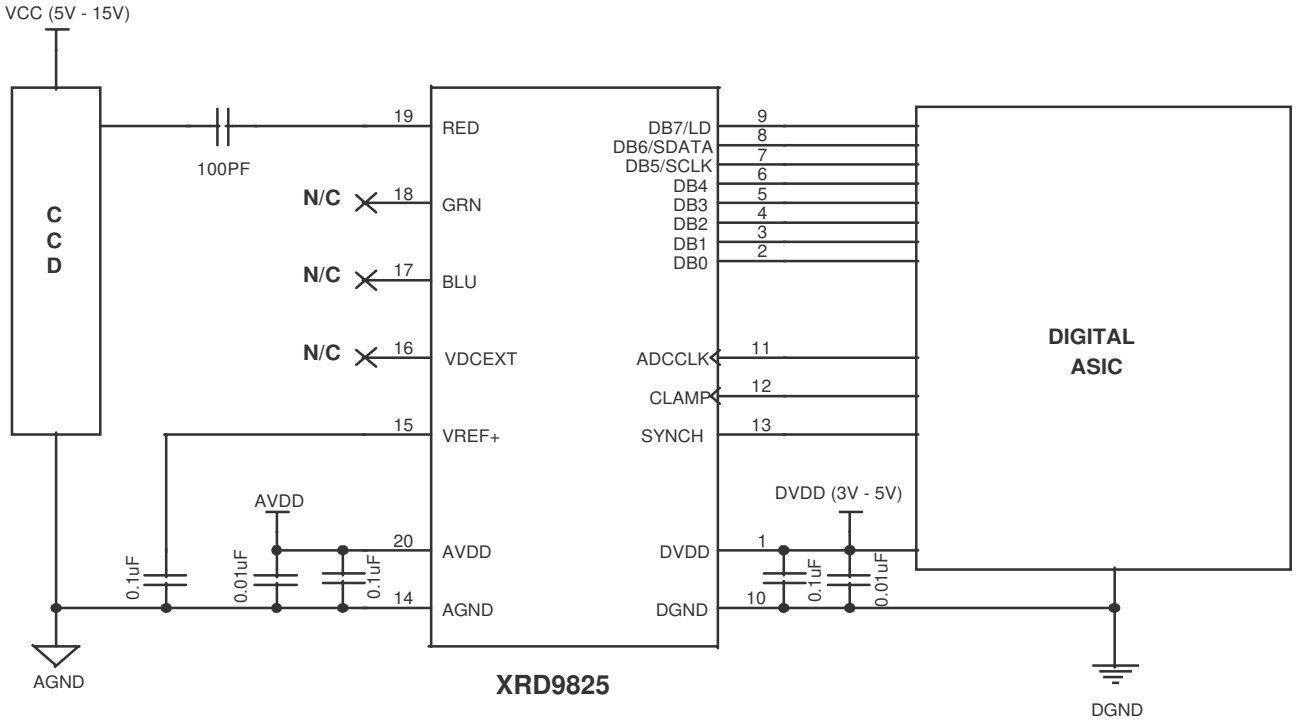
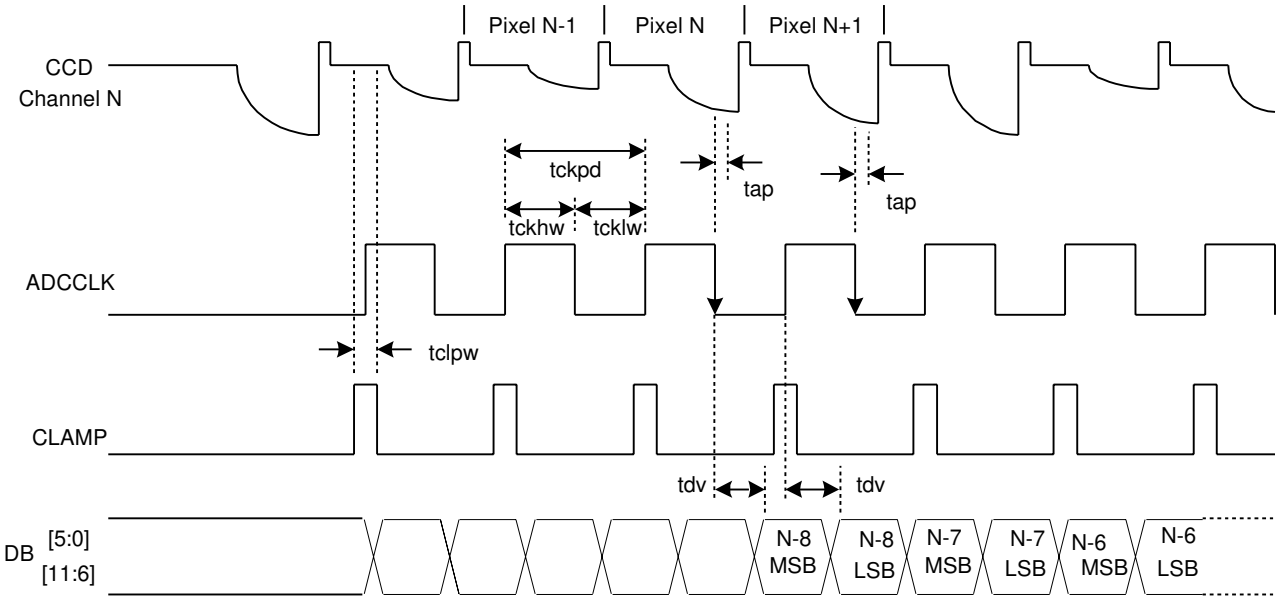


Figure 14. Typical Application Circuitry Single Channel CCD AC Coupled Inverted Mode

AREA, LINEAR or B/W CCD -- AC Coupled
(CLAMP Enabled)



Note: *There is an 8 clock latency at the output.*

Figure 15. Timing Diagram for Figure 14

Triple Channel CCD Application

Figure 6 is a block diagram for pixel-by-pixel applications with triple channel CCDs. During the optically shielded section of a pixel, CLAMP must go high to store the black reference on each capacitor to the input.

The gain and offset is automatically rotated to adjust for each channel input. The MSBs (8 upper bits) are available on the output bus on the falling edge of ADCCLK. The LSBs (8 lower bits) are available on the rising edge of ADCCLK.

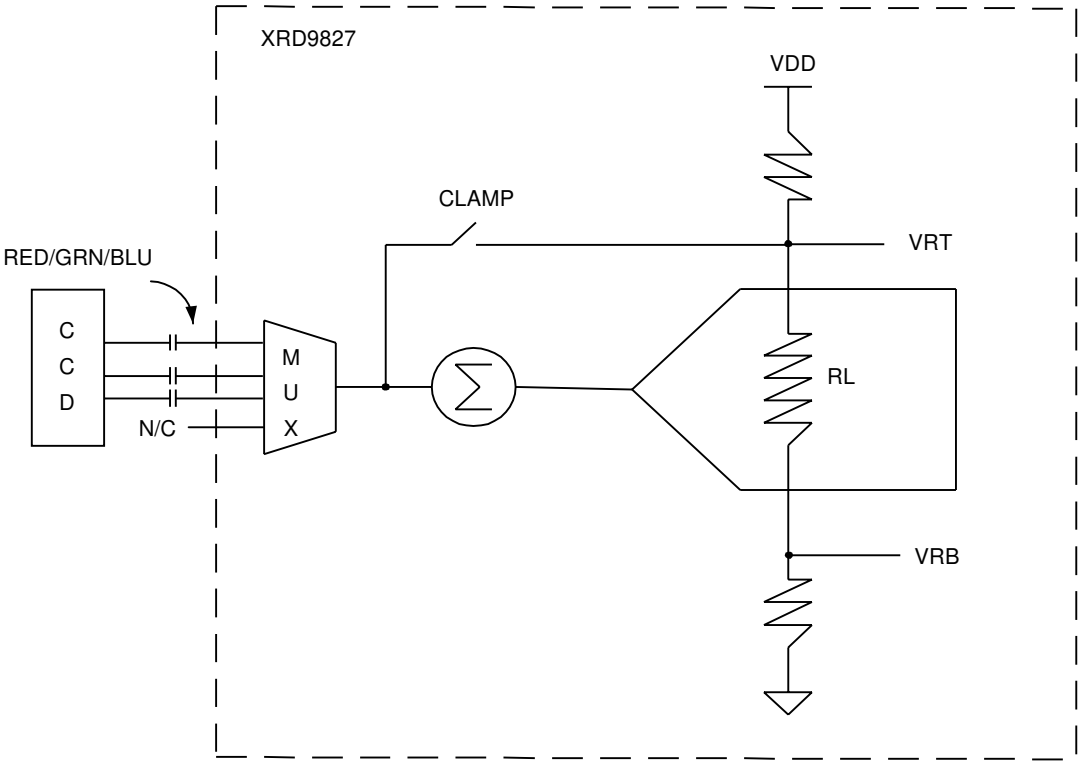


Figure 16. CCD AC Coupled Application

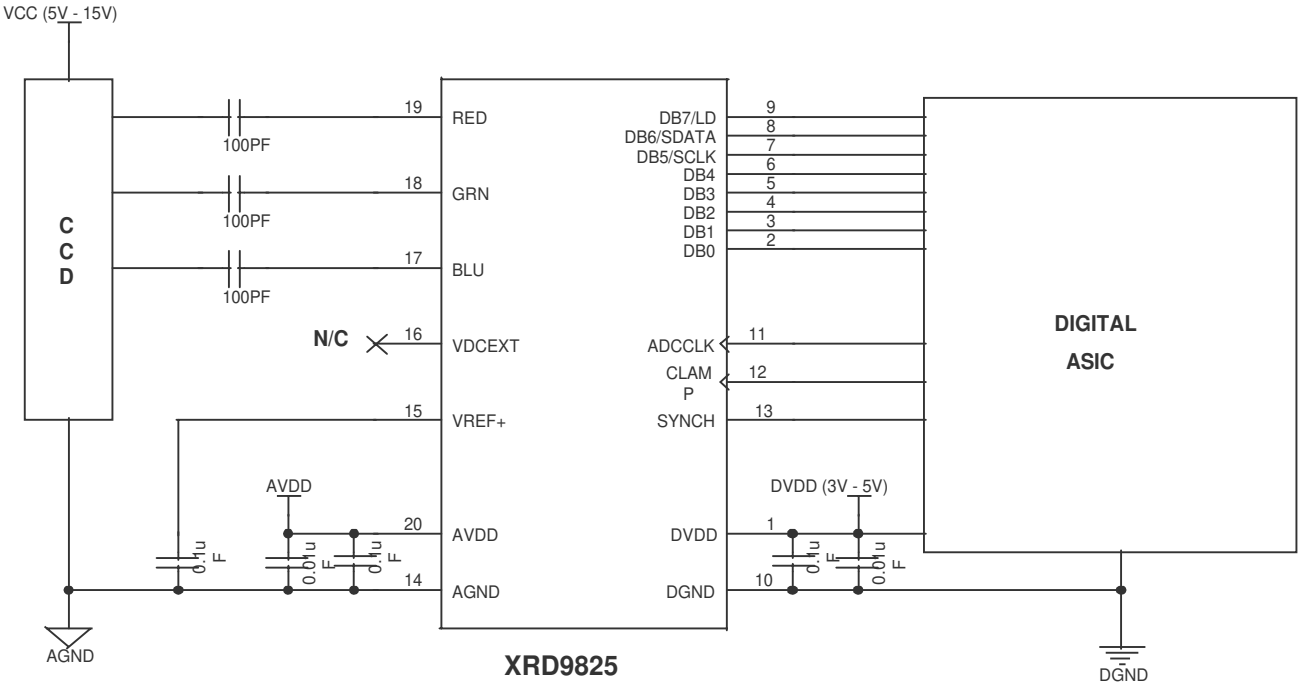
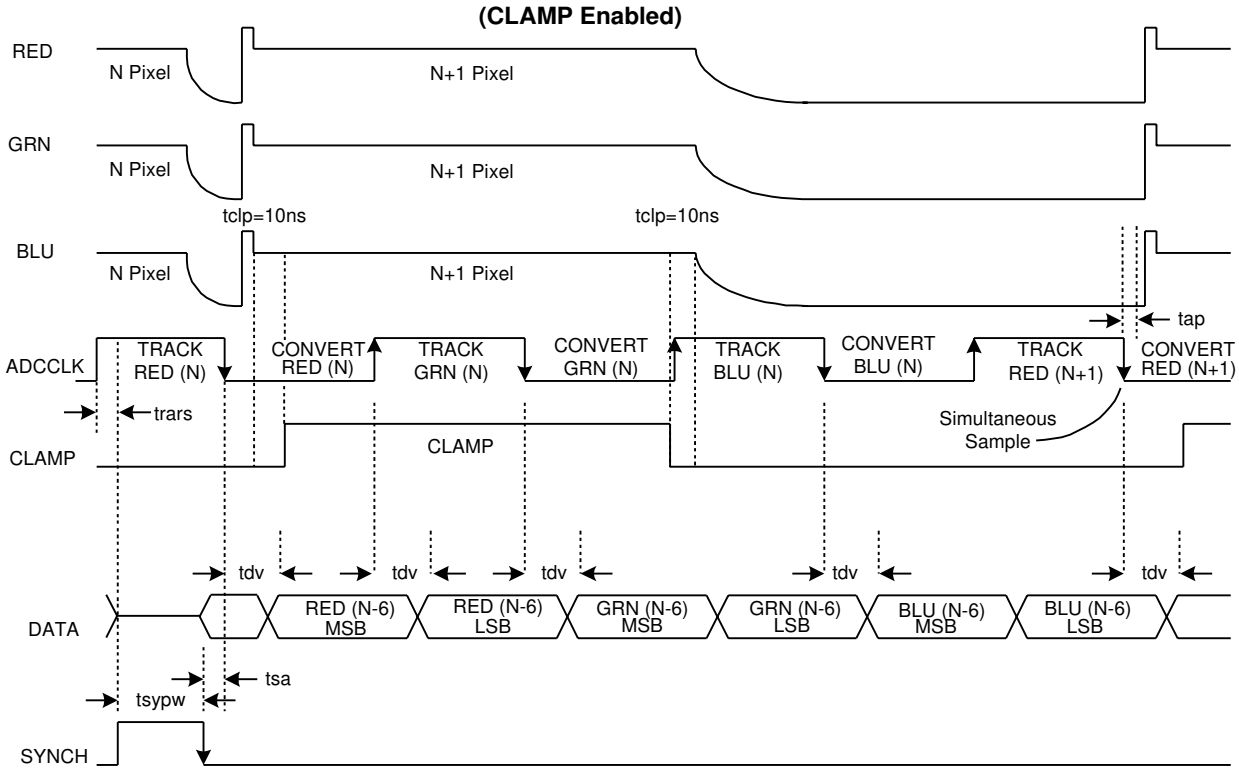


Figure 17. Typical Application Circuitry Triple Channel CCD AC Coupled Inverted Mode

PIXEL-BY-PIXEL 3 CHANNEL CCD -- AC Coupled

(CLAMP Enabled)



Note: *There is an 8 clock latency at the output.*

Figure 18. Timing Diagram for Figure 17

ADCCLK	**Events**
3rd ↓	Simultaneous RED/GRN/BLU Sample Every 3rd CLK. Convert RED, S/H GRN, S/H BLU.
All ↓	MSB Data Out (8 upper bits)
↑	LSB Data Out (8 lower bits)
HI	ADC Track PGA Output
LO	ADC Hold/Convert
CLAMP	**Events**
HI	Internal Clamp Enabled
LO	Internal RED/GRN/BLU Tracking Enabled
SYNCH	**Events**
HI	Reset Internal Mux to Red, Output Bus is Tri-stated
LO	Increment Mux Color on Falling Edge of ADCCLK

Table 5.

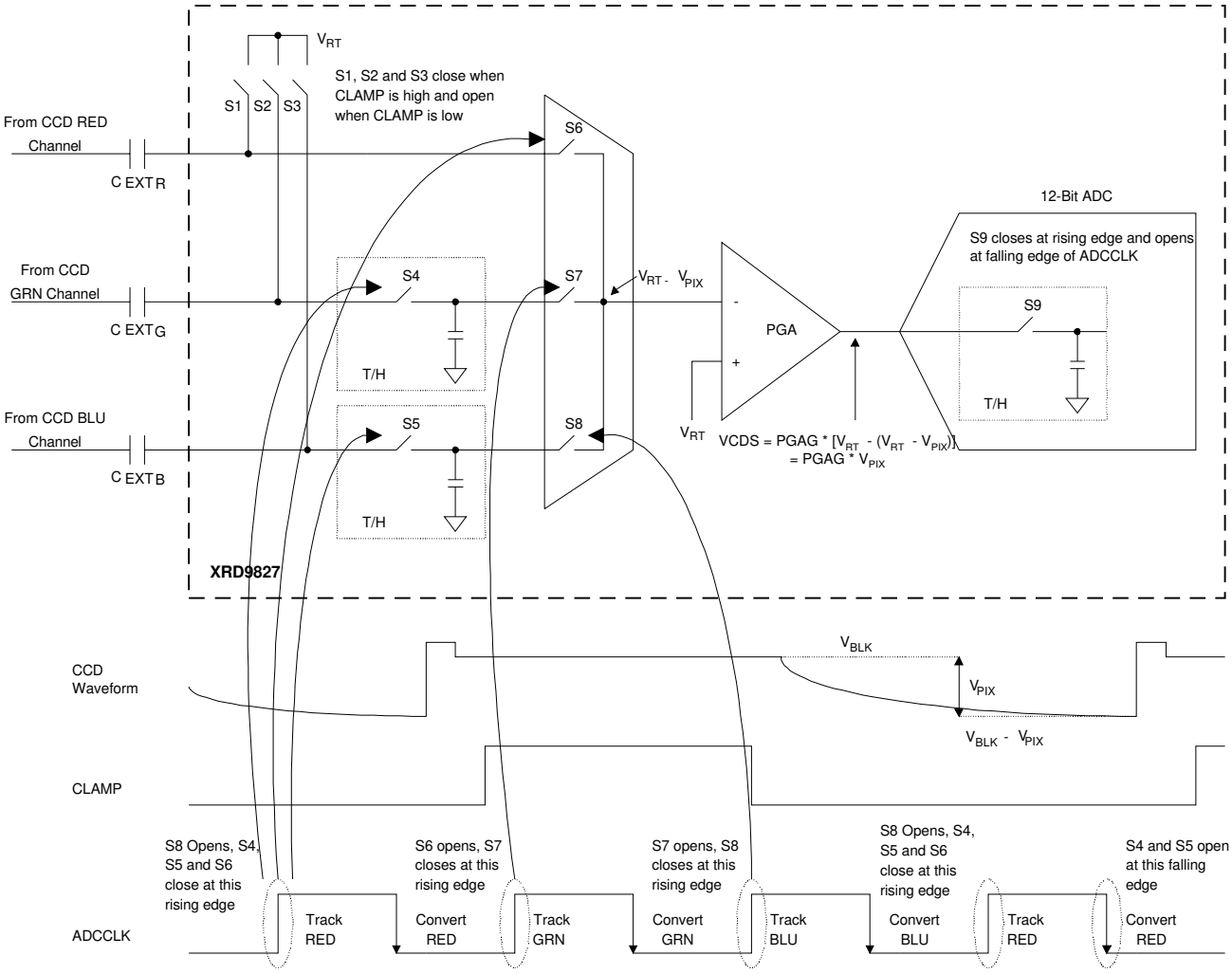


Figure 19. CDS Timing (Triple Channel)
Mode: 110 00001110