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# XRD9824

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

May 2000-3

### FEATURES

- 14-Bit Resolution, No Missing Codes
- One-channel 6MSPS Pixel Rate
- Triple-channel 2MSPS 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
- 5V Operation
- 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 XRD9824 is a complete linear CIS or CCD sensor signal processor on a single monolithic chip. The XRD9824 includes a high speed 14-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 XRD9824. The CIS signal is level shifted to VRB in

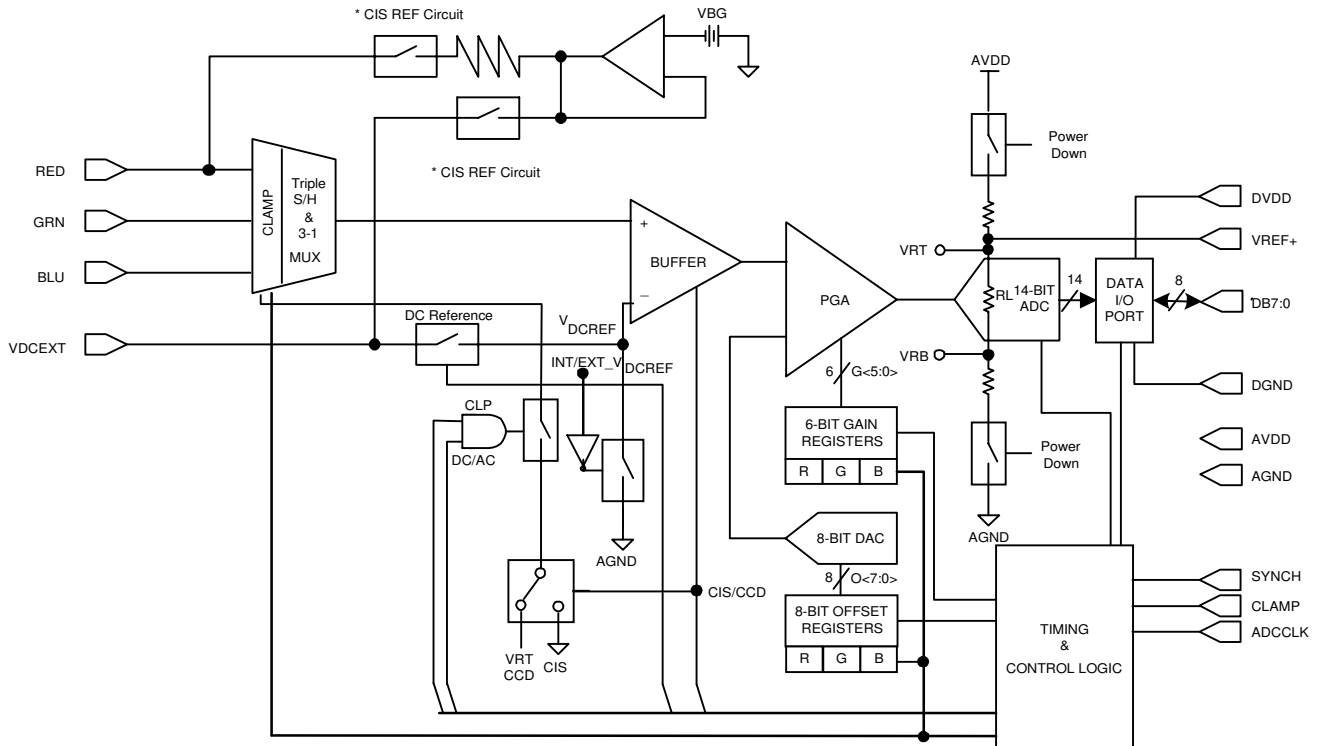
order to use the full range of the ADC. In the CIS configuration the input can also be AC coupled similar to the CCD configuration. This enables CIS signals with large black levels to be internally clamped to a DC reference equal to the black level. The DC reference is internally subtracted from the 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	XRD9824ACD
20-Lead SSOP	0°C to +70°C	XRD9824ACU

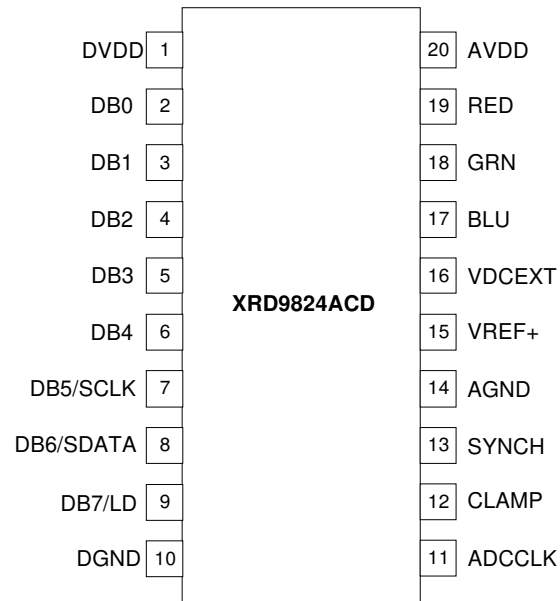
Rev. 2.00



**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:  $AV_{DD}=DV_{DD}=5V$ ,  $ADCCLK=6MHz$ , 50% Duty Cycle,  $T_A=25^{\circ}C$  unless otherwise specified.

Symbol	Parameter	Min.	Typ.	Max.	Unit	Conditions
<b>Power Supplies</b>						
$AV_{DD}$	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		40	55	mA	$V_{DD}=5V$
$IDD_{PD}$	Power Down Power Supply Current			50	$\mu A$	$V_{DD}=5V$
<b>ADC Specifications</b>						
RES	Resolution	14			Bits	
$F_s$	Maximum Sampling Rate	12			MSPS	
DNL	Differential Non-Linearity	-3.0	$\pm 1.5$	3.0	LSB	
$V_{RT}$	Top Reference Voltage	3.50	$AV_{DD}/1.3$	3.90	V	
$V_{RB}$	Bottom Reference Voltage		$AV_{DD}/10$		V	
$DV_{REF}$	Differential Reference Voltage ( $V_{RT} - V_{RB}$ )	0.3	$0.67AV_{DD}$		V	
$R_L$	Ladder Resistance	300	600	780	$\Omega$	
<b>PGA &amp; Offset DAC Specifications</b>						
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
$OFF_{\Delta}$	Offset Adjustment Step Size		3.14		mV	

**Note 1:** The additional  $\pm 100$  mV of adjustment with respect to the black level input range is needed to compensate for any additional offset introduced by the XRD9824 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:  $AV_{DD}=DV_{DD}=5V$ ,  $ADCCLK=6MHz$ , 50% Duty Cycle,  $T_A=25^{\circ}C$  unless otherwise specified.

Symbol	Parameter	Min.	Typ.	Max.	Unit	Conditions
<b>Buffer Specifications</b>						
$I_{IL}$	Input Leakage Current			100	nA	
$C_{IN}$	Input Capacitance		10		pF	
$V_{IN_{PP}}$	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		$DV_{REF}$	V	CCD AC; INT $V_{DCREF}$ Config Reg => XXX011XX Gain=1 (Note 1)
$V_{IN}$	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	$V_{DCEXT}-0.1$		$V_{DCEXT}+$ $DV_{REF}$	V	CIS DC; EXT $V_{DCREF}$ Config Reg => XXX100XX Gain=1 (Note 3) $V_{DCEXT}+DV_{REF} \leq AV_{DD}$
$V_{DCEXT}$ Pin 16=Input	External DC Reference	0.3		$AV_{DD}/2$	V	CIS DC; EXT $V_{DCREF}$ Config Reg Mode 110 => XXX100XX
$V_{DCEXT}$ Pin 16=Output	Internal DC Reference	1.17		1.34	V	Internal CIS Reference Circuit Config Reg Mode 111 => XXX1XXXX
$V_{IN_{BW}}$	Input Bandwidth (Small Signal)		10		MHz	
$V_{IN_{CT}}$	Channel to Channel Crosstalk		-60	-50	dB	$f_{in}=3MHz$
<b>Internal Clamp Specifications</b>						
$V_{CLAMP}$	Clamp Voltage		AGND	50	mV	CIS (AC) Config
		3.5	$V_{RT}$		V	CCD (AC) Config
$R_{INT}$	Clamp Switch On Resistance		100	150	$\Omega$	
$R_{OFF}$	Clamp Switch Off Resistance	10			M $\Omega$	

**Note 1:**  $V_{IN_{PP}}$  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,  $T_A=25^{\circ}C$  unless otherwise specified.

Symbol	Parameter	Min.	Typ.	Max.	Unit	Conditions
<b>System Specifications (MUX + Buffer + PGA + ADC)</b>						<b>Note 1</b>
$SYS_{DNL}$	System DNL	-1.0	$\pm 0.5$	+2.3	LSB	
$SYS_{LIN}$	System Linearity		$\pm 6.0$		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
<b>System Timing Specifications</b>						
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
<b>Write Timing Specifications</b>						
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	
<b>ADC Digital Output Specifications</b>						
tap	Aperture Delay		10		ns	
tdv	Output Data Valid	40			ns	
t <sub>sa</sub>	SYNCH to ADCCLK	15			ns	3ch Pixel Md
tlat	Latency		8		cycles	Config 00, 11
tlat	Latency		6		pixels	Config 01, 10
<b>Digital Input Specifications</b>						
$V_{IH}$	Input High Voltage	$AV_{DD}-2.5$			V	
$V_{IL}$	Input Low Voltage			1	V	
$I_{IH}$	High Voltage Input Current		5		$\mu A$	
$I_{IL}$	Low Voltage Input Current		5		$\mu A$	
$C_{IN}$	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:  $AV_{DD}=DV_{DD}=5V$ ,  $ADCCLK=6MHz$ , 50% Duty Cycle,  $T_A=25^{\circ}C$  unless otherwise specified.

Symbol	Parameter	Min.	Typ.	Max.	Unit	Conditions
<b>Digital Output Specifications</b>						
$V_{OH}$	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	$\mu A$	
$C_{OUT}$	Output Capacitance		10		pF	
SR	Slew Rate (10% to 90% $DV_{DD}$ )	2		15	ns	$C_L=10pF$ , $DV_{DD}=3.3V$



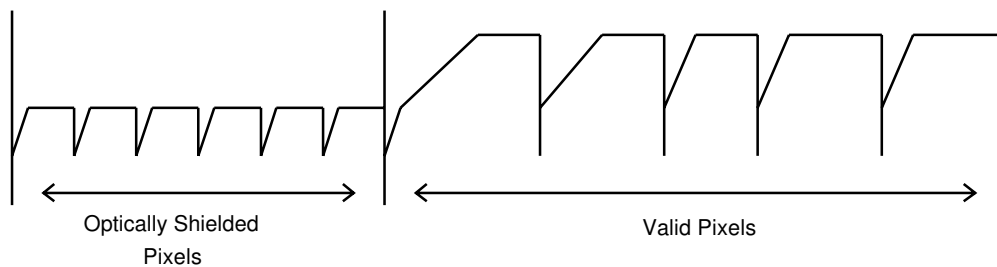
## THEORY OF OPERATION

### CIS Configuration (Contact Image Sensor)

The XRD9824 has two configurations for CIS applications. Each configuration is set by the control registers accessed through the serial port.

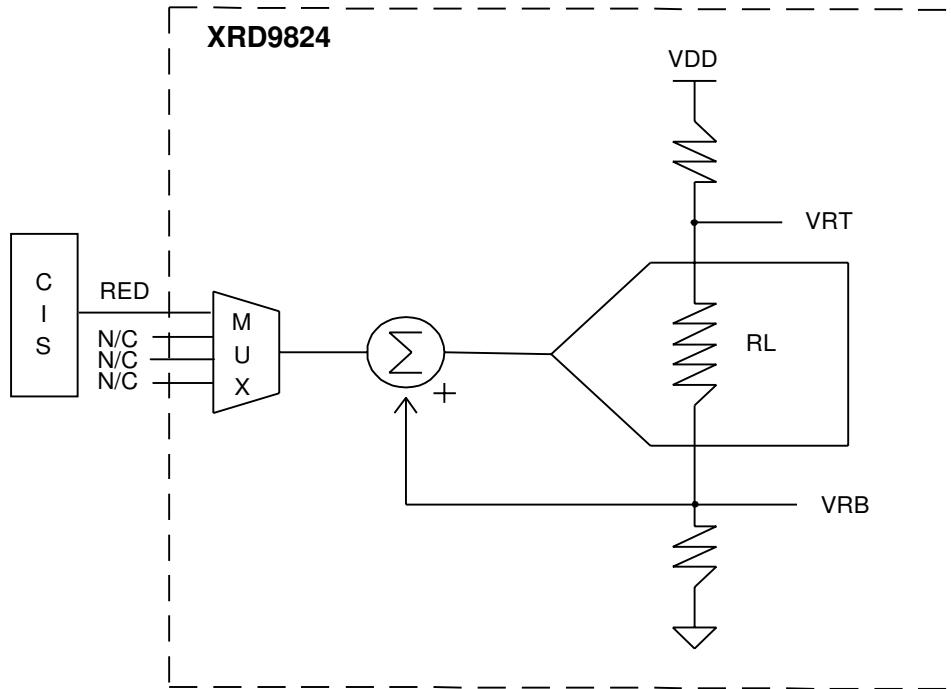
#### Mode 1. DC Coupled

If the CIS does not have leading or trailing black pixels as shown in Figure 2, then DC couple the CIS output to the XRD9824 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 XRD9824 to set the black pixel value when the LEDs of the CIS are off. When the LEDs are on, use the XRD9824 Programmable Gain to maximize the ADCs dynamic range. Figure 3 shows a typical application for a CIS with an offset of -100mV to 500mV.

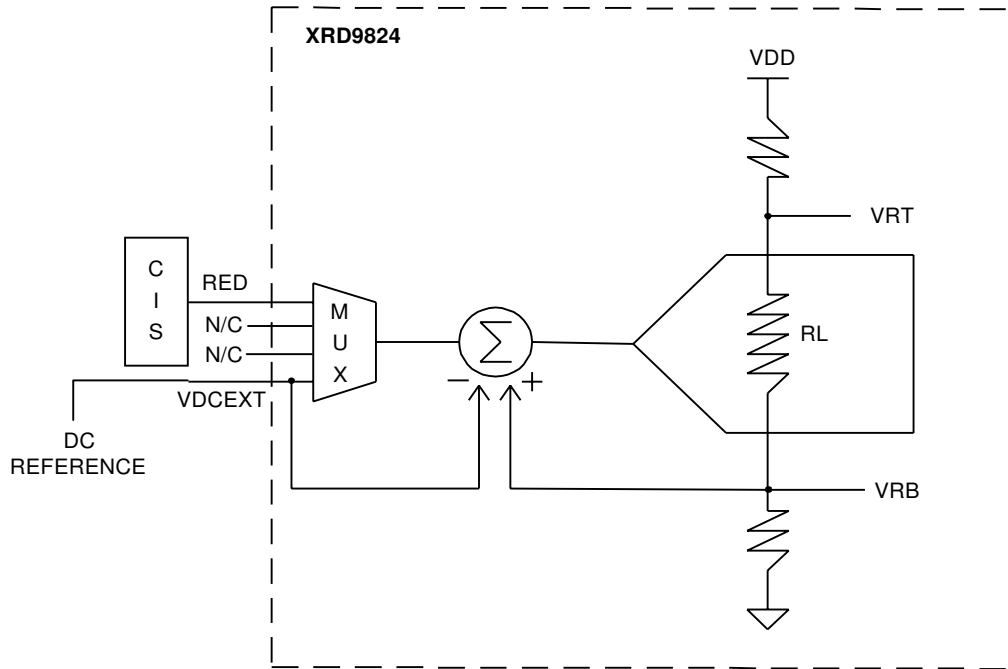


**Figure 3. Application with Offset in the Range (-100mv to 500mv)**

The input is added to VRT 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

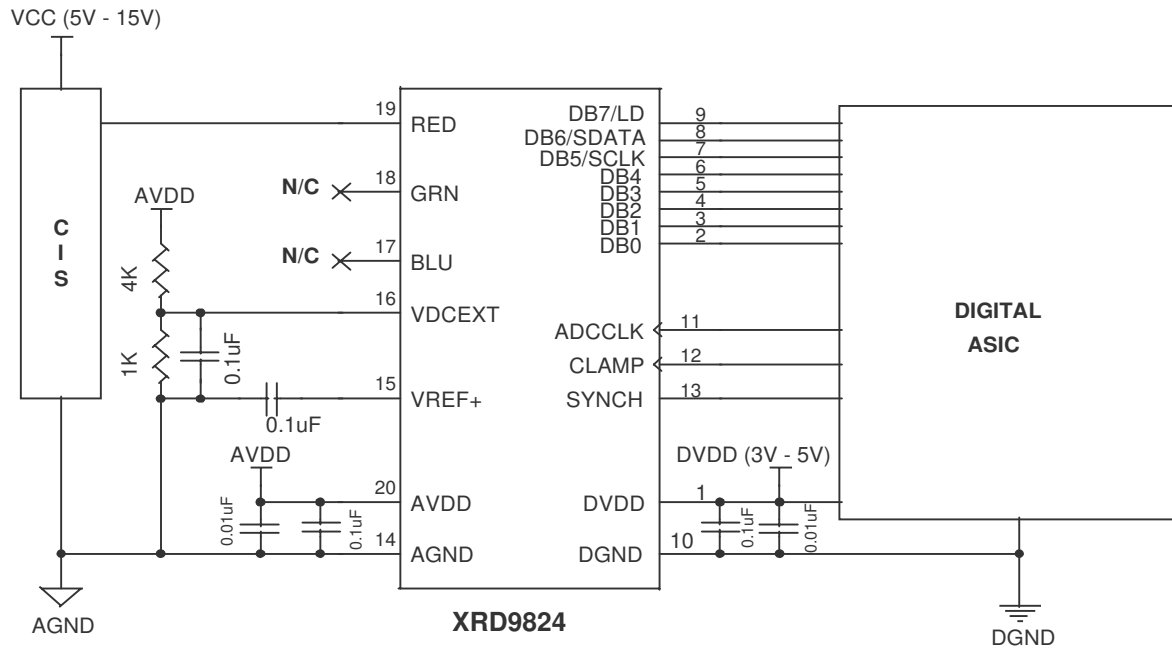
beyond the offset range of the XRD9824 (see Offset Control DAC, Pg. 28) set the internal mode registers to external reference. An external reference voltage equal to the value of the CIS offset voltage can be applied to VDCEXT (Figure 4) in order to meet the dynamic range of the XRD9824. Figure 4 is a diagram of the XRD9824 in the external reference mode for CIS, DC coupled applications.



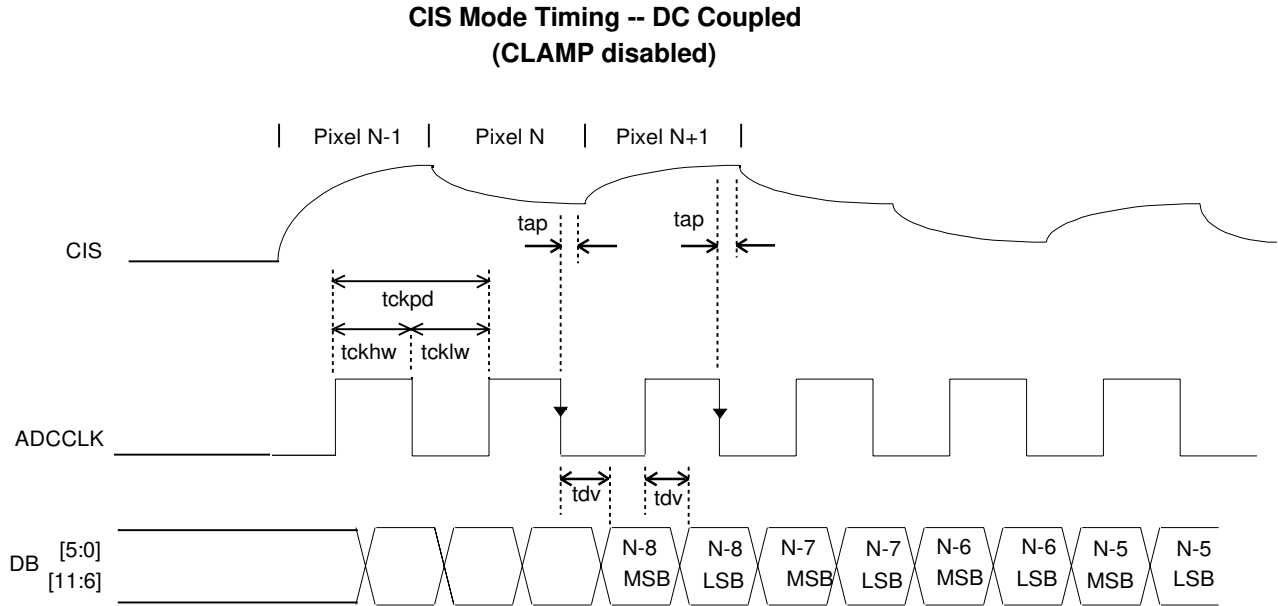
**Figure 4. Application with Offset Greater Than (-100mv to 500mv)**

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**



**Figure 6. Timing Diagram for Figure 5**

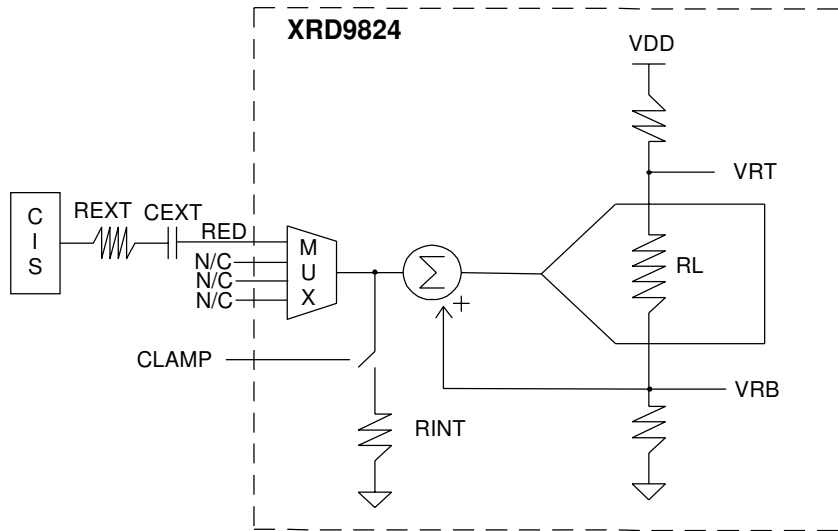
ADCCLK	Events
↓	ADC Sample & PGA Start Tracking next Pixel MSB Data Out
↑	LSB Data Out
HI	ADC Track PGA Output
LO	ADC Hold/Convert

**Table 1.**

## 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).



**Figure 7. CIS AC Coupled Application**

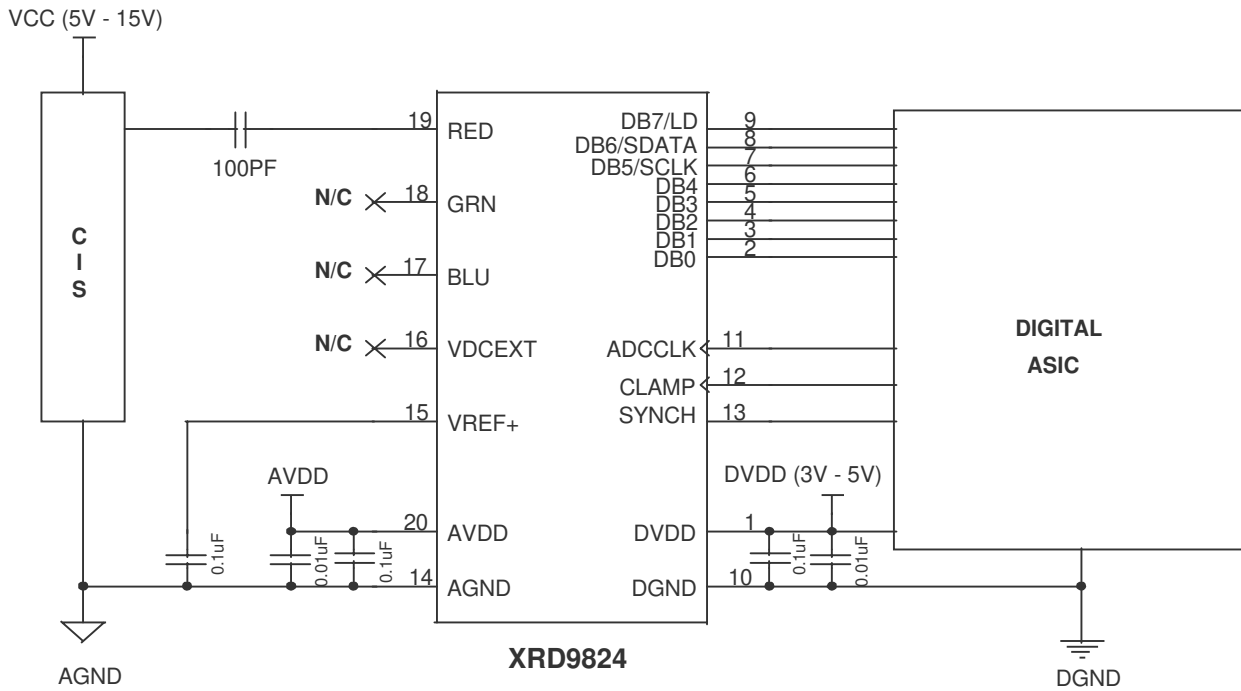
This value corresponds to the black reference of the image sensor. When the CLAMP pin is set back to low, the ADC samples the video signal with respect to the black reference. The typical value for the external capacitor is 100pF. This value should be adjusted according to the time constant (Tc) needed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

$$\text{Therefore, } T_c = 1/R_{INT} C_{EXT}$$

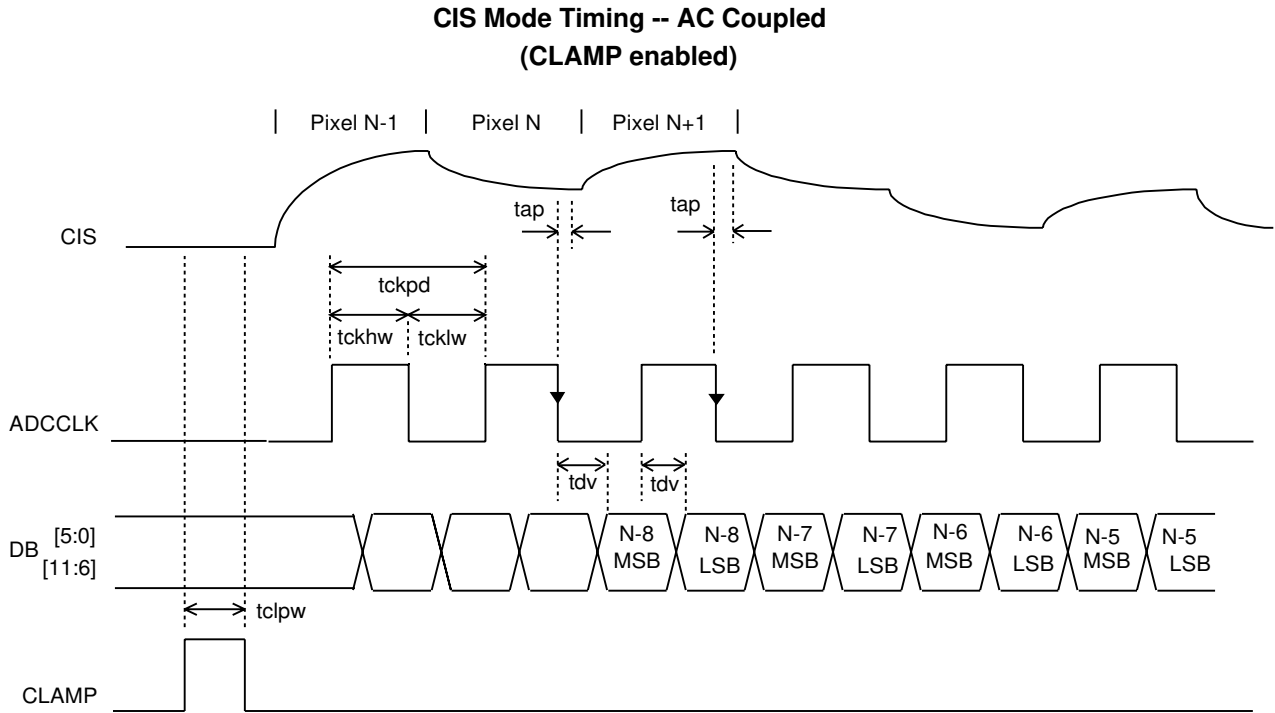
If the input to the external capacitor has a source impedance ( $R_{EXT}$ ), then:

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





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



**Figure 9. Timing Diagram for Figure 8**

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

**Table 3.**

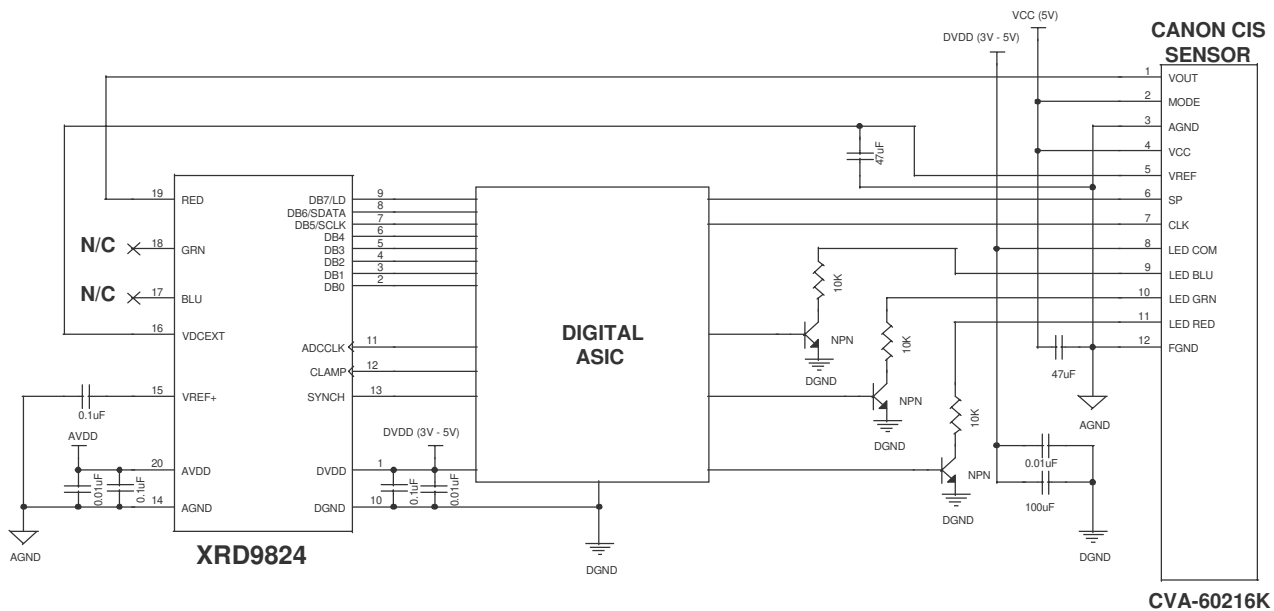
CLAMP	Events
HI	PGA Tracks $V_{CLAMP}$ & $C_{EXT}$ is Charged to
LO	$V_{BLACK} - V_{CLAMP}$ , which is equal to $V_{BLACK}$ PGA Tracks $V_{IN_{PP}}$

**Table 4.**

## Internal CIS Reference Circuit (DB 4 = 1)

The XRD9824 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 15) 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 XRD9824 for this mode of operation). Below is a typical application circuit using the XRD9824 and the Canon CVA-60216K CIS sensor.

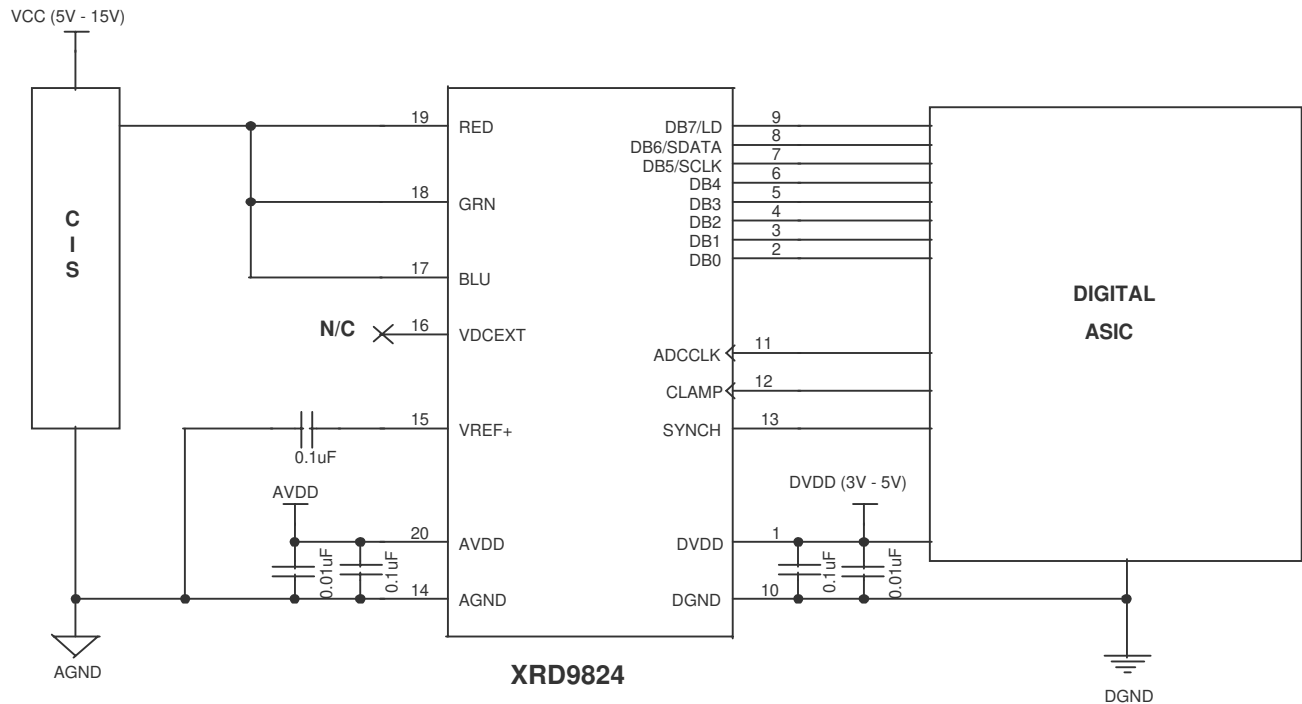


**Figure 10. Typical Application Circuitry Internal CIS Reference Circuit Mode  
CANON CIS Sensor, Model #CVA=60216k**

**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)

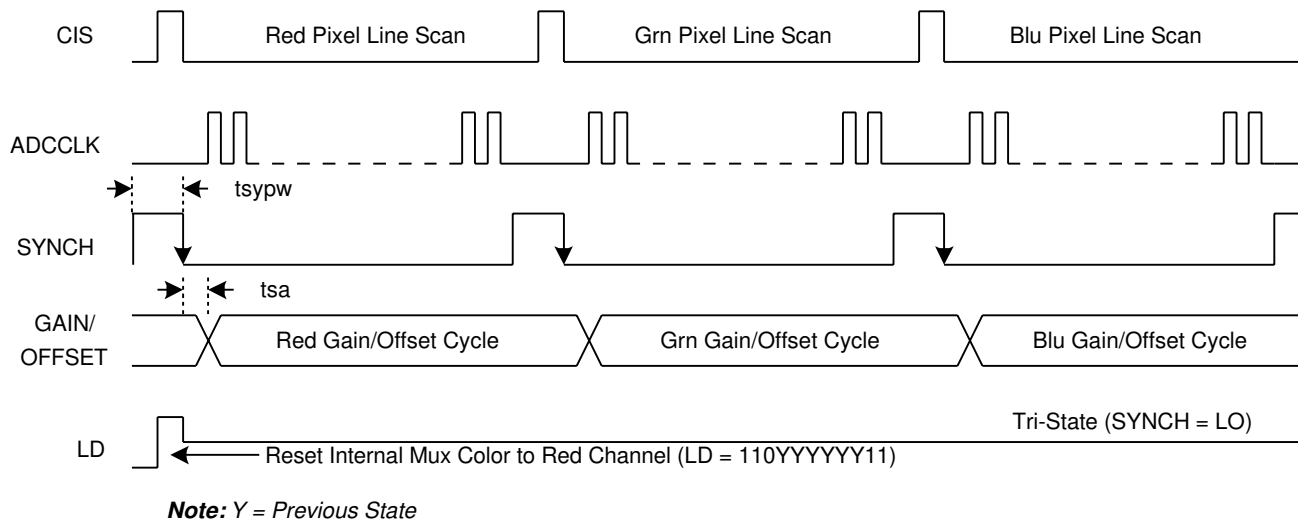


Figure 12. Timing Diagram for Figure 11

### CCD Configuration (Charge Coupled Device)

#### Mode 1. AC Coupled

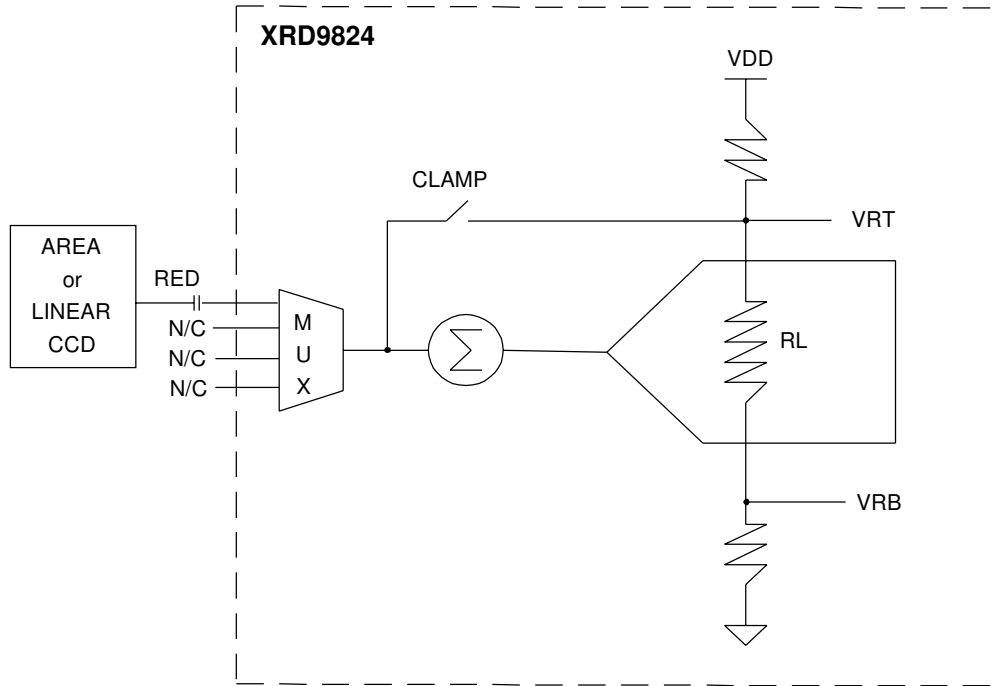
In the CCD configuration of operation, an external capacitor needs to be chosen according to the equations below. The typical value for the external capacitor is 100pF. This value should be adjusted according to the time constant ( $T_c$ ) needed in a particular application. The CLAMP pin has an internal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

$$\text{Therefore, } T_c = 1/(R_{INT} \cdot C_{EXT})$$

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

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

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.



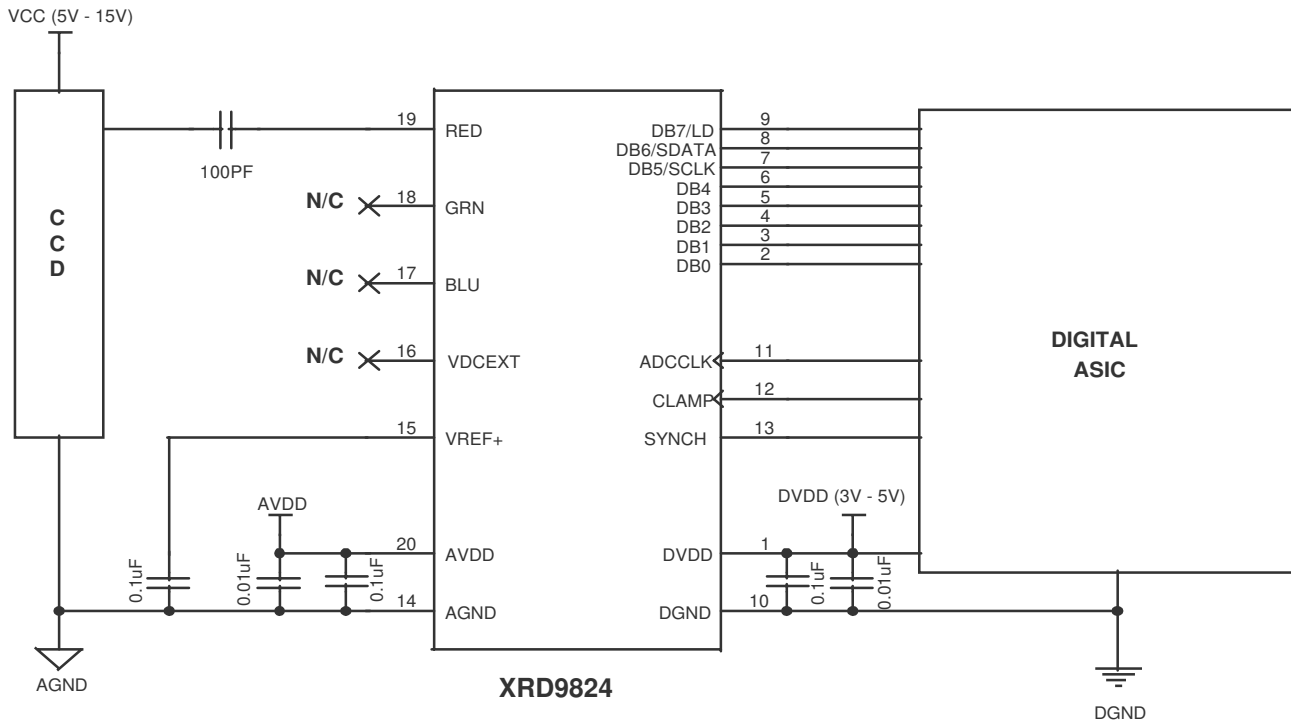
**Figure 13. CCD AC Coupled Application**

**Area or Linear CCD Applications**

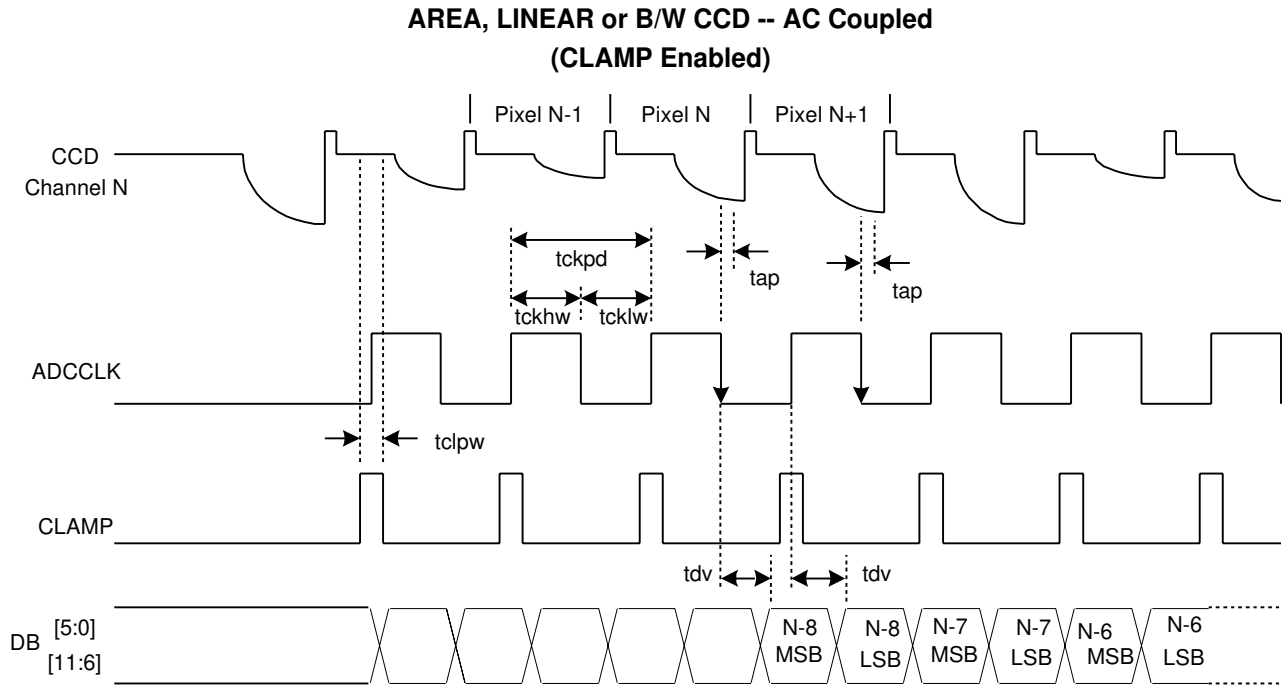
Figure 13 is a block diagram for applications with Area or Linear CCDs (The timing for Area CCDs and B/W CCDs is the same). For Area or Linear CCD applications, a global offset is loaded into the serial port at the beginning of a line. The gain is set to adjust for the highest color intensity of the 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**



**Figure 15. Timing Diagram for Figure 14**

**Triple Channel CCD Application**

Figure 16, 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 are available on the output bus on the falling edge of ADCCLK. The LSBs are available on the rising edge of ADCCLK.

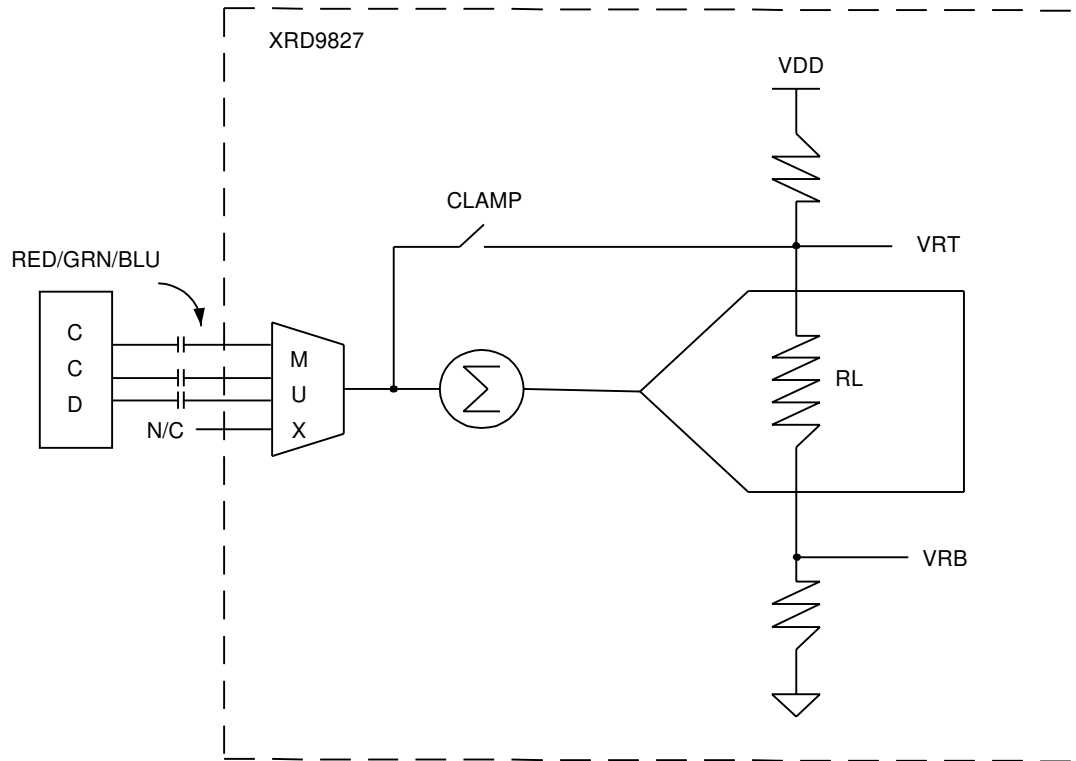
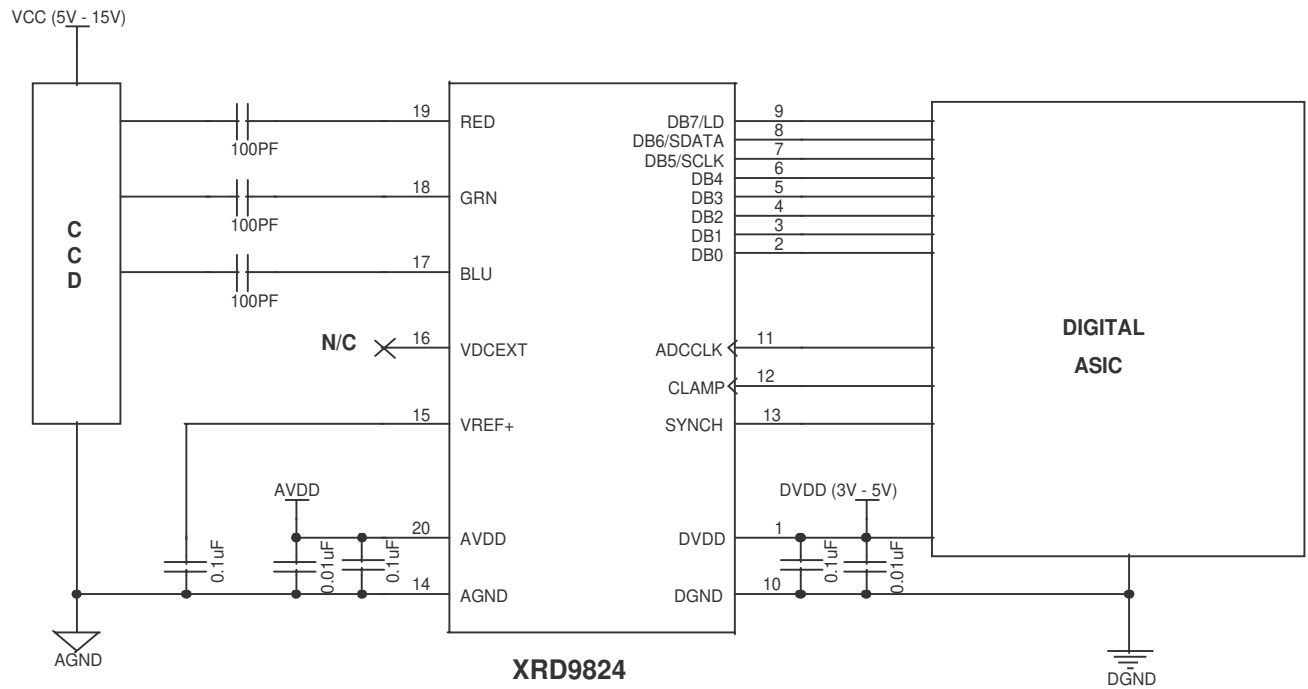
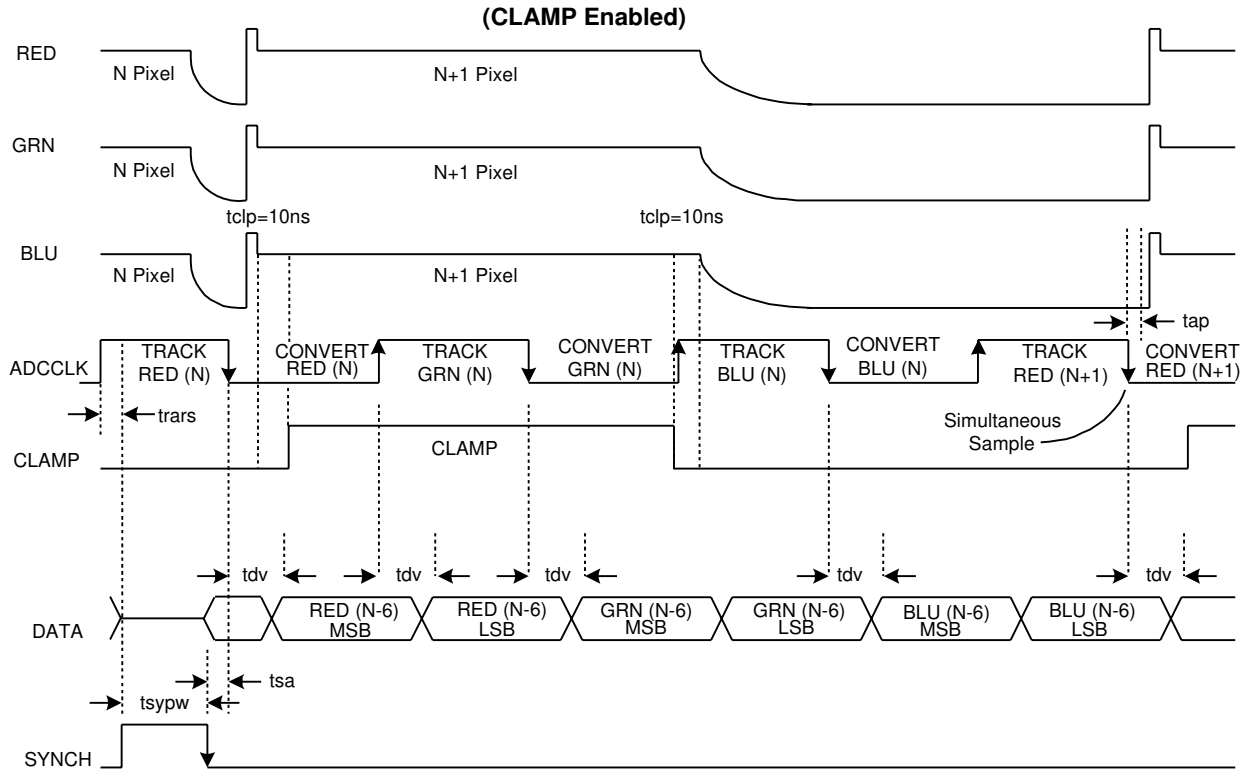


Figure 16. CCD AC Coupled Application



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

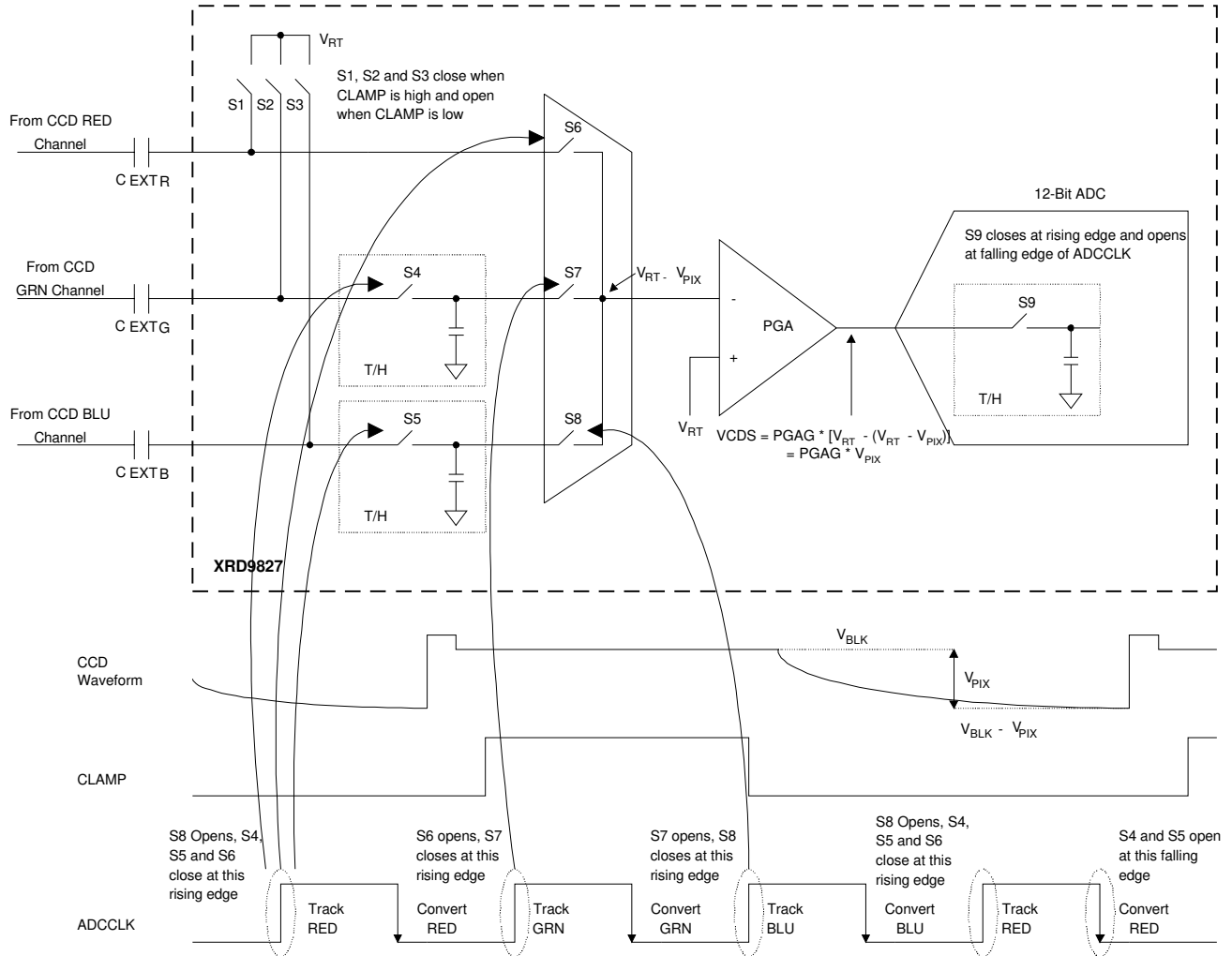
## PIXEL-BY-PIXEL 3 CHANNEL CCD -- AC Coupled



**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
↑	LSB Data Out
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**