

FEATURES

- 10-Bit 6MSPS Pixel Rate
- 6-Bit Programmable Gain Amplifier
- 8-Bit Programmable Offset Adjustment
- 4:1 Analog Multiplexer
- CIS or CCD Compatibility
- Internal Clamp for CIS or CCD AC Coupled Modes
- 3.3V or 5V Operation & I/O Compatibility
- Serial Load Control Registers
- Low Power CMOS: 150mW
- Low Cost 20-Lead SOIC Package
- Monotonic

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

GENERAL DESCRIPTION

The XRD9829 is a complete linear CIS or CCD sensor signal processor on a single monolithic chip. The XRD9829 includes a high speed 10-bit 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 mode the input signal is AC coupled with an external capacitor. An internal clamp sets the black level. In the CIS mode the input can also be AC coupled similar to the CCD mode. This enables CIS signals with black

levels to be referenced to ground and then level shifted internally to correspond to VRB. For CIS sensors without black references the clamp switch can be disabled in DC Coupled mode. The CIS signal is level shifted to VRB in order to use the full range of the ADC.

The CIS DC Coupled mode can also be used in other applications that do not require a CDS function but require programmable gain and offset such as low cost data acquisition.

ORDERING INFORMATION

Part No.	Package	Operating Temperature Range
XRD9829ACD	20-Lead SOIC	0°C to +70°C

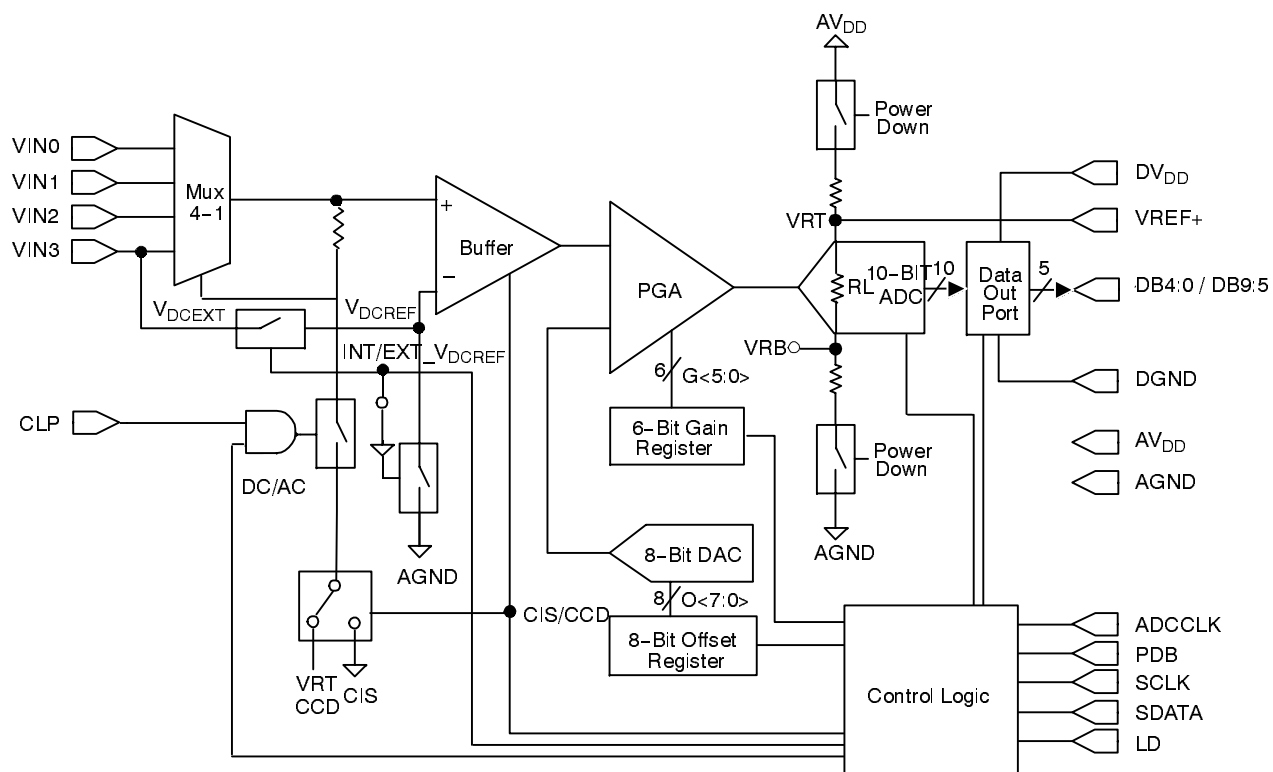
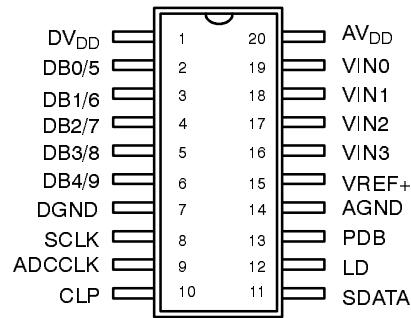


Figure 1. Functional Block Diagram

PIN CONFIGURATION



20 Lead SOIC (Jedec, 0.300")

PIN DESCRIPTION

Pin #	Symbol	Description
1	DV _{DD}	Digital V _{DD} (for Output Drivers)
2	DB0/5	Data Output Bit 0/5
3	DB1/6	Data Output Bit 1/6
4	DB2/7	Data Output Bit 2/7
5	DB3/8	Data Output Bit 3/8
6	DB4/9	Data Output Bit 4/9
7	DGND	Digital Ground (for Output Drivers)
8	SCLK	Serial Data Clock for Write Operation
9	ADCCLK	A/D Converter Clock
10	CLP	Black Level Clock for Internal Clamp
11	SDATA	Serial Data for Write Operation
12	LD	Serial Data Load for Write Operation
13	PDB	Active Low Power Down Signal
14	AGND	Analog Ground
15	VREF+	A/D Positive Reference for Decoupling Cap
16	VIN3	Analog Input 3
17	VIN2	Analog Input 2
18	VIN1	Analog Input 1
19	VIN0	Analog Input 0
20	AV _{DD}	Analog Power Supply

DC ELECTRICAL CHARACTERISTICS

Test Conditions: $AV_{DD}=DV_{DD}=3.3V / 5V$, $ADCCLK=6MHz$, 50% Duty Cycle, $T_A=25^{\circ}C$ unless otherwise specified.

Symbol	Parameter	Min.	Typ.	Max.	Unit	Conditions
Power Supplies						
AV_{DD}	Analog Power Supply	3.0	3.3	5.5	V	
DV_{DD}	Digital I/O Power Supply	3.0	3.3	5.5	V	$DV_{DD} \leq AV_{DD}$
I_{DD}	Supply Current		30		mA	$V_{DD}=5V$
I_{DDPD}	Power Down Power Supply Current			TBD	μA	$V_{DD}=5V$
ADC Specifications						
RES	Resolution	10			Bits	
F_s	Maximum Sampling Rate	10			MSPS	TEST1 mode enabled. (Refer to Control Register 'Mode & Test'.)
DNL	Differential Non-Linearity		± 0.5		LSB	
INL	Integral Non-Linearity		± 1.0		LSB	
MON	Monotonicity		Yes			No Missing Codes Guaranteed
V_{RT}	Top Reference Voltage		$AV_{DD}/1.3$		V	
V_{RB}	Bottom Reference Voltage		$AV_{DD}/10$		V	
ΔV_{REF}	Differential Reference Voltage ($V_{RT} - V_{RB}$)		$0.67 AV_{DD}$		V	
R_L	Ladder Resistance	360	600	780	Ω	
PGA & Offset DAC Specifications						
PGARES	PGA Resolution	6			Bits	
$PGAG_{MIN}$	Minimum Gain		1.0		V/V	
$PGAG_{MAX}$	Maximum Gain		10.0		V/V	
$PGAG_{\Delta}$	Gain Adjustment Step Size		0.14		V/V	
V_{BLACK}	Black Level Input Range	-100		500	mV	DC Mode
DACRES	Offset DAC Resolution	8			Bits	
OFF_{MIN}	Minimum Offset Adjustment		-200		mV	¹
OFF_{MAX}	Maximum Offset Adjustment		+600		mV	¹
OFF_{Δ}	Offset Adjustment Step Size		3.14		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 XRD9829 Buffer/PGA internally.

Specifications are subject to change without notice

ELECTRICAL CHARACTERISTICS

Test Conditions: $AV_{DD}=DV_{DD}=3.3V / 5V$, $ADCCLK=6MHz$, 50% Duty Cycle, $T_A=25^{\circ}C$ unless otherwise specified.

Symbol	Parameter	Min.	Typ.	Max.	Unit	Conditions
Buffer Specifications						
I_{IL}	Input Leakage Current			100	nA	
C_{IN}	Input Capacitance		10		pF	
V_{INPP}	AC Input Voltage Range	0		$AV_{DD}-1.4$	V	CIS AC; INT V_{DCREF} Mode Reg => XXX010XX Gain=1 ¹
	AC Input Voltage Range	0		ΔV_{REF}	V	CCD AC; INT V_{DCREF} Mode Reg => XXX011XX Gain=1 ¹
V_{IN}	DC Input Voltage Range	-0.1		$AV_{DD}-1.4$	V	CIS DC; INT V_{DCREF} Mode Reg => XXX000XX Gain=1 ²
	DC Input Voltage Range	$V_{DCEXT}-0.1$		$V_{DCEXT}+\Delta V_{REF}$	V	CIS DC; EXT V_{DCREF} Mode Reg => XXX100XX Gain=1 ³ $V_{DCEXT}+\Delta V_{REF} \leq AV_{DD}$
V_{DCEXT}	External DC Reference	0.3		$AV_{DD}/2$	V	CIS DC; EXT V_{DCREF} Mode Reg => XXX100XX
V_{INBW}	Input Bandwidth	10			MHz	
V_{INCT}	Channel to Channel Crosstalk		-60		dB	
Internal Clamp Specifications						
V_{CLAMP}	Clamp Voltage		AGND		V	CIS (AC) Mode
	Clamp Voltage		V_{RT}		V	CCD (AC) Mode
R_{INT}	Clamp Switch On Resistance		100	150	Ω	
R_{OFF}	Clamp Switch Off Resistance	10			M Ω	

Note:

- ¹ V_{INPP} is the signal swing before the external capacitor tied to the MUX inputs.
- ² The -0.1V minimum is specified in order to accommodate black level signals lower than the external DC reference (clamp) voltage.
- 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

Test Conditions: $AV_{DD}=DV_{DD}=3.3V / 5V$, $ADCCLK=6MHz$, 50% Duty Cycle, $T_A=25^{\circ}C$ unless otherwise specified.

Symbol	Parameter	Min.	Typ.	Max.	Unit	Conditions
System Specifications (MUX + Buffer + PGA + ADC)¹						
SYS _{DNL}	System DNL		±0.5		LSB	
SYS _{LIN}	System Linearity		±1.0		%	
SYS _{GE}	System Gain Error	-5.0		+5.0	%	
IRN	Input Referred Noise		TBD		μV _{rms}	Gain=1
	Input Referred Noise		TBD		μV _{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	
tcipw	CLP Pulse Width	30			ns	²

Notes:

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

² The actual minimum 'tcipw' is dependent on the external capacitor value, the CIS output impedance, the Internal Clamp R_{INT} , and the maximum voltage across the external capacitor.

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 Mode.

System Transfer Function

$$DB9:0_{CODE} = (2^{10} - 1) \frac{G \left\{ V_{SIG} + V_{BLK} + V_{ERREXT} + V_{ERRINT} - \left[0.8 \left(\frac{DAC7:0_{CODE}}{255} \right) - 0.2 \right] \right\}}{0.67 A V_{DD}}$$

$$G = \left[1 + \left(\frac{9}{63} \right) GAIN5:0_{CODE} \right],$$

where	DB9:0 _{CODE}	=>	Numerical Representation of the Digital Output Between 0 and 1023;
	G	=>	PGA Gain;
	V _{SIG}	=>	Signal Level;
	V _{BLK}	=>	Black Level, (V _{IN} =V _{SIG} + V _{BLK});
	V _{ERREXT}	=>	Difference between External Clamp Level and Black Level (±100 mV min/max);
	V _{ERRINT}	=>	Internal Offset Error (±100 mV min/max);
	DAC7:0 _{CODE}	=>	Numerical Representation of the DAC Offset Adjustment Between 0 and 255.
	GAIN5:0 _{CODE}	=>	Numerical Representation of the Gain Adjustment Between 0 and 63.

ELECTRICAL CHARACTERISTICS

Test Conditions: $AV_{DD}=DV_{DD}=3.3V / 5V$, $ADCCLK=6MHz$, 50% Duty Cycle, $T_A=25^{\circ}C$ unless otherwise specified.

Symbol	Parameter	Min.	Typ.	Max.	Unit	Conditions
Write Timing Specifications						
t _{clk}	SCLK Pulse Width	40			ns	
t _{ds}	Input Data Set-up Time	20			ns	
t _{dh}	Input Data Hold Time	0			ns	
t _{dl}	SCLK High to LD High	50			ns	
t _{dz}	LD Low to SCLK High	20			ns	
ADC Digital Output Specifications						
t _{ap}	Aperture Delay		10		ns	
t _{dv}	Output Data Valid			40	ns	
t _{lat}	Latency		3		cycles	
Digital Input Specifications						
V _{IH}	Input High Voltage	$AV_{DD}-1$			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	
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	
t _{SR}	Slew Rate (10% to 90% DV _{DD})	2		15	ns	C _L =10pF, DV _{DD} =3.3V
	Slew Rate (10% to 90% DV _{DD})	TBD		TBD	ns	C _L =10pF, DV _{DD} =5.0V

THEORY OF OPERATION

CIS Mode (Contact Image Sensor)

The XRD9829 has two modes of operation for CIS applications. Each mode is set by the control registers accessed through the serial port.

Mode 1. DC Coupled (Control Register D4:D3:D2, 000)

If the CIS does not have leading or trailing black pixels as shown in Figure 1, then DC couple the CIS output to the XRD9829 input.

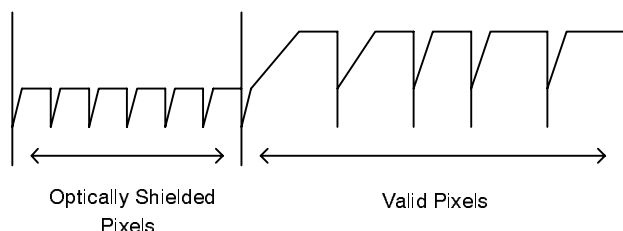


Figure 1. Typical CIS Output

Adjust the offset of the CIS (-100mV to 500mV) by setting the internal registers of the XRD9829 to set the black pixel value when the LEDs of the CIS are off. When the LEDs are on use the XRD9829 Programmable Gain to maximize the ADCs dynamic range. Figure 2. shows a typical application for a CIS with an offset of -100 mV to 500mV.

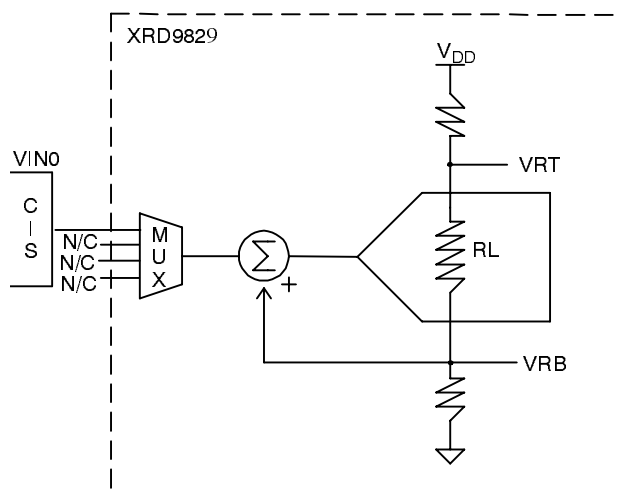


Figure 2. Application With Offset in the Range (-100 mv to 500mv)

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 500 mV. If the CIS output is beyond the offset range of the XRD9829 (see Offset Control DAC, Pg. 15) set the internal mode registers to external reference (Control Register D4:D3:D2, 100). An external reference voltage equal to the value of the CIS offset voltage can be applied to VIN3 (Figure 3.) in order to meet the dynamic range of the XRD9829. Figure 3. is a diagram of the XRD9829 in the external reference mode for CIS, DC Coupled applications.

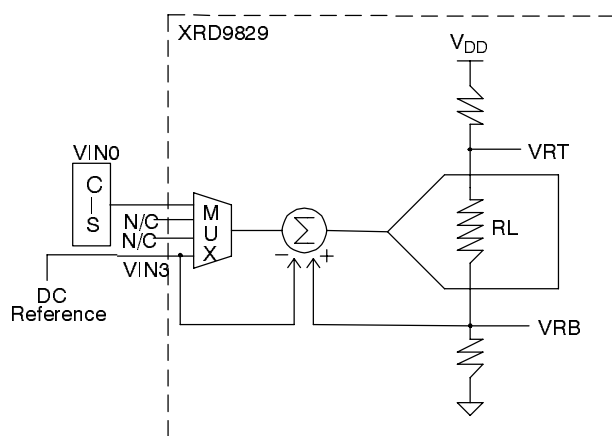


Figure 3. Application with Offset Greater Than (-100mv to 500mv)

The DC reference voltage applied to VIN3 does not have to be accurate. The internal offset DAC voltage is still used in this mode for fine adjustment. VIN3 cannot be used as an input from the CIS. Any signal applied to VIN3 will be subtracted from the output signal of the multiplexer.

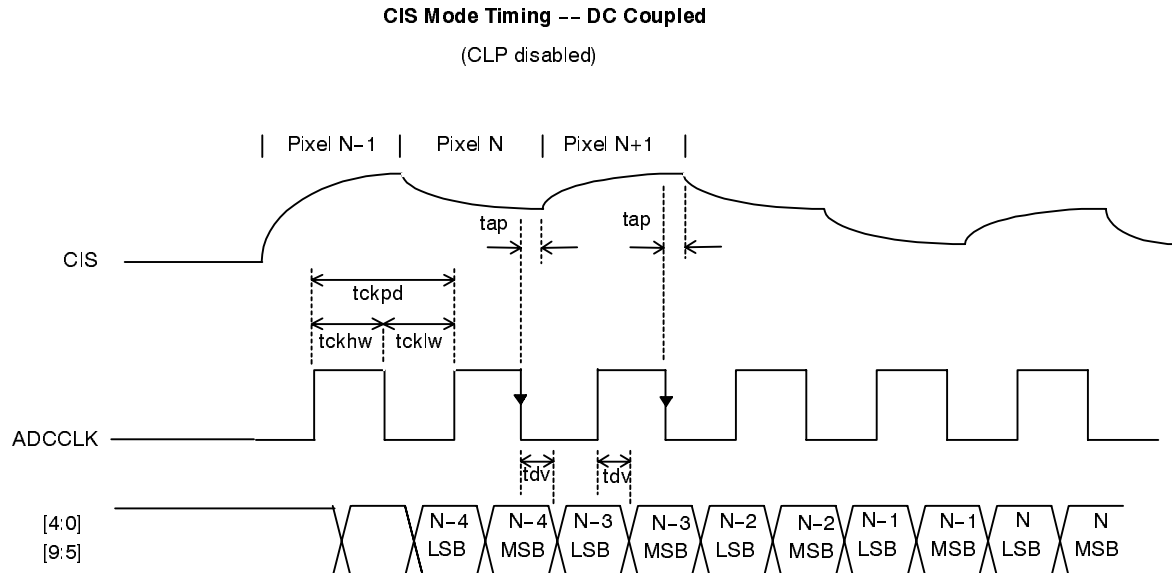


Figure 4. Timing Diagram for Figure 2. and Figure 3.

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

Mode 2. AC Coupled (Control Register D4:D3:D2, 010)

If the CIS signal has a black reference for the video signal, an external capacitor C_{EXT} is used. When CLP (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 5.).

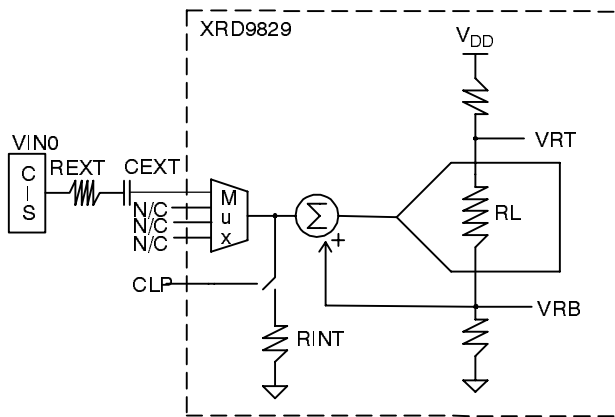


Figure 5. CIS AC Coupled Application

This value corresponds to the black reference of the image sensor. When the CLP 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 (T_c) needed in a particular application. The CLP pin has an internal 150 ohm impedance (R_{INT}) which is in series with the external capacitor (C_{EXT}).

$$T_c = 1/R_{INT}C_{EXT}$$

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

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

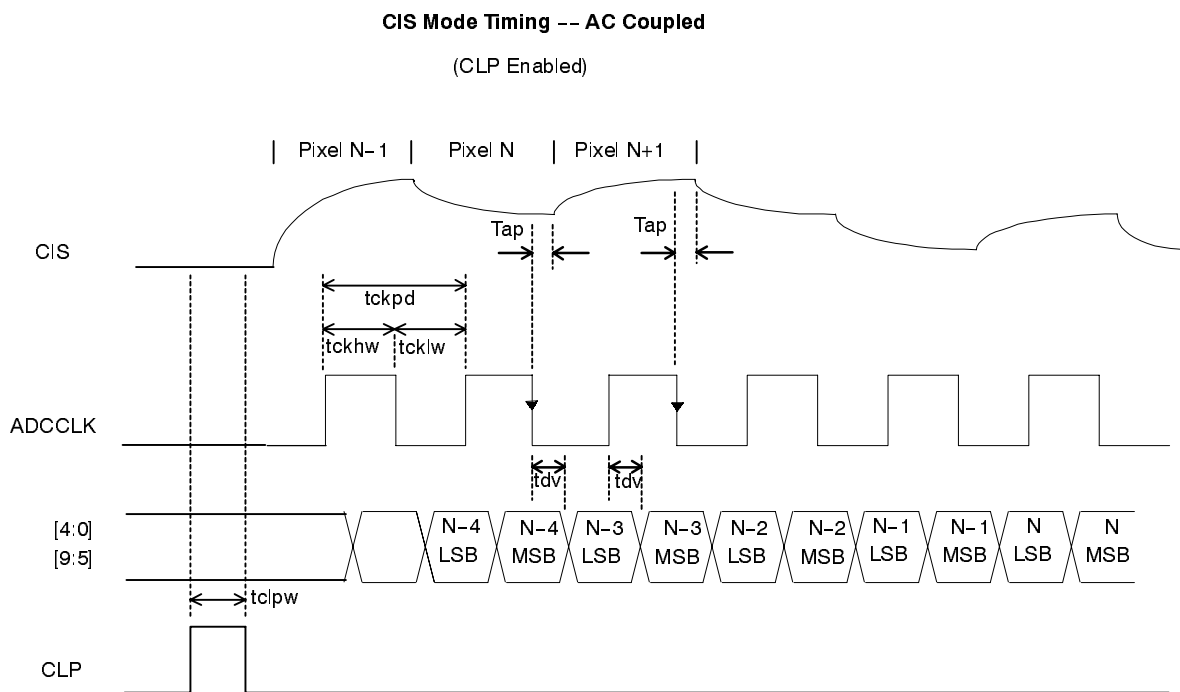


Figure 6. Timing Diagram for Figure 5.

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

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

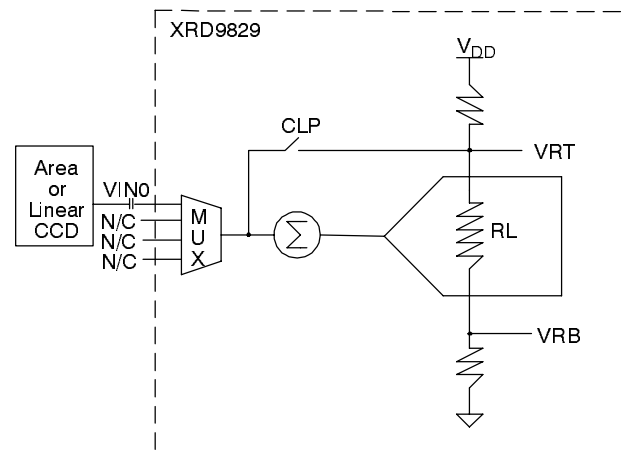


Figure 7. CCD AC Coupled Application

CCD Mode (Charge Coupled Device)

Mode 1. AC Coupled (Control Register D4:D3:D2, 011)

In the CCD mode 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 CLP 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 load impedance (R_{EXT}), then

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

When CLP (clamp) pin is set high an internal switch allows one side of the external capacitor to be set to VRT (Figure 7.). This value corresponds to the black reference of the CCD. When the CLP 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.

Area or Linear CCD Applications

Figure 7. 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.

Triple Channel CCD Application

Figure 8. is a block diagram for applications with triple channel CCDs. During the optically shielded section of a pixel CLP must go high three times to store the black reference on each capacitor to the input. In between the CLP pulses the MUX is internally programmed to the next input selection along with the required offset. Accordingly, the time constant will be higher for this application. Once the black reference is stored on the external capacitors the ADC samples the selected output channel. The MUX is internally programmed to the next input selection along with the gain and offset adjustments associated with the new color pixel being sampled. The ADC samples the new output, and this process is repeated until all three CCD outputs have been sampled. As before, the LSBs are available on the output bus on the

falling edge of ADCCLK. The MSBs are available on the rising edge of ADCCLK

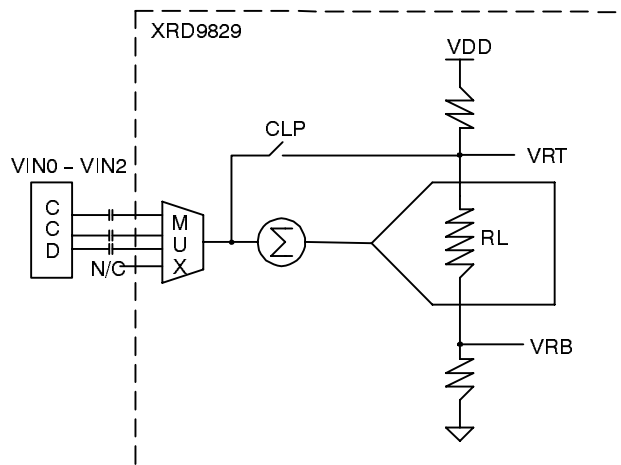


Figure 8. CCD AC Coupled Application

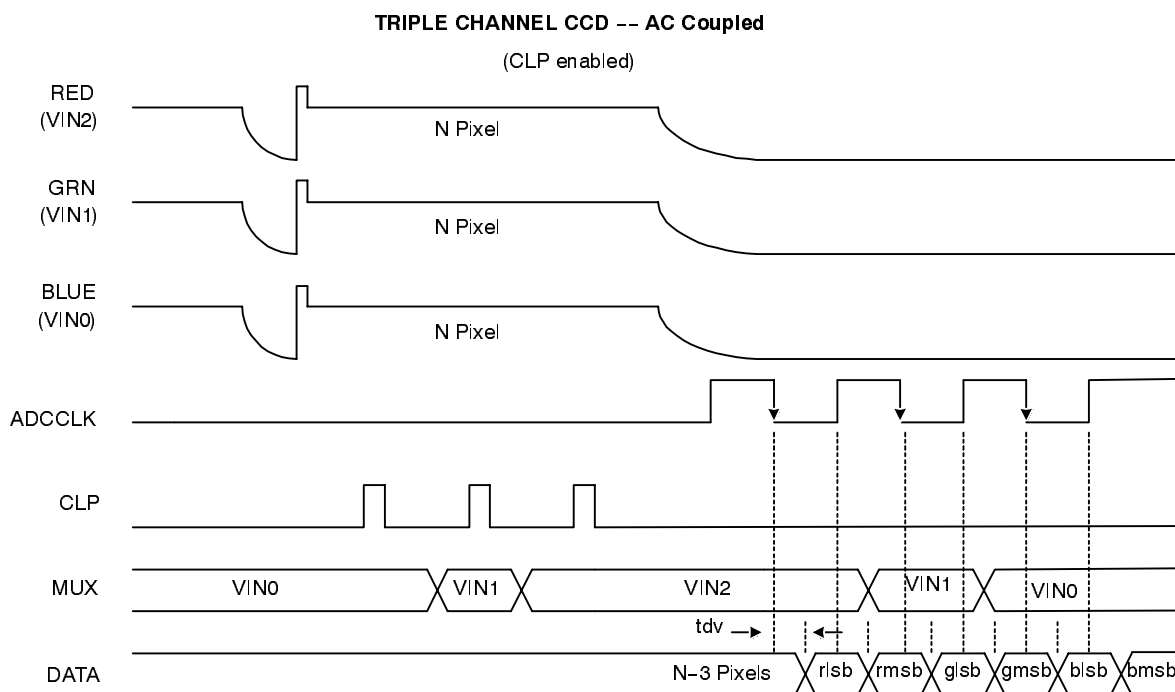


Figure 9. Timing Diagram for Figure 8.

CLK	Events
↓	ADC Sample & PGA Start Track of next Pixel V_{CLAMP} LSB Data Out
↑	MSB Data Out
HI	ADC Track PGA Output
LO	ADC Hold/Convert
CLP	Events
HI	PGA Tracks V_{CLAMP} & C_{EXT} is Charged to $V_{BLACK} - V_{CLAMP}$, which is equal to $V_{BLACK} - V_{RT}$
LO	PGA Tracks V_{INPP}

Mode 2. DC Coupled (Control Register D4:D3:D2, 001)

Typical CCDs have outputs with black references. Therefore, DC Coupled is not recommended for CCD applications.

Offset Control DAC

The offset DAC is controlled by 8 bits. The offset range is 800mV ranging from -200mV to +600mV. Therefore, the resolution of the 8-bit offset DAC is 3.14mV. However, the XRD9829 has +/-100mV reserved for internal offsets. Therefore the effective range for adjusting for CIS offsets or black reference is -100mV to +500mV. The offset adjustment is used primarily to correct for the difference between the black level of the image sensor and the bottom ladder reference voltage (VRB) of the ADC. By adjusting the black level to correspond to VRB the entire range of the ADC can be used.

If the offset of the CIS output is greater than 500mV an external reference can be applied to VIN3. The external reference can be used to adjust for large offsets only when the internal mode is configured through the serial port.

Since the offset DAC adjustment is done before the gain stage it is gain-dependent. For example: If the gain needs to be changed between lines (red to blue, etc.) the offset is calibrated before the signal passes through the PGA.

PGA (Programmable Gain Amplifier) DAC

The gain of the input waveform is controlled by a 6-bit PGA. The PGA is used along with the offset DAC for the purpose of using the entire range of the ADC. The PGA has a linear gain from 1 to 10. Figure 10. is a plot of the transfer curve for the PGA gain.

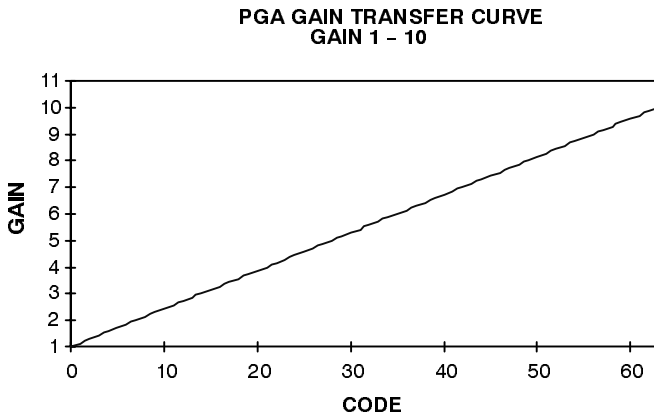


Figure 10. Transfer Curve For The 6-Bit PGA

After the signal is level shifted to correspond with the bottom ladder reference voltage, the system can be calibrated such that a white video pixel can represent the top ladder reference voltage to the ADC. This allows for a full scale conversion maximizing the resolution of the ADC.

Analog to Digital Converter

The ADC is a 10-bit, 10 MSPS analog-to-digital converter for high speed and high accuracy. The ADC uses a subranging architecture to maintain low power

consumption at high conversion rates. The output of the ADC is a 5-bit databus. ADCCLK samples the input on its falling edge. After the input is sampled the LSB is latched to the output drivers. On the rising edge of the ADCCLK, the MSB is latched to the output drivers. The output needs to be demultiplexed with external circuitry or a digital ASIC. There is a three clock cycle latency for the analog-to-digital converter.

The VRT and VRB reference voltages for the ADC are generated internally, unless the external V_{RT} mode (D5 set to [1]) is selected. In the external V_{RT} mode, the V_{RT} voltage is set through the VREF+ pin. This allows the user to select the dynamic range of the ADC.

Serial Load Control Registers

The serial load registers are controlled by a standard three wire serial interface. LD, SCLK and SDATA are the three input signals that control this process. The LD signal is set low to initiate the loading of the internal registers.

There are four internal mode registers that are accessed via a 10-bit data string. The SDATA is latched automatically after ten SCLKs have been counted. If ten clocks are not present on SCLK before the LD signal returns high, no data will be loaded into the internal registers. If more than 10 clocks are present on SCLK, the additional clocks will be ignored. The data corresponding to the first ten SCLKs will be loaded only.

The first two MSBs choose which internal register will be selected. The remaining 8 LSBs contain the data needed for programming the internal register for a particular configuration.

Power Up State of the Internal Registers

The control register settings upon initial power up are for CIS, DC Coupled Mode (VRT is set to internal, Input DC Reference=AGND and MUX input VIN0). Gain and Offset are set to zero. The test modes are disabled in the power up state.

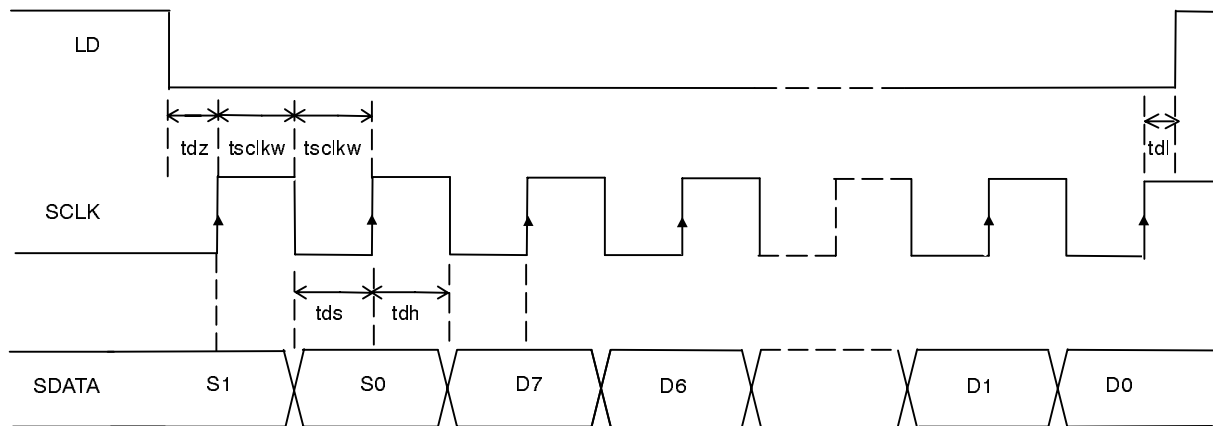


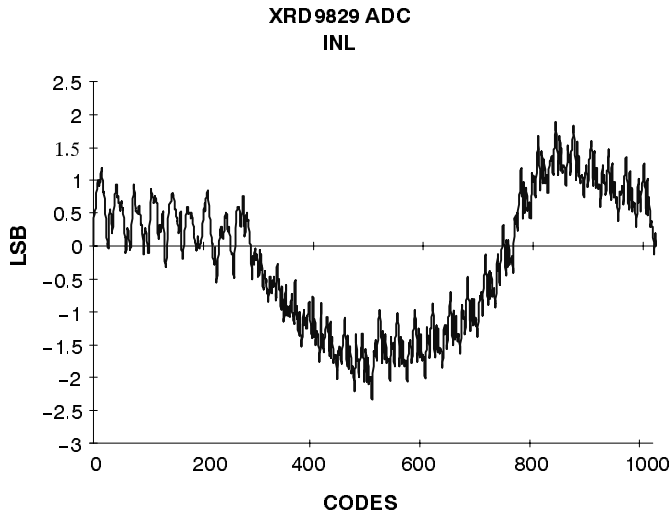
Figure 11. Write Timing Diagram

Control Registers

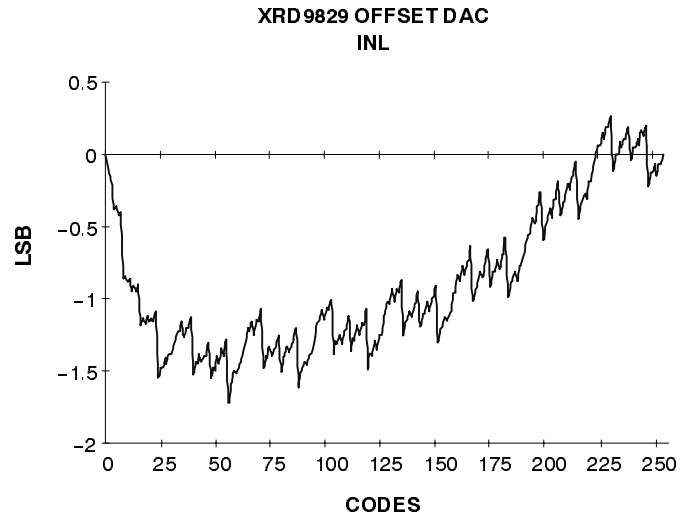
Function (Register S1/S0)	D7	D6	D5	D4	D3	D2	D1	D0	Power-up State (Note 1)
Gain (00)	G5 (MSB)	G4	G3	G2	G1	G0 (LSB)	X	X	000000XX
Offset (01)	O7 (MSB)	O6	O5	O4	O3	O2	O1	O0 (LSB)	01000000
Mode (10)	X	X	V _{RT} 0: INTERNAL 1: EXTERNAL	INPUT DC REFERENCE (V _{DCREF}) 0: INTERNAL (V _{DCREF} = AGND) 1: EXTERNAL (V _{DCREF} =V _{DC EXT})	DC/AC 0: DC 1: AC	CIS/CCD 0: CIS 1: CCD	MUX SEL 0 0: VIN0 0 1: VIN1 1 0: VIN2 1 1: VIN3	MUX SEL 0 0: VIN0 0 1: VIN1 1 0: VIN2 1 1: VIN3	XX000000
Mode & Test (11)	X	X	X	DIGITAL RESET 0: NO RESET 1: RESET (REGISTERS ARE RESET TO POWER-UP STATES)	TEST3 0: TEST3 DISABLED 1: OUTPUT OF BUFFER TIED TO VIN3 PIN (VIN3 PIN BECOMES AN OUTPUT)	TEST2 0: TEST2 DISABLED 1: OUTPUT OF PGA TIED TO VIN2 PIN (VIN2 PIN BECOMES AN OUTPUT)	TEST1 0: TEST1 DISABLED 1: VIN1 PIN TIED TO INPUT OF ADC (PGA OUTPUT DISCONNECT ED FROM INPUT OF ADC)	X	XXX0000X

Note:

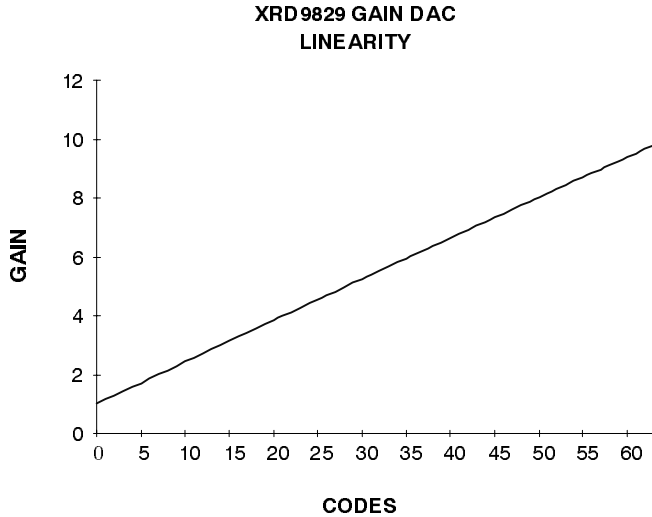
1 These are the control register settings upon initial power-up. The previous register settings are retained following a logic power-down initiated by the PDB signal.



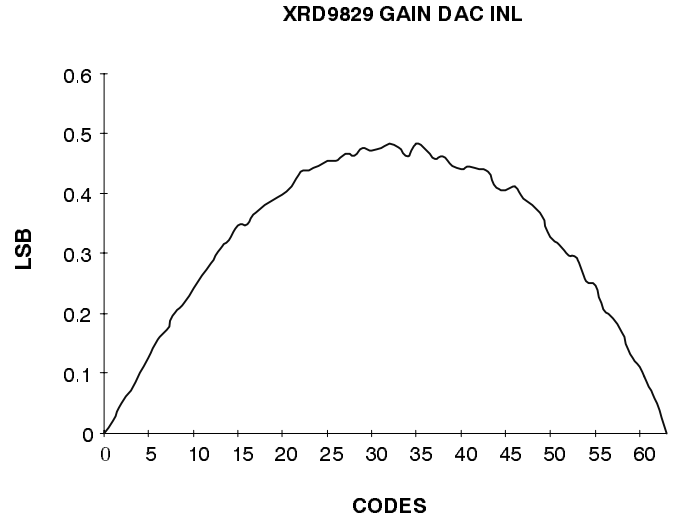
Graph 1.



Graph 2.



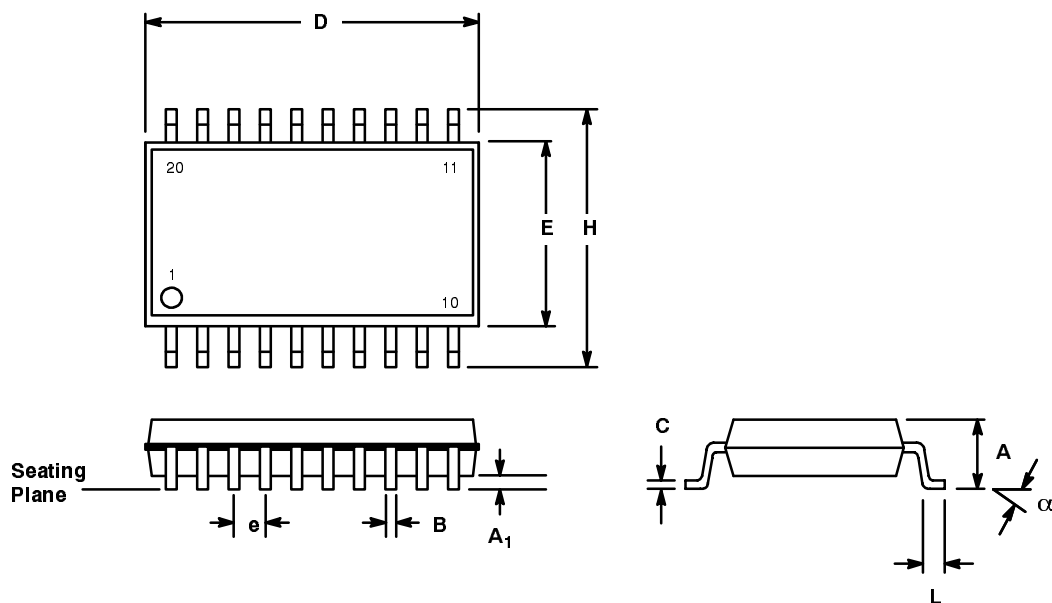
Graph 3.



Graph 4.

20 LEAD SMALL OUTLINE (300 MIL JEDEC SOIC)

Rev. 1.00



SYMBOL	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.093	0.104	2.35	2.65
A ₁	0.004	0.012	0.10	0.30
B	0.013	0.020	0.33	0.51
C	0.009	0.013	0.23	0.32
D	0.496	0.512	12.60	13.00
E	0.291	0.299	7.40	7.60
e	0.050 BSC		1.27 BSC	
H	0.394	0.419	10.00	10.65
L	0.016	0.050	0.40	1.27
α	0°	8°	0°	8°

Note: The control dimension is the millimeter column

Notes

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